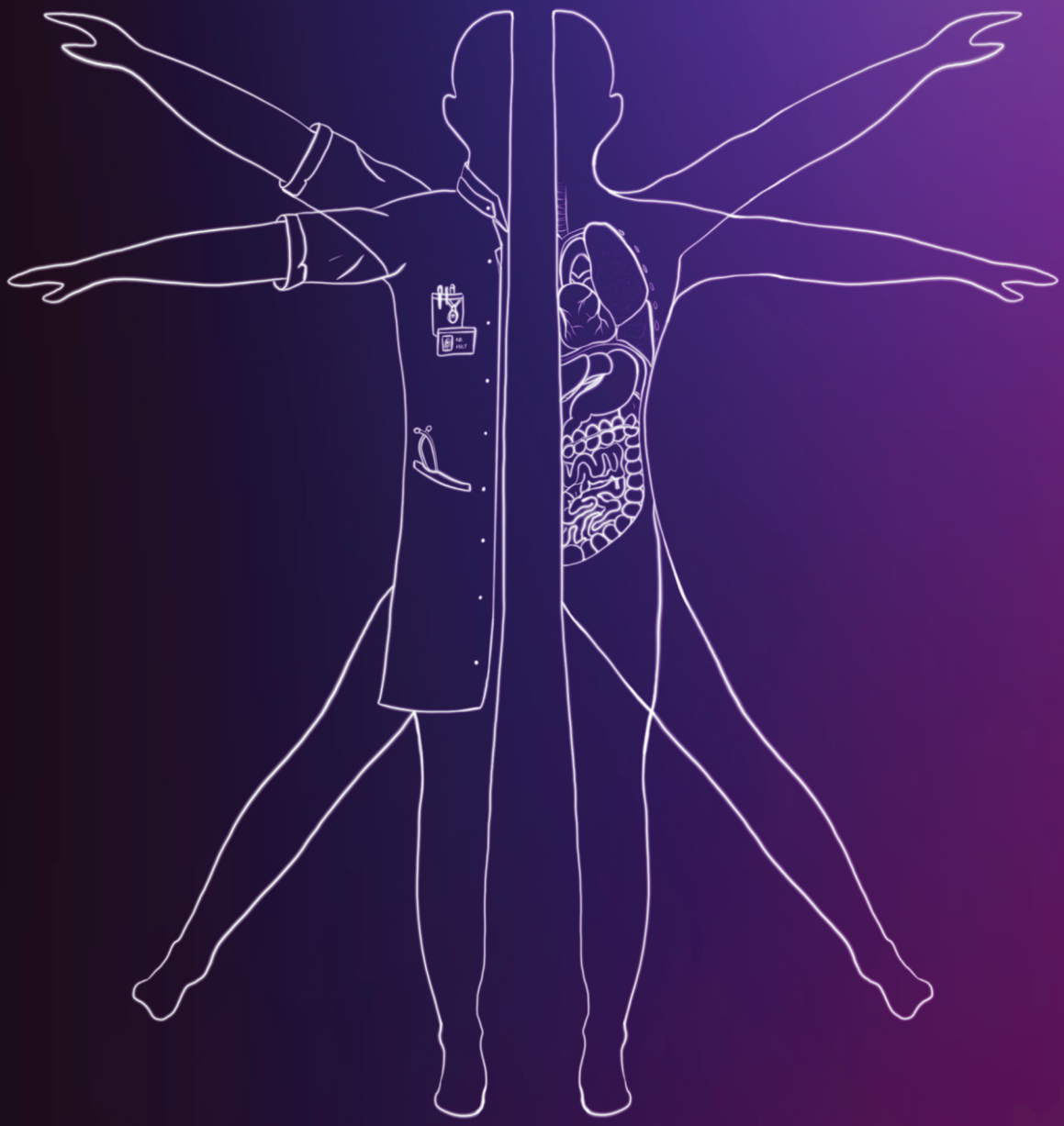
Redesigning cardiovascular healthcare: patient and professional perspectives on value

Hilt, A.D.



REDESIGNING CARDIOVASCULAR HEALTHCARE - PATIENT AND PROFESSIONAL PERSPECTIVES ON VALUE

ALEXANDER DANIËL HILT

REDESIGNING CARDIOVASCULAR HEALTHCARE - PATIENT AND PROFESSIONAL PERSPECTIVES ON VALUE

ALEXANDER DANIËL HILT

Colofon

The studies described in this thesis were performed at the department of Cardiology of the Leiden University Medical Hospital, Leiden, the Netherlands.

Cover: R.J.J van der Nagel
Layout: Proefschriftmaken.nl & R.J.J van der Nagel
Print: Proefschriftmaken.nl
ISBN: 978-946-4239-935

Financial support by the Dutch Heart Foundation for the publication of this thesis is gratefully acknowledged.

Financial support by the Alrijne Hospital Leiderdorp for the publication of this thesis is equally gratefully acknowledged.

Redesigning Cardiovascular Healthcare - Patient and Professional Perspectives on Value.

Proefschrift

ter verkrijging van
de graad van doctor aan de Universiteit Leiden,
op gezag van rector magnificus prof.dr.ir. H. Bijl,
volgens besluit van het college voor promoties
te verdedigen op dinsdag 29 november 2022
klokke 11.15 uur

door

Alexander Daniël Hilt
geboren te Rotterdam
in 1988

Promotor
Prof. Dr. M. J. Schalij

Co-promotores
Dr. S.L.M.A. Beeres
Dr. R.W.C. Scherptong

Leden Promotiecommissie

Prof. Dr. J.F. Hamming	
Prof. Dr. D.H Biesma	
Prof. Dr. A.A. Kaptein	
Prof. Dr. M.C. de Vries	
Prof. Dr. Ir. M.S. Kleinsmann	Faculteit Industrieel Ontwerpen, TU Delft
Dr. Ir. M. Melles	Faculteit Industrieel Ontwerpen, TU Delft

Voor mijn ouders

Table of contents

CHAPTER I
GENERAL INTRODUCTION

The Setting

"Cardiovascular disease" includes diseases involving the blood vessels (major- and minor arteries) and the heart with its anatomical structures (myocardium, valves, coronary vessels)(1-4). Myocardial infarction, valvular disease and aneurysms of the aorta are the most frequent encountered pathologies today(5-11).

A plethora of risk factors contribute to the chance of becoming affected by these diseases in a human life-time. Although some are fixed, such as gender, age or genetic profile, others are modifiable such as diet or daily exercise. In particular, life-style related habits such as smoking or poor dietary intake combined with inactivity leading to obesity, are important modifiable risk factors of the 20th and 21st century among others(1, 12, 13). Despite these risk factors becoming increasingly present in modern society, past discoveries on pharmaceutical and technical levels advanced cardiovascular healthcare to new heights, drastically improving survival of patients.

The introduction of clinical electrocardiography by Willem Einthoven in 1901, the use of cardioprotective medication, cardiovascular surgery and percutaneous interventions have decreased mortality roughly from 50% in the 1950's, down to 2% in 2020 in myocardial infarction patients alone(14, 15).

The evaluation of novel treatments on clinical end-points has been studied in numerous retrospective-, prospective-, randomized- and meta-analytic studies over the years. Randomized- and meta-analytic study outcomes are perceived as the highest achievable level of scientific evidence in clinical care, and for that reason, used as the foundation of many clinical practice guidelines in daily cardiovascular care(16-18).

The *value* of clinical care- and outcomes, as observed by the professional, can be defined through (for example) low mortality rates, fewer adverse events such as post-procedural bleeding, or medication-related side effects. Although important for patients' survival and general health, this definition of *value* is rather one-dimensional in character, only seen from the professional's point of view. It is questionable if a sole focus on this one-dimensional view of value is enough to improve clinical care further. And more importantly; is the professional view equal to the *patients'* perspective on value and health?

Value of Health(care)

The definition of "health" by The World Health Organization (WHO) is "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity." Three aspects of health are interchangeably linked; physical-, mental and social aspects of health(19).

First, *physical* health reflects the ability of individuals to maintain physiological homeostasis during changing conditions ("allostasis"), for instance an increase in heart rate when ascending stairs. Illness develops when physiological mechanisms fail during harmful circumstances, such as an increased thrombotic risk due to smoking, resulting in myocardial infarction. Second, *mental* health comprises of how individuals coherently manage and adapt to changing circumstances to improve their subjective well-being. And third, *social* health projects both physical and mental health aspects of life in general; how does one manage life when there is interaction with other living objects and environments(19).

Healthcare interventions for patients, preventive or curative, have outcomes across all these aspects of health, establishing a personal level of 'health'.

Health(care) outcomes as stated by Porter, are equally multi-layered(20). The result of an intervention is not only 'dead or alive' (Tier 1) but also the occurrence of complications or return to daily life after clinical care (Tier 2) and the sustainability of health during life in general (Tier 3)(20).

Healthcare professionals (both physicians and non-physicians) define "value" of an outcome, by comparing patient's outcome to evidence-based studies (i.e. LDL-cholesterol levels lowered by 25% after one year of statin treatment). However, whether an outcome is positive or negative or deemed valuable, should be a combination of both the professional-, and patient's perceived sense of 'value' regarding treatment and outcome. Although extensive treatment options have increased patient survival, the true challenge for cardiovascular science of the 21st century lies not merely in improving clinical outcomes as seen by the professional but equally the patient perspective on value across all three tiers.

Value Based Healthcare

The focus on value in healthcare is embedded in the concept of 'Value Based Healthcare' (VBHC) as described by Porter and Teisberg, which has become a subject of growing interest in healthcare related research(20-24). In general, it attempts to transform care to become more 'patient-centered' and actively pursue the input of the patient in the development and design of healthcare.

VBHC attempts to prioritize the patients' perspective of healthcare by "the creation and operation of a health system that explicitly prioritizes health outcomes which matter to patients, relative to the cost of achieving this outcome"(25, 26).
Research in this domain questions foremost the relevance of certain evidence-based interventions and outcomes in regard to patient-specific health aspects and personal preferences.

This approach differs greatly from cost-effectiveness studies, which primarily focus on costs and benefits of healthcare outcomes on a societal-, and healthcare sector level. VBHC studies asses outcomes on a patient-clinician level and adopt the patient perspective regarding health into the healthcare experience and what matters during the care process(27).

The assessment of a patient's perception of 'health' is crucial in VBHC research, primarily done via qualitative methods such as observations, interviews and questionnaires. The three C method is an example of this, which proposes that healthcare related outcomes consist of three personal dimensions; capability, comfort and calm(28). First, *capability* describes the ability of a patient to be themselves and do the things that define them as individuals. Second, *comfort* is the level of relief from physical and emotional suffering that often accompany illnesses. This not only encompasses physical pain but equally emotional distress or anxiety. And lastly, *calm* includes all that enables the ability to live normally while getting care, such as the freedom of 'experienced chaos' while getting extensive treatment regimens(28). By addressing the impact of an outcome on such personal levels, can ultimately increase the efficacy of experienced healthcare by creating a better understanding of the patient's view on what is valuable during care(24).

It is difficult to obtain a comprehensive view on 'valuable outcome' for both the patient and professional in the clinical context of cardiovascular healthcare; a complex environment with multi-layered treatment options, extensive care tracks and outcomes across multiple tiers of personal health. Individual and subjective perspectives on the value of treatment and outcome are ever present among patient and professional, but it can be worthwhile to investigate these patterns systematically, to improve clinical care.

Value of Cardiovascular Healthcare

This thesis aims to systematically assess clinical cardiovascular care on a national and local-hospital level, to increase the understanding of patterns of 'value' from both the patient,- and professional perspective. Ultimately to provide suggestions to modify and improve daily clinical care further.

First, cardiovascular patients are assessed on a *national level* using claims data. This data enables insight into clinical care patterns, but more importantly helps unravel if that which is perceived as valuable by the professional (i.e. guideline evidence), is truly applied in daily practice. Second, cardiovascular care on a *local hospital level* is qualitatively assessed via Human Factors (HF) science.

As a novelty in clinical research and in line with VBHC, it helps to understand how the patient and professional experience healthcare within a certain context.

Claims Databases

After receiving in-hospital treatment, patients' financial claims are sent to healthcare insurance companies and subsequently collected in central databases. Extensively validated, this 'real-world' data is a unique and accessible source to analyze healthcare usage patterns in cardiovascular patients(29-32). It uncovers which real world, evidence based choices are made by professionals treating patients.

Part I of this thesis describes how this type of data was used to understand treatment of myocardial infarction patients on a national level, regarding two paramount therapeutic pillars; revascularization and secondary preventive medication use. The goal is to gain perspective of national treatment patterns of ST elevation myocardial infarction (STEMI) and non-ST elevation myocardial infarction (NSTEMI) patients in regard to common treatment guidelines. A key question is, if recommended evidence based treatments (=value) are equally found in real world patterns?

Chapter II describes a study using claims data which aimed to find modifiable factors in the treatment of Dutch NSTEMI patients in 2015 by assessing revascularization- and secondary preventive medication patterns in these patients.

Chapter III describes a study which aimed to find modifiable factors in STEMI-, and NSTEMI care regarding revascularization and secondary preventive medication use among patients of different socioeconomic classes by combining claims data with governmental data on income and education.

Human Factors Science

Human Factors (HF) science, at the intersection of psychology, biology and engineering, poses an interesting field to shape VBHC research in cardiovascular care. It assesses human performance on the physical and cognitive level in complex systems to promote safety and efficiency(33). HF science originally emerged during the second world war. As a theoretical discipline developed by the United States Navy, it provided a framework to assess crew performance and the effect of it on naval warfare and air-combat(34). Following this, HF science found its way into industries heavily relying on human performance such as aviation and off-shore industries.

As of the early 2000's, HF science has become an accepted discipline in healthcare, providing a systems approach to design healthcare, improve patient safety and quality of care(35). First described in the 'To Err is Human' manifest of 1999 by Kohn(36), HF research has evolved over the past 20 years into a theoretical and practical framework to understand healthcare work and the effect on outcomes(37-39). In healthcare, HF science is applied for two purposes: i) reducing the cognitive and physical load of professionals and ii) promoting safe, efficient and high quality care to patients(33, 39). To improve care, it focusses on the concept that patient care is more than just a single encounter or task, but a journey/experience across multiple care-givers and organizations(40, 41). The core method involves a human centered design approach or; assessment of humans (patient and professional) in healthcare through series of extensive observations and interviews, understanding daily work, stakeholders' roles and their key interactions with tools and environments (42). Eventually visually mapping this as a patient and/or professional experience(38, 43). Importantly, it highlights patient-professional interaction to the organizational level and vice versa.

As this provides direction to improve safety of clinical care, the World Health Organization (WHO) added elements of HF science to the foundation of the Patient Safety Curriculum(44). HF science provides an interesting addition to VBHC research to understand what is valuable for a patient in the healthcare experience. It structurally assesses the patient within the healthcare environment and the patient-professional interaction with attention to personal aspects of delivered care on outcomes. This enables an empathic understanding of how a patient perceives a certain care track when treated for specific disease(24).

In this thesis, it is discussed how HF science with a focus on the patient-professional experience/journey, can contribute to cardiovascular research by evaluating the patient and professional perspective of value in clinical care. Ultimatly to improve this further in a meaningful way. To illustrate this novel approach, several example studies are discussed in **Part II** of this thesis.

Chapter IV is an editorial which addresses the potential benefit of HF science in clinical cardiovascular research of myocardial infarction patients. **Chapter V** focusses on interprofessional collaboration during complex aortic surgeries.

A HF aviation questionnaire was used to assess teamwork and the perceived safety climate during these procedures among physicians and support personnel, ultimately to improve patient safety and care during surgery.

Chapters VI and VII give an overview of the utilization of a HF design approach to tackle a clinical problem; educating myocardial patients on the importance of statins. The development, design and implementation of a Mixed Reality (MR) statin education model is described with a focus on patient participation and statin education. **Chapter VIII** utilizes a similar HF design approach with patient participation to assess the acceptability and feasibility of a Virtual Reality (VR) pre-cardiac catheterization application for patients in the outpatient setting. Finally, **chapter IX** provides a summary of this thesis, as well as a discussion of the results and an appraisal of the future perspectives regarding Value Based Healthcare in cardiovascular research.

References

1. Andersson C, Johnson AD, Benjamin EJ, Levy D, Vasan RS. 70-year legacy of the Framingham Heart Study. Nature reviews Cardiology. 2019;16(11):687-98.
2. Labarthe DR. From cardiovascular disease to cardiovascular health: a quiet revolution? Circulation Cardiovascular quality and outcomes. 2012;5(6):e86-92.
3. Mahmood SS, Levy D, Vasan RS, Wang TJ. The Framingham Heart Study and the epidemiology of cardiovascular disease: a historical perspective. Lancet (London, England). 2014;383(9921):999-1008.
4. Sistino JJ, Fitzgerald DC. Epidemiology of cardiovascular disease in the United States: implications for the perfusion profession. A 2017 update. Perfusion. 2017;32(6):501-6.
5. Domenech B, Pomar JL, Prat-González S, Vidal B, López-Soto A, Castella M, et al. Valvular Heart Disease Epidemics. The Journal of heart valve disease. 2016;25(1):1-7.
6. Erdmann J, Kessler T, Munoz Venegas L, Schunkert H. A decade of genome-wide association studies for coronary artery disease: the challenges ahead. Cardiovascular research. 2018;114(9):1241-57.
7. Iung B, Vahanian A. Epidemiology of valvular heart disease in the adult. Nature reviews Cardiology. 2011;8(3):162-72.
8. Kuzmik GA, Sang AX, Elefteriades JA. Natural history of thoracic aortic aneurysms. Journal of vascular surgery. 2012;56(2):565-71.
9. Malakar AK, Choudhury D, Halder B, Paul P, Uddin A, Chakraborty S. A review on coronary artery disease, its risk factors, and therapeutics. Journal of cellular physiology. 2019;234(10):16812-23.
10. Swerdlow NJ, Wu WW, Schermerhorn ML. Open and Endovascular Management of Aortic Aneurysms. Circulation research. 2019;124(4):647-61.
11. Weintraub WS, Taggart DP, Mancini GBJ, Brown DL, Boden WE. Historical Milestones in the Management of Stable Coronary Artery Disease over the Last Half Century. The American journal of medicine. 2018;131(11):1285-92.
12. Francula-Zaninovic S, Nola IA. Management of Measurable Variable Cardiovascular Disease' Risk Factors. Current cardiology reviews. 2018;14(3):153-63.
13. Yatsuya H, Matsunaga M, Li Y, Ota A. Risk Factor of Cardiovascular Disease Among Older Individuals. Journal of atherosclerosis and thrombosis. 2017;24(3):258-61.
14. O'Gara PT, Kushner FG, Ascheim DD, Casey DE, Jr., Chung MK, de Lemos JA, et al. 2013 ACCF/AHA guideline for the management of ST-elevation myocardial infarction: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines. Circulation. 2013;127(4):e362-425.
15. Thygesen K, Alpert JS, Jaffe AS, Simoons ML, Chaitman BR, White HD, et al. Third universal definition of myocardial infarction. Circulation. 2012;126(16):2020-35.
16. Collet JP, Thiele H, Barbato E, Barthélémy O, Bauersachs J, Bhatt DL, et al. 2020 ESC Guidelines for the management of acute coronary syndromes in patients presenting without persistent ST-segment elevation. European heart journal. 2021;42(14):1289-367.

17. Ibanez B, James S, Agewall S, Antunes MJ, Bucciarelli-Ducci C, Bueno H, et al. 2017 ESC Guidelines for the management of acute myocardial infarction in patients presenting with ST-segment elevation: The Task Force for the management of acute myocardial infarction in patients presenting with ST-segment elevation of the European Society of Cardiology (ESC). European heart journal. 2018;39(2):119-77.
18. Upchurch GR, Jr., Escobar GA, Azizzadeh A, Beck AW, Conrad MF, Matsumura JS, et al. Society for Vascular Surgery clinical practice guidelines of thoracic endovascular aortic repair for descending thoracic aortic aneurysms. Journal of vascular surgery. 2021;73(1s):55s-83s.
19. Huber M, Knottnerus JA, Green L, van der Horst H, Jadad AR, Kromhout D, et al. How should we define health? BMJ (Clinical research ed). 2011;343:d4163.
20. Porter ME, Teisberg EO. How physicians can change the future of health care. Jama. 2007;297(10):1103-11.
21. Akmaz B, Zipfel N, Bal RA, Rensing B, Daeter EJ, van der Nat PB. Developing process measures in value-based healthcare: the case of aortic valve disease. BMJ open quality. 2019;8(4):e000716.
22. Porter ME. Value-based health care delivery. Annals of surgery. 2008;248(4):503-9.
23. Ray JC, Kusumoto F. The transition to value-based care. Journal of interventional cardiac electrophysiology : an international journal of arrhythmias and pacing. 2016;47(1):61-8.
24. Teisberg E, Wallace S, O'Hara S. Defining and Implementing Value-Based Health Care: A Strategic Framework. Academic medicine : journal of the Association of American Medical Colleges. 2020;95(5):682-5.
25. Porter ME, Teisberg EO. Redefining competition in health care. Harvard business review. 2004;82(6):64-76, 136.
26. Putera I. Redefining Health: Implication for Value-Based Healthcare Reform. Cureus. 2017;9(3):e1067.
27. Tsevat J, Moriates C. Value-Based Health Care Meets Cost-Effectiveness Analysis. Annals of internal medicine. 2018;169(5):329-32.
28. Wallace S TE. Measuring what matters: Connecting excellence, professionalism, and empathy. 2022 [Available from: http://braininjuryprofessional.com.
29. Eindhoven DC, Hilt AD, Zwaan TC, Schalij MJ, Borleffs CJW. Age and gender differences in medical adherence after myocardial infarction: Women do not receive optimal treatment - The Netherlands claims database. European journal of preventive cardiology. 2018;25(2):181-9.
30. Eindhoven DC, van Staveren LN, van Erkelens JA, Ikkersheim DE, Cannegieter SC, Umans V, et al. Nationwide claims data validated for quality assessments in acute myocardial infarction in the Netherlands. Netherlands heart journal : monthly journal of the Netherlands Society of Cardiology and the Netherlands Heart Foundation. 2018;26(1):13-20.
31. Eindhoven DC, Wu HW, Kremer SWF, van Erkelens JA, Cannegieter SC, Schalij MJ, et al. Mortality differences in acute myocardial infarction patients in the Netherlands: The weekend-effect. American heart journal. 2018;205:70-6.
32. Yusuf S, Joseph P, Rangarajan S, Islam S, Mente A, Hystad P, et al. Modifiable risk factors, cardiovascular disease, and mortality in 155 722 individuals from 21 high-income, middle-

income, and low-income countries (PURE): a prospective cohort study. Lancet (London, England). 2020;395(10226):795-808.
33. Saleem JJ, Russ AL, Sanderson P, Johnson TR, Zhang J, Sittig DF. Current challenges and opportunities for better integration of human factors research with development of clinical information systems. Yearbook of medical informatics. 2009:48-58.
34. Merriman SC, Karn KS. History of Human Factors in US Navy Aircraft Cockpit Design: 1969-2019. Proceedings of the Human Factors and Ergonomics Society Annual Meeting. 2019;63(1):1883-7.
35. Carayon P, Wetterneck TB, Rivera-Rodriguez AJ, Hundt AS, Hoonakker P, Holden R, et al. Human factors systems approach to healthcare quality and patient safety. Applied ergonomics. 2014;45(1):14-25.
36. Kohn L CJ, Donaldson M. To Err is human: Building a Safer Health System: National Academies Press; 1999.
37. Carayon P, Wooldridge A, Hoonakker P, Hundt AS, Kelly MM. SEIPS 3.0: Human-centered design of the patient journey for patient safety. Applied ergonomics. 2020;84:103033.
38. Holden RJ, Carayon P. SEIPS 101 and seven simple SEIPS tools. BMJ quality & safety. 2021;30(11):901-10.
39. Karsh BT, Holden RJ, Alper SJ, Or CK. A human factors engineering paradigm for patient safety: designing to support the performance of the healthcare professional. Quality & safety in health care. 2006;15 Suppl 1(Suppl 1):i59-65.
40. Carayon P. Human factors of complex sociotechnical systems. Applied ergonomics. 2006;37(4):525-35.
41. Kianfar S, Carayon P, Hundt AS, Hoonakker P. Care coordination for chronically ill patients: Identifying coordination activities and interdependencies. Applied ergonomics. 2019;80:9-16.
42. Carayon P, Kianfar S, Li Y, Xie A, Alyousef B, Wooldridge A. A systematic review of mixed methods research on human factors and ergonomics in health care. Applied ergonomics. 2015;51:291-321.
43. Russ AL, Fairbanks RJ, Karsh BT, Militello LG, Saleem JJ, Wears RL. The science of human factors: separating fact from fiction. BMJ quality & safety. 2013;22(10):802-8.
44. Walton M, Woodward H, Van Staalduinen S, Lemer C, Greaves F, Noble D, et al. The WHO patient safety curriculum guide for medical schools. Quality & safety in health care. 2010;19(6):542-6.

PART ONE

COMPARING GUIDLINE RECOMMENDATIONS TO REAL WORLD CARE PATTERNS - NATIONAL AND REGIONAL MYOCARDIAL INFARCTION CARE ANALYSIS THROUGH CLAIMS DATA

CHAPTER II

NON ST ELEVATION MYOCARDIAL INFARCTION IN THE NETHERLANDS: ROOM FOR IMPROVEMENT!

P. Ten Have, MD*; A.D. Hilt, MD*; H. Paalvast, MEng; D.C. Eindhoven, MD, PhD; M.J. Schalij, MD PhD; S.L.M.A. Beeres, MD, PhD.

* shared first: both authors contributed equally to this manuscript.

Published
Neth. Heart J. 2020 Oct;28(10):537-545

Abstract

Aim

To analyse NSTEMI care in the Netherlands and identify modifiable factors to improve NSTEMI healthcare.

Methods

This retrospective cohort study analysed hospital and pharmaceutical claims data of all NSTEMI patients in the Netherlands in 2015. The effect of PCI during hospitalisation on 1-year mortality was investigated in the cohort alive 4 days after NSTEMI. The effect of medical treatment on 1-year mortality was assessed in the cohort alive 30 days after NSTEMI. The effect of age, gender and co-morbidities was evaluated. PCI during hospitalisation was defined as PCI within 72 hours after NSTEMI and optimal medical treatment was defined as the combined use of an aspirin specie, P2Y12-inhibitor, statin, beta-blocker and ACE-inhibitor/AT-2-receptor blocker, started within 30 days after NSTEMI.

Results

Data from 17,997 NSTEMI patients (age 69.6(SD=12.8) years, 64% male) were analysed. In patients alive 4-days after NSTEMI, 43% of patients had a PCI during hospitalisation and 1-year mortality was 10%. In the cohort alive 30-days after NSTEMI, 47% of patients had optimal medical treatment at 30-days and 1-year mortality was 7%.

PCI during hospitalisation (OR 0.42; 95%CI 0.37-0.48) and optimal medical treatment (OR 0.59; 95%CI 0.51-0.67) were associated with a lower 1-year mortality.

Conclusion

In Dutch NSTEMI patients, use of PCI during hospitalisation and optimal medical treatment is modest. As both are independently associated with a lower 1-year mortality, this study provides direction on how to improve NSTEMI healthcare quality in the Netherlands.

Abbreviations

ACE-/AT2-inhibitors	Angiotensin Converting Enzyme / Angiotensin II receptor -inhibitors
CI	Confidence Interval
DBC	Diagnose Behandel Combinatie
DIS	DBC Informatie Systeem
GIP	Geneesmiddelen Informatie Project
NSTEMI	Non ST-elevation Myocardial Infarction
OR	Odds Ratio
PCI	Percutaneous Coronary Intervention
P2Y12	Thienopyridine receptor blockers
SMD	Standardized Mean Difference
STEMI	ST-elevation Myocardial Infarction
ZINL	Zorginstituut Nederland

Introduction

Improvements in early recognition and revascularisation significantly decreased mortality after myocardial infarction over the last decades(1-3). This reduction in mortality, however, is especially achieved in ST-elevation myocardial infarction (STEMI) patients. Unfortunately, non ST-elevation myocardial infarction (NSTEMI) mortality rate did not decline over the last years (4, 5).

Most recent European and American guidelines emphasize that the use of an early invasive strategy, as well as optimal medical therapy contribute to a better long term survival after NSTEMI (both evidence class 1, level A)(2, 3, 6). The European guidelines even indicate them as performance measures of NSTEMI-care, based on various large meta-analyses and randomized controlled trials(7, 8). Recently, Hall et al. demonstrated that optimal use of guideline-indicated care for NSTEMI was associated with greater survival gain(9). However, in Hall's study the adherence rate was suboptimal indicating that survival can potentially be improved.

This recent study illustrates that large-scale monitoring of guideline indicated care adherence is crucial to provide insight on how to improve NSTEMI care, ultimately resulting in improved survival.

The National Healthcare Institute (Zorginstituut Nederland, ZINL) has an advisory role to the Dutch government with the primary objective to improve Dutch national healthcare. For this purpose, ZINL has access to all Dutch patients' claims data in the Netherlands. The use of these claims data has been proven to reflect the real clinical data and to be correct and adequate in prior studies(10-12). The current study is performed in close collaboration with ZINL and aims to analyse NSTEMI care in the Netherlands and identify modifiable performance factors to analyse and improve the quality of NSTEMI healthcare in the Netherlands.

Methods

Hospital claims are sent to patient's insurance companies and subsequently collected in the central database of the insurance companies in the Netherlands. The use of this type of data has been validated in previous studies(11). The National Healthcare Institute has access to both clinical- and pharmaceutical claims databases and can access data on a patient level, which can be linked but is anonymous (Figure 1).

Study Population

This is a retrospective cohort design study. Three cohorts were used for analysis, as shown in Figure 2.

- The entire study cohort comprises all Dutch patients above 18 years old who were admitted with a NSTEMI (diagnosis code 0320.11.205) in 2015. Only the first infarction during the study period was used for analysis. Patients who died on the first day of admission with the diagnosis of NSTEMI were excluded, in order to evaluate the effect of the different treatments.
- A sub-cohort, "NSTEMI-4days alive", comprises all patients alive 4 days after NSTEMI. This cohort was used to evaluate the effect of PCI during hospitalisation on 1-year mortality.
- A second sub-cohort, "NSTEMI-30 days alive", comprises all patients alive 30 days after NSTEMI. This cohort was used to evaluate the effect of medication use at 30 days on 1-year mortality.

Outcome Measures: Baseline Characteristics

Age, gender, co-morbidities and 1-year mortality were evaluated for all patients alive at 4 days and 30 days. For each patient, the absence or presence of diabetes mellitus, hypercholesterolemia and obstructive pulmonary disease (COPD/asthma) at the time of infarction was determined based on medication use, 180 days before admission. Diabetes mellitus was defined as use of glucose lowering medication (code A10XX, oral antidiabetics or insulin), hypercholesterolemia as use of any form of cholesterol lowering medication (code C10XX, all forms of cholesterol lowering medication) and obstructive pulmonary disease as use of any inhalation medication (code R03XX, all forms of inhalation medication).

These types of medication had to be used at least 180 days prior to the admission to qualify a patient as having the specified comorbidity.

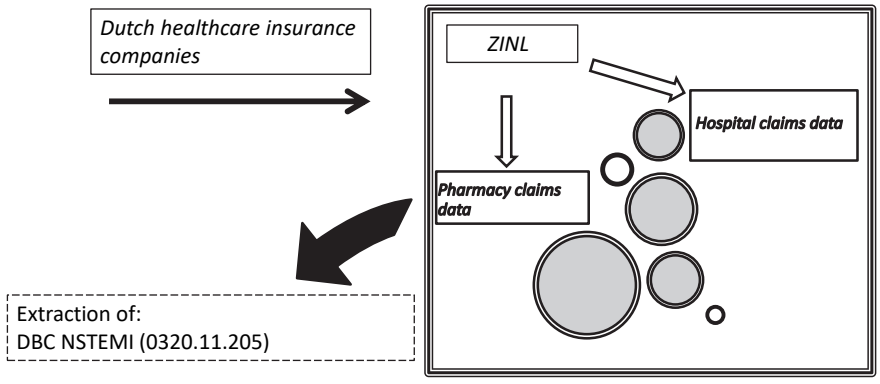


Figure 1: Data collection.

All healthcare claims from the Dutch healthcare insurance companies are stored and collected by the National Healthcare institute (ZINL). This includes hospital claims data as well as pharmacy claims data. Dara are available for analysis when approved (Figure 1). From each dataset from different years, the claims for NSTEMI -care can be collected for all patients (Figure 2) but also specific patient cohorts.

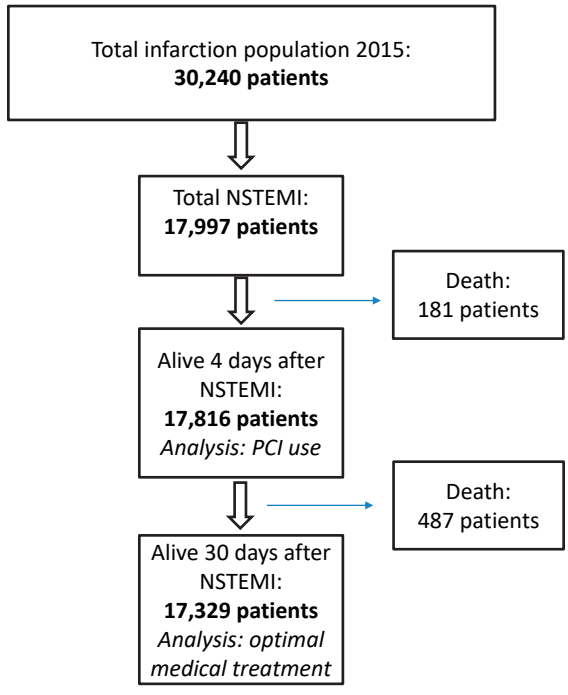


Figure 2: NSTEMI patient cohort.

PCI Treatment

In the "NSTEMI-4days alive" cohort, the effect of PCI within 4 days of the diagnosis on mortality was evaluated (figure 2) in all patients alive at 4 days. The cut-off of 4 days was based on European and American guidelines which recommend an invasive strategy, meaning coronary angiography, within the first 72 hours, which is the acute or semi-acute phase of the infarction. (6, 13). PCI at a later moment for instance after 7- or 30 days , were not analyzed as this was not deemed 'acute phase' of the NSTEMI.

Optimal Medical Treatment

In the "NSTEMI-30 days alive" cohort, the effect of complete optimal medical treatment on mortality was evaluated (figure 2). Optimal medical treatment after NSTEMI was defined as the combined use of an aspirin specie, a P2Y12- inhibitor, a statin, a beta-blocker and an ACE-/AT2-inhibitor. Fulfilled prescriptions of each of these were collected from the pharmacological database (GIP database).

Statistical Analysis

Data are presented as absolute numbers and as a proportion of the total population. Proportion comparisons were done by a X^2 test. Multivariate logistic regression analysis was done to understand the relation between 1-year mortality as dependent variable and independent variables: gender, age, diabetes, hypercholesterolemia, obstructive pulmonary disease, PCI treatment and optimal medical treatment use. To assess the relation of treatment (PCI/optimal medical treatment) and 1-year mortality, propensity score matching was applied.

Statistics: Propensity Score Matching

Patients were matched 1-to-1 using caliper matching. This procedure ensures an optimal balance of covariates between the treatment and the reference group. Age, gender and co-morbidities were analyzed as risk factors and used for matching. When assessing effectiveness of PCI and optimal medical treatment, interference of the added effect of the other (respectively optimal medical treatment or PCI when assessing the effect of optimal medical treatment) was unwanted and thus corrected for in all propensity score analyses. With propensity score matching a treatment and a reference cohort were created with a comparable load of risk factors.

Matching was done specifically for PCI and a second time specifically for optimal medical treatment. (Appendix A). Statistics were done with R statistical program version 3.3.2 (x64), R packages MatchtIt and tableone and SAS™ (SAS Institute, Cary, NC, USA.). For all tests, a P-value <0.05 was considered statistically significant.

Ethical Considerations

This research uses pseudo anonymous and encrypted patient data. Dutch law states that prior ethical review and approval is not necessary.

Results

Study Population

In 2015, a total of 30,240 myocardial infarction patients were admitted to Dutch hospitals. In 60% of them it concerned NSTEMI patients (N=17,997). Average age was 69.6 (SD=12.8) years. In total, 64% of the NSTEMI patients were male and 1-year mortality was 11% (Table 1)

In the first 4 days 181 patients died. The sub-cohort of "NSTEMI-4days alive" consisted of 17,816 patients (Table 1, NSTEMI 4 days). Average age was 69.5 (SD=12.7) years with 64% being male and 1-year mortality in this cohort was 10%.

Additionally, in the following 26 days 487 patients died. This sub-cohort, "NSTEMI-30 days alive" consisted of 17,329 patients (Table 1, NSTEMI 30 days). Average age was 69.2 (SD=12.7) years, with 64% being male. The 1-year mortality in this cohort was 7%. Co-morbidities were frequent in all cohorts, and equally distributed (P=NS, table 1).

Table 1. Patient Characteristics

	NSTEMI	NSTEMI 4 days	NSTEMI 30 days	P-value
Total patients (N)	**17,997**	**17,816**	**17,329**	
Age (average, SD)	69.6(12.8)	69.5(12.7)	69.2(12.7)	NS
Male (N, %)	11,518(64%)	11,388(64%)	11,089(64%)	NS
Diabetes (N, %)	3,779(21%)	3,765(21%)	3,610(21%)	NS
Hypercholesterolemia (N, %)	7,739(43%)	7,632(43%)	7,375(43%)	NS
Obstructive Pulmonary disease (N, %)	2,880(16%)	2,793(16%)	2,691(16%)	NS
1-year mortality	1,980(11%)	1,781(10%)	1,285(7%)	<0.001

NSTEMI = total non ST-elevation myocardial infarction population.

NSTEMI 4 days = non ST-elevation myocardial infarction patients alive at 4 days.

NSTEMI 30 days = non ST-elevation myocardial infarction patients alive at 30 days.

PCI Treatment (NSTEMI-4days alive)

In the "NSTEMI-4days alive' sub cohort (N= 17,816), PCI within the first 72 hours (3 days) was performed in 43% of patients. Of interest, PCI treatment was performed in 35% of the female NSTEMI patients as compared to 47% of the male NSTEMI patients (P<0.001).

Medication Use (NSTEMI-30 days alive)

Table 2 displays medication use at 30 days in the "NSTEMI-30 days alive" cohort (N=17,329). In this subgroup, the percentage of patients with complete "optimal medical treatment" was 47% at 30 days. Aspirin-specie use was 91%, P2Y12-inhibitors use 76%, statin use 85%, bètablocker use 74% and ACE/AT-2 inhibitor use 75%.

Effect of PCI on Mortality (NSTEMI-4days alive)

Table 3 displays the predictors of 1-year mortality in the "NSTEMI-4days alive" cohort (N=17,816). The following predictors add significantly to increased mortality: increasing age (OR 1.09; 95% CI 1.08-1.09), male gender (OR 1.27; 95% CI 1.14-1.42), diabetes mellitus (OR 1.51; 95% CI 1.34-1.70), and obstructive pulmonary disease (OR 1.52; 95% CI 1.37-1.71).

Noticeably, PCI treatment within 4 days (OR 0.42; 95% CI 0.37-0.48) is associated with a substantial lower 1-year mortality.

Table 2. NSTEMI-30 days alive cohort: medication use at 30 days.

Total complete optimal medical treatment use	**8,144(47%)**
Aspirin species	15,769(91%)
P2Y12-inhibitor	13,170(76%)
Statin	14,729(85%)
Bètablocker	12,823(74%)
ACE/AT-2-inhibitor	12,996(75%)

ACE/AT-2 = angiotensin converting enzyme/ angiotensin II -receptor inhibitor;

NSTEMI-30 days = non ST-elevation myocardial infarction alive at 30 days.

Table 3. Multivariate logistic regression of predictors of 1-year mortality in the subcohort of non-ST-elevation myocardial infarction patients alive at 4 days.

Factor	**Odds ratio**	**95%-confidence interval**	**P-value**
Age (increase by 1 year)	1.09	1.08-1.09	<0.001
Male gender	1.27	1.14-1.42	<0.001
Diabetes mellitus	1.51	1.34-1.70	<0.001
Hypercholesterolemia	1.11	0.99-1.23	NS
Obstructive Pulmonary disease	1.52	1.37-1.71	<0.001
PCI during hospitalisation	0.42	0.37-0.48	<0.001

NSTEMI = non ST-elevation myocardial infarction; PCI = percutaneous coronary intervention

Table 4. Multivariate logistic regression of predictors of 1-year mortality in the subcohort of non ST-elevation myocardial infarction patients alive at 30 days.

Factor	Odds ratio	95%-confidence interval	P-value
Age (increase by 1 year)	1.08	1.08-1.09	<0.001
Male gender	1.21	1.07-1.37	<0.01
Diabetes mellitus	1.54	1.34-1.76	<0.001
Hypercholesterolemia	1.23	1.08-1.39	<0.01
Obstructive Pulmonary disease	1.61	1.40-1.85	<0.001
Complete optimal medical treatment	0.59	0.51-0.67	<0.001
PCI during hospitalisation*	0.52	0.45-0.60	<0.001

NSTEMI = non ST-elevation myocardial infarction; PCI = percutaneous coronary intervention

* = In the patients alive at 30 days, the effect of PCI within 3 days was equally calculated to correct for it and to use this variable in propensity score matching (see Methods section)

Effect of Medication on Mortality (NSTEMI-30 days alive)

Predictors for 1-year mortality in the "NSTEMI-30 days alive" sub cohort (N=17,329) are shown in Table 4. In line with the entire study cohort, the following predictors add significantly to increased mortality: increasing age (OR 1.08; 95% CI 1.08-1.09), male gender (OR 1.21; 95% CI 1.07-1.37), diabetes mellitus (OR 1.54; 95% CI 1.34-1.76), hypercholesterolemia (OR 1.23; 95% CI 1.08-1.39) and obstructive pulmonary disease (OR 1.61; 95% CI 1.40-1.85). Importantly, complete "optimal medical treatment" (OR 0.59; 95% CI 0.51-0.67) is associated with a substantial lower 1-year mortality.

Propensity Score Matched Cohort

Propensity score matching was performed in both cohorts; 14,364 patients could be matched in case of PCI and 13,038 patients could be matched in case of optimal medical treatment. After matching the standardised mean differences (SMDs) of nearly all covariates was less than 0.1.

The effect of PCI and the effect of optimal medical treatment, when compared with a reference group with a nearly identical mix of covariates, was significant ($p < 0.001$), stressing that both PCI treatment within 4 days and optimal medical treatment are both significantly associated with increased survival for the Dutch NSTEMI population (Appendix A).

Discussion

The current study analyses NSTEMI care in the Netherlands through hospital and pharmaceutical claims data. The main findings can be summarized as; NSTEMI patients are predominantly older, male patients. The use of PCI within 4 days of hospitalisation and " complete optimal medication treatment-use" within 30-days after NSTEMI is both modest, but both significantly lower 1-year mortality in these patients. Non-use of both factors is independently associated with increased mortality, which suggests that through present study, NSTEMI healthcare quality can be improved in the Netherlands.

The current call for awareness for a wider use of PCI within 4 days of admission after NSTEMI and "optimal medical treatment-use" is in line with the recommendations in the ESC guidelines(3). Furthermore, it is congruent with a recently published study by Hall et al. analyzing over 400,000 hospital survivors of a NSTEMI in England and Wales, in order to investigate whether improved survival associated with the use of NSTEMI guideline-indicated treatments(9).

In this somewhat older cohort (2003-2013), Hall et al. demonstrate that guideline-indicated treatment is associated with improved survival that persisted over the longer term. An invasive coronary strategy was found to have the most comprehensive and persistent impact on survival. This is consistent with the finding of the current study where PCI treatment for NSTEMI substantially reduces 1-year mortality with an OR of 0.42.

A potential argument for non-use of PCI in NSTEMI patients in daily practice may be that the beneficial effect of PCI is less in the elderly with more comorbidities and complications are more prominent in this group. Interestingly, Couture et al. found that especially in older patients with more comorbidities a more invasive strategy should be considered (14). With the NSTEMI cohort in our study having a similar profile and low PCI rate, this can be an important finding to improve on in the Netherlands. This issue was indeed also raised in a very recent registry by Hoedemaker et al. evaluating treatment patterns of NSTEMI patients in 23 non-PCI centers in the Netherlands.

In this registry, the majority of high risk patients underwent angiography at a non-PCI center. Despite guideline recommendation only a quarter of these high risk patients was transferred to a PCI center within 1 day(15).

Apart from early PCI, the present study also underlines the importance of "optimal medical treatment-use" implemented within 30 days after NSTEMI. Where Hall et al reported on recipes at discharge, the current study reveals which medication is collected at pharmacies up to 30 days after NSTEMI.

Since primary non-adherence of prescribed medication has reported to be very common in patients with ischemic heart disease(16), we think that the current results provide additional insight in the significance of secondary prevention medication use after NSTEMI, especially since mortality differences were already observed within the first year. Accordingly, a conjoint effort of cardiologists and patients is warranted to improve medication adherence after NSTEMI.

The current study confirms the findings by Hall et al and extends them to the entire Dutch population with additional insights in the impact of secondary prevention medication truly collected at pharmacies. Interestingly, the method of data collection substantially differs between the two studies. In particular, Hall et al reported on data gathered from national clinical audits.

Data collection for audits, however, is time consuming and expensive. We want to stress the need for new effective ways of evaluating healthcare as a key element in healthcare innovation. The use of claims data has been proven correct and adequate in prior studies(10, 11). National claims data provide a good representation of "the real world setting" in contrast to the common single centre registries in NSTEMI studies(17-22). Furthermore, it has the advantage of coming with a low administrational load, costs, an absence of reporting bias and it provides easy follow-up of patients being treated in more than one hospital.

Some limitations should nonetheless be considered when interpreting the results. First the study uses a non-randomized design with observational data. The addition of propensity score matching however, strengthens the results(23).

Second, this study only assessed PCI treatment in the acute phase of the infarction; an effect of PCI on mortality after the acute phase of NSTEMI was not calculated. Identically, the effect of bypass surgery (CABG) on mortality after NSTEMI was not calculated. Third, the level of clinical detail is limited such as completeness of revascularization or infarct size. Common used risk scores (e.g. Global Registry of Acute Coronary Events (GRACE) risk score) cannot be applied as well. Potentially there could have been a bias from patients, registered as NSTEMI, who did not meet all the criteria of myocardial infarction and therefore should have been classified as unstable angina. For our study we however rely on the correctness of registration of Dutch cardiologists. Equally, used definitions for comorbidities are only determined through medication use prior to the infarction and not clinical data. Equally, used definitions for comorbidities are only determined through medication use prior to the infarction and not clinical data. Likewise, clinical details on differences between male and female PCI rates lack from financial claim data. Fourth, although mortality data are available, the cause of death is not specified. Fifth, the pharmaceutical claims data only represent the collected medication, not the consumed medication.

Furthermore, it remains unclear if medication was contra-indicated or not prescribed. And lastly, further randomized trials are needed to validate the healthcare benefit of PCI during hospitalization and optimal medical treatment.

Future perspectives

The use of financial claims data in the medical field is a relatively novel and modern way of analyzing healthcare. It provides insight in where healthcare quality can be improved, both for clinicians and patients as well as for healthcare managers, insurance companies and policy makers on a national level. Particular attention should go to a wider use of PCI within 4 days of admission for NSTEMI as well as to patient, doctor and financial factors contributing to medication adherence. Financial claims data can again be used to monitor the impact of such initiatives.

Conclusion

The present study analyzed hospital and pharmaceutical claims data of more than 17,000 NSTEMI patients in the Netherlands. PCI use during hospitalization and "optimal medical treatment" both are moderately applied in this patient group but are independently associated with a lower 1-year mortality.

These findings importantly suggest that attention for a wider use of PCI during hospitalization and particular attention for "optimal medical treatment" prescription by cardiologists and its use by patients, may substantially improve outcome after NSTEMI.

Conflict of interest

None.

Funding

No funding was received for this research.

References

1. Nabel EG, Braunwald E. A tale of coronary artery disease and myocardial infarction. N Engl J Med. 2012;366(1):54-63.
2. Amsterdam EA, Wenger NK, Brindis RG, et al. 2014 AHA/ACC Guideline for the Management of Patients With Non–ST-Elevation Acute Coronary Syndromes: Executive Summary. J Am Coll Cardiol. 2014;130(25):2354-94.
3. Roffi M, Patrono C, Collet JP, et al. 2015 ESC Guidelines for the management of acute coronary syndromes in patients presenting without persistent ST-segment elevation: Task Force for the Management of Acute Coronary Syndromes in Patients Presenting without Persistent ST-Segment Elevation of the European Society of Cardiology (ESC). Eur Heart J.2016;37(3):267-315.
4. Hall M, Dondo TB, Yan AT, et al. Association of clinical factors and therapeutic strategies with improvements in survival following non–st-elevation myocardial infarction, 2003-2013. JAMA. 2016;316(10):1073-82.
5. Yeh RW, Sidney S, Chandra M, et al.Population Trends in the Incidence and Outcomes of Acute Myocardial Infarction. N Engl J Med. 2010;362(23):2155-65.
6. Gencer B, Brotons C, Mueller C, et al. 2015 ESC Guidelines for the management of acute coronary syndromes in patients presenting without persistent ST-segment elevation: Task Force for the Management of Acute Coronary Syndromes in Patients Presenting without Persistent ST-Segment Elevation of the European Society of Cardiology (ESC). Eur Heart J. 2016;37(3):267-315.
7. Bavry AA, Kumbhani DJ, Rassi AN, et al. Benefit of early invasive therapy in acute coronary syndromes: a meta-analysis of contemporary randomized clinical trials. J Am Coll Cardiol. 2006;48(7):1319-25.
8. Navarese EP, Gurbel PA, Andreotti F, et al. Optimal timing of coronary invasive strategy in non–st-segment elevation acute coronary syndromes: A systematic review and meta-analysis. Ann Intern Med. 2013;158(4):261-70.
9. Hall M, Bebb OJ, Dondo TB, et al.Guideline-indicated treatments and diagnostics, GRACE risk score, and survival for non-ST elevation myocardial infarction. Eur Heart J.2018;39(42):3798-806.
10. Eindhoven DC, Hilt AD, Zwaan TC, et al. Age and gender differences in medical adherence after myocardial infarction: Women do not receive optimal treatment - The Netherlands claims database. Eur J Prev Cardiol. 2018;25(2):181–189.
11. Eindhoven DC, van Staveren LN, van Erkelens JA, et al. Nationwide claims data validated for quality assessments in acute myocardial infarction in the Netherlands. Neth Heart J. 2018;26(1):13–20.
12. Eindhoven DC, Wu HW, Kremer SWF, et al. Mortality differences in acute myocardial infarction patients in the Netherlands: The weekend-effect. Am Heart J. 2018;205:70–76.
13. Amsterdam EA, Wenger NK, Brindis RG, et al.2014 AHA/ACC Guideline for the Management of Patients With Non–ST-Elevation Acute Coronary Syndromes: A Report of the American College

of Cardiology/American Heart Association Task Force on Practice Guidelines. J Am Coll Cardiol. 2014;64(24):e139-e228.

14. Couture EL, Farand P, Nguyen M, et al.Impact of an invasive strategy in the elderly hospitalized with acute coronary syndrome with emphasis on the nonagenarians. Catheterization and cardiovascular interventions : official journal of the Society for Cardiac Angiography & Interventions. Catheter Cardiovasc Interv. 2018;92(7):E441–E448.
15. Hoedemaker NPG, Damman P, Bosker HA, et al. Treatment patterns of non-ST-elevation acute coronary syndrome patients presenting at non-PCI centres in the Netherlands and possible logistical consequences of adopting same-day transfer to PCI centres: a registry-based evaluation. Neth Heart J. 2019;27(4):191–199.
16. Tamblyn R, Eguale T, Huang A, et al.The incidence and determinants of primary nonadherence with prescribed medication in primary care: a cohort study. Ann Intern Med. 2014;160(7):441-50.
17. Costa JR, Jr., Abizaid A. "Let's not hurry, but let's not waste time": The importance of appropriate management of non-ST-elevation myocardial infarction. Rev Port Cardiol. 2018;37(1):63–65.
18. Cyrne Carvalho H. Management of non-ST-elevation myocardial infarction: A constant challenge. Rev Port Cardiol. 2016;35(12):655–657.
19. Denlinger LN, Keeley EC. Medication Administration Delays in Non-ST Elevation Myocardial Infarction: Analysis of 1002 Patients Admitted to an Academic Medical Center. Crit Pathw Cardiol. 2018;17(2):73–76.
20. Engel J, Damen NL, van der Wulp I, et al.Adherence to Cardiac Practice Guidelines in the Management of Non-ST-Elevation Acute Coronary Syndromes: A Systematic Literature Review. Curr Cardiol Rev. 2017;13(1):3–27.
21. Gonzalez-Cambeiro MC, Lopez-Lopez A, Abu-Assi E, et al. Mortality benefit of long-term angiotensin-converting enzyme inhibitors or angiotensin receptor blockers after successful percutaneous coronary intervention in non-ST elevation acute myocardial infarction. Rev Port Cardiol. 2016;35(12):645–653.
22. Hoedemaker NPG, Damman P, Ottervanger JP, et al. Trends in optimal medical therapy prescription and mortality after admission for acute coronary syndrome: a 9-year experience in a real-world setting. Eur Heart J Cardiovasc Pharmacother. 2018;4(2):102–110.
23. Hannan EL. Randomized clinical trials and observational studies: guidelines for assessing respective strengths and limitations. JACC Cardiovasc Interv. 2008;1(3):211–217.

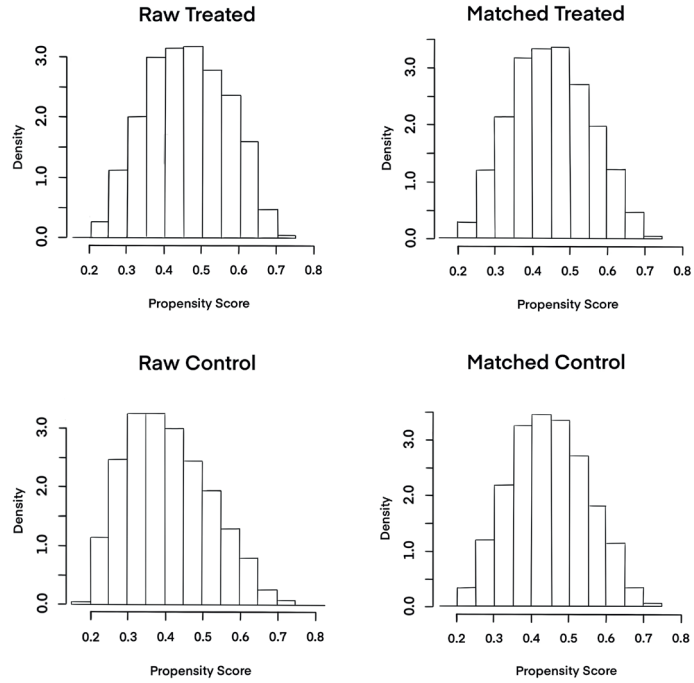
Appendix A: propensity score matching for PCI during hospitalisation and complete optimal medical treatment-use.

Part 1: PCI

To assess the effect of PCI during hospitalisation on 1-year mortality, a treatment (PCI) and a reference group with an identical balance of covariates were created. This was done by calculating propensity scores with the R programming language and logistic regression on covariates: age, gender, use of diabetes mellitus medication in year before NSTEMI, use of medication for obstructive pulmonary disease in the year before NSTEMI and use of medication for hypercholesterolemia in year before NSTEMI.

With the R package 'MatchIt' patients were matched 1:1 based on corresponding propensity scores and a caliper of 0.9. Of the patients, 14,368 were matched. After matching the histograms of propensity scores of optimal medical treatment and reference group were nearly identical.

With the R package 'tableone' we checked if standardized mean differences (SMD) between the PCI and the reference group were comparable. Before propensity score matching (unadjusted table), age and sex were unevenly distributed between the reference and PCI group. After propensity score matching (adjusted table), all variables were evenly distributed; nearly all SMDs were < 0.1.



Unadjusted (before propensity scoring)	Reference Group	PCI group	SMD
Patients (N=)	10,172	7,644	
Age (Mean (SD))	71.69(12.91)	66.48(11.89)	0.420
Male (Mean(SD))	0.59(0.49)	0.71(0.46)	0.243
Diabetes Mellitus (Mean(SD)	0.23(0.42)	0.19(0.39)	0.109
Hypercholesterolemia (Mean(SD))	0.46(0.50)	0.39(0.49)	0.129
Obstructive Pulmonary Disease (Mean(SD))	0.18(0.38)	0.13(0.34)	0.121

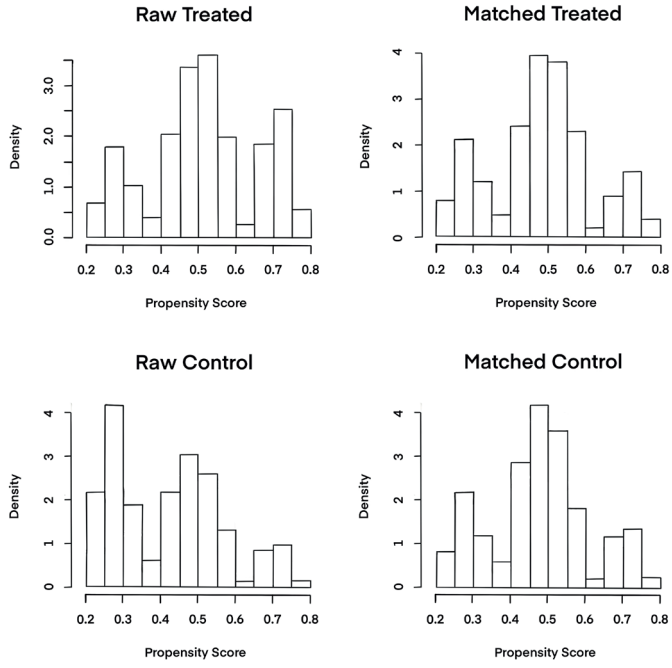
Adjusted (after propensity scoring)	Reference Group	PCI group	SMD
Patients (N=)	7,184	7,184	
Age (Mean (SD))	67.87 (12.29)	67.54 (11.40)	0.028
Male (Mean(SD))	0.69 (0.46)	0.70 (0.46)	0.021
Diabetes Mellitus (Mean(SD)	0.20 (0.40)	0.19 (0.39)	0.034
Hypercholesterolemia (Mean(SD))	0.42 (0.49)	0.41 (0.49)	0.018
Obstructive Pulmonary Disease (Mean(SD))	0.14 (0.35)	0.13 (0.34)	0.026

With a paired T test we evaluated the effect difference on 1-year mortality. The effect difference of PCI treatment was significant ($P < 0.001$). Effect size: In this total group of 14,368 matched patients, the 1-year mortality was 7.7%. In the PCI group 1-year mortality was 4.6%, in the reference group 1-year mortality was 10.9%.

Part 2: Complete optimal medical treatment (OMT)

To assess the effect of complete optimal medical treatment on 1-year mortality, a treatment (optimal medical treatment) and a reference group with an identical balance of covariates were created. This was done by calculating propensity scores with the R programming language and logistic regression on covariates: age, gender, use of diabetes mellitus medication in year before NSTEMI, use of medication for obstructive pulmonary disease in the year before NSTEMI, use of medication for hypercholesterolemia in year before NSTEMI and PCI during hospitalisation.

With the R package 'MatchIt' patients were matched 1:1 based on corresponding propensity scores and a caliper of 0.5. Of the patients, 13,456 were matched. After matching the histograms of propensity scores of (optimal medical treatment) treatment and reference group were nearly identical.



With the R package 'tableone' we checked if standardized mean differences (SMD) between the optimal medical treatment and the reference group were comparable. Before propensity score matching, noticeably patients with hypercholesterolemia and having had a PCI during hospitalisation were unevenly distributed amongst the reference and OMT group. After propensity score matching, nearly all SMDs for used variables were < 0.1.

Unadjusted (before propensity scoring)	Reference Group	OMT group	SMD
Patients (N=)	9,303	8,026	
Age (Mean (SD))	70,07(13.03)	68.11(12.23)	0.156
Male (Mean(SD))	0.62(0.49)	0.67(0.47)	0.102
Diabetes Mellitus (Mean(SD)	0.18(0.39)	0.24(0.43)	0.137
Hypercholesterolemia (Mean(SD))	0.35(0.48)	0.51(0.50)	0.323
Obstructive Pulmonary Disease (Mean(SD))	0.16(0.37)	0.15(0.36)	0.036
PCI during hospitalisation (Mean(SD))	0.33(0.47)	0.57(0.50)	0.497

Adjusted (after propensity scoring)	Reference Group	OMT group	SMD
Patients (N=)	6,728	6,728	
Age (Mean (SD))	69.32 (12.40)	68.01 (12.59)	0.105
Male (Mean(SD))	0.64 (0.48)	0.65 (0.48)	0.004
Diabetes Mellitus (Mean(SD)	0.21 (0.41)	0.23 (0.42)	0.054
Hypercholesterolemia (Mean(SD))	0.47 (0.50)	0.44 (0.50)	0.068
Obstructive Pulmonary Disease (Mean(SD))	0.16 (0.36)	0.16 (0.37)	0.011
PCI during hospitalisation (Mean(SD))	0.45 (0.50)	0.49 (0.50)	0.075

With a paired T test we evaluated the effect difference on 1-year mortality. The effect difference of optimal medical treatment was significant (P < 0.001). Effect size: In the total group of 13,456 matched patients, the 1-year mortality was 6.7%. In the optimal medical treatment group it was 5.1% and in the reference group it was 8.6%.

CHAPTER III

MYOCARDIAL INFARCTION CARE IN LOW AND HIGH SOCIOECONOMIC ENVIRONMENTS - CLAIMS DATA ANALYSIS

A.D. Hilt, MD; V.A.W.M. Umans, MD, PhD; T.N.E Vossenberg, MD, MSc; M.J. Schalij, MD, PhD; S.L.M.A. Beeres, MD, PhD.

Submitted

Abstract

Background

Claims data have not yet been used to study outcome differences between low and high Socio Economic Status (SES) patients surviving ST elevation myocardial infarction (STEMI) and non-ST elevation myocardial infarction (NSTEMI).

Objective

To evaluate STEMI and NSTEMI care among patients with low and high SES in the referral area of three Dutch percutaneous coronary intervention (PCI) centres, using claims data as a source.

Methods

STEMI and NSTEMI patients treated in 2015-2017 were included. Patients' SES scores were collected based on ZIP-code via an open access government database. In low (SES1) and high (SES4) patients, revascularisation strategies and secondary prevention medication were compared.

Results

2,022 SES1 patients (age 68±13 years, 58% NSTEMI) and 1,635 SES4 patients (age 68±13 years, 63% NSTEMI) were included. PCI use was lower in SES1 compared to SES4 in both STEMI (80% vs 84%, p<0.012) and NSTEMI (42% vs 48%, p<0.002).

CABGs were performed more often in SES1 compared to SES4 in both STEMI (7% vs 4%, p=NS) and NSTEMI (11% vs 7%, p<0.001). Optimal medical therapy use in STEMI patients was higher in SES1 compared to SES4 (52% vs 46%, p=0.01); among NSTEMI this was comparable (39% vs 40%, p=NS). One-year mortality was comparable between SES1 and SES4 in STEMI (14 vs 16%, p=NS), and NSTEMI (10% vs 11%, p=NS).

Conclusion

Combined analysis of claims data and area specific socioeconomic statistics can provide unique insight on how to improve myocardial infarction care for low and high SES patients.

Abbreviations

ATC	Anatomic Therapeutic Chemical code
CABG	Coronary Artery Bypass Graft
DDD	Daily Defined Dosage
NSTEMI	non-ST elevation myocardial infarction
OMT	Optimal Medical Therapy
PCI	Percutaneous Coronary Intervention
SCP	The Netherlands Institute for Social Research (Sociaal en Cultureel Planbureau)
SES	Socioeconomic Status
STEMI	ST elevation myocardial infarction
ZINL	Dutch National Healthcare Institute (Zorginstituut Nederland)

Introduction

Socioeconomic status (SES) provides insight in the welfare level of an area and its inhabitants on various components including education, income and employment(1, 2). In patients with coronary artery disease, previous studies reported that low SES associated with increased morbidity and mortality (3-7). Therefore, low SES is a risk factor for a worse outcome in ST elevation myocardial infarction (STEMI) and non-ST elevation myocardial infarction (NSTEMI) patients.

Improving socioeconomic environment is foremost a governmental matter. However, cardiologists and allied professionals should be concerned with the evaluation and improvement of clinical care after myocardial infarction in different socioeconomic environments. Prospective registry-based studies can provide insight in demographic, ethnic and SES differences among myocardial infarction patients(7-9). Despite being executed well, these studies are often laborious and limited to selected patients. Contemporary databases, such as claims data registries, provide a unique alternative to assess outcomes of patients surviving myocardial infarction, as these databases provide accurate 'real world' data (10-12). To date, claims data has not been used to study differences between low and high SES myocardial infarction patients.

The current 'proof of concept' study evaluates STEMI and NSTEMI care among patients with low and high SES in the referral area of three Dutch percutaneous coronary intervention (PCI) centres, using claims data as a source. In particular, revascularisation strategies, secondary preventive medication-use and one-year mortality after STEMI and NSTEMI are analysed. The results of the current study may ultimately help to develop improvement strategies for modifiable factors on a loco-regional level.

Methods

In the Netherlands, hospital - and pharmaceutical claims data are sent to patient's insurance companies and subsequently collected in the central database of the insurance companies. The current study was done in close collaboration with the Dutch National Healthcare Institute (ZINL) which has an advisory role to the Dutch government and has access to both hospital- and pharmaceutical claims databases.

Study Design

This is a retrospective cohort study. Pseudo-anonymous and encrypted patient data were used. Dutch law states that prior ethical review and approval is not necessary for this type of analysis. Access to the claims data of each hospital was granted after obtaining signed consent from the head of the cardiology departments from each of the participating hospitals.

Study Population and Data Collection

All adult myocardial infarction patients treated in three participating Dutch PCI centers (two on-site; Leeuwarden Medical Center and Leiden University Medical Center, and one off-site PCI center, North-West Hospitals - Alkmaar) were eligible for inclusion. Inclusion criteria were: (1) diagnosis of STEMI (claims code 0320.11.204) or NSTEMI (claims code 0320.11.205) between January 1st 2015 and December 31st 2017, (2) follow-up of at least one year in one of three participating hospitals and (3) patients residing in surrounding ZIP-codes of participating hospitals (appendix 1). As described below, ZIP codes were used to classify patients in SES classes: SES1 was the lowest class and SES4 was the highest class. As the scope of the study was to compare myocardial infarction care in the lowest (SES1) vs. in the highest SES (SES4), patients in SES2 and SES3 were excluded. Patients who had more than one myocardial infarction during the study period were also excluded. Demographic data, revascularization strategies, medication use, and one-year mortality were evaluated in patients.

Socioeconomic Status (SES) Score

SES-scores are calculated for all ZIP-codes in the Netherlands by the Dutch government (Netherlands Institute for Social Research (SCP)) and are available through an online open-access database. The SES-score of a ZIP-code provides insight in the welfare status of that area. Scores are based on yearly income, employment status and education(13, 14). The average national SES-score score has a given numerical value of 0. This numerical vector changes by diverse variables: low income and low educational level result in a low numerical SES-score values, higher income and educational level result in higher numerical SES-score values. Between 2015 and 2017, Dutch national SES-scores were divided in four quartiles with the lowest SES score being SES1 and the highest SES score being SES4.

The SES quartiles were classified as follows: SES1: -8.19 to -0.57, SES2: -0.57 to 0.15, SES3: 0.15 to 0.71, SES4: 0.71 to 2.93.

Outcome Measure – Revascularisation

Revascularisation through either PCI or coronary artery bypass grafting (CABG) was assessed. PCI was defined as patients 'having had an angiography *with* placement of a stent or balloon angioplasty within four days of the initial STEMI or NSTEMI diagnosis registration'. The cut-off of 4 days was based on European and American guidelines, which recommend an invasive strategy within the first 72 hours (the acute or semi-acute phase of the STEMI or NSTEMI)(15-17).

CABG was defined as patients 'having had bypass surgery within 30 days of initial STEMI or NSTEMI diagnosis registration'. PCI or CABG at different time intervals were not analyzed in the current study. In addition, the total amount of re-PCI or re-CABG procedures were not analyzed.

Outcome Measure – Optimal Medical Treatment

Optimal medical treatment (OMT) after myocardial infarction was defined as the *combined* use of an aspirin specie, a P2Y12- inhibitor, a statin, a betablocker and an ACE-/AT2-inhibitor as recommended by international STEMI and NSTEMI guidelines(15, 16). For all patients, OMT use was measured one year after the initial STEMI or NSTEMI diagnosis registration, extracted from the national pharmacy database as a combination of anatomical therapeutic chemical (ATC) codes together with DDD of that type of medication. For each drug, a DDD threshold of at least 10 dosage-units per day during one year was used. The DDD is composed by the World Health Organization Collaborating Centre for Drug Statistics Methodology. It is the assumed average maintenance dose for a drug used for its main indication in adults. The use of these ATC and DDD definitions per medication has been validated in previous studies(10).

Statistical Analysis

Data are presented as absolute numbers and as a proportion of the total population (%). Proportion comparisons were done by a X^2 test. A p-value of 0.05 was considered statistically significant. Data were analyzed using SPSS version 25™ (IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp.)

Results

Study Population

During the study period, 7,264 unique myocardial infarction patients were treated in the participating hospitals. After exclusion of the SES 2 and SES 3 patients, the study population comprised 3,704 patients. Of these, 2,065 (28%) were SES1 patients and 1,639 (23%) were SES4 patients (Table1). In both groups, the majority concerned NSTEMI patients: 1,195 (58%) in the SES 1 group and 1,040 (63%) in the SES 4 group. Mean age at the time of STEMI and NSTEMI was similar in SES1 and SES4 patients (table 1). Significant less males were present in the SES1 group compared to SES4 group in STEMI patients (64% vs 74%, P<0.001) and to a lesser extent in NSTEMI patients (65% vs 66%, P=0.02). One-year mortality in SES1 and SES4 was similar in STEMI (14% vs 16%) and NSTEMI (11% vs 10%) patients (P=NS).

Table 1. Demographics of AMI patients within socioeconomic classes 2015-2017

SES	SES1	SES4	p-value
AMI (N)	2,065	1,639	
STEMI (N,%)	870(42)	599(37)	
Age (Mean,SD)	66.5(13)	66.7(13)	NS
Male (N,%)	551(64)	322(74)	<0.001
1-year mortality (N,%)	121(14)	70(16)	NS
NSTEMI (N,%)	1,195(58)	1,040(63)	
Age(Mean, SD)	70.5(13)	70.4(12)	NS
Male (N,%)	759(65)	612(66)	0.02
1-year mortality (N,%)	134(11)	94(10)	NS

AMI = Acute Myocardial Infarction; NS = Not Significant; NSTEMI = non ST elevation myocardial infarction; STEMI = ST elevation myocardial infarction

Table 2. PCI and CABG in STEMI and NSTEMI by SES.

SES	SES1	SES4	p-value
STEMI (N=)	870	599	
PCI(N,%)	697(80)	508(84)	0.02
CABG-30(N,%)	59(7)	22(4)	0.01
NSTEMI (N=)	1195	1040	
PCI(N,%)	505(42)	505(48)	0.003
CABG-30(N,%)	136(11)	72(7)	<0.001

CABG-30 = coronary artery bypass graft, within 30 days of admission

NSTEMI = non ST elevation myocardial infarction; PCI = percutaneous coronary intervention, within 4 days of admission; SES = socioeconomic status;

STEMI = ST elevation myocardial infarction

Revascularization by SES

Table 2 and figures 1a and 1b show treatment by PCI and CABG among STEMI and NSTEMI patients stratified by SES. In both STEMI and NSTEMI patients, PCI procedures were significantly less frequently performed in SES1 patients as compared to SES4 patients (P=0.02 for STEMI and P=0.003 for NSTEMI). On the contrary, in both STEMI and NSTEMI patients, CABG procedures were more often performed in SES1 patients compared to SES4 patients (P=0.01 for STEMI and P<0.001 for NSTEMI).

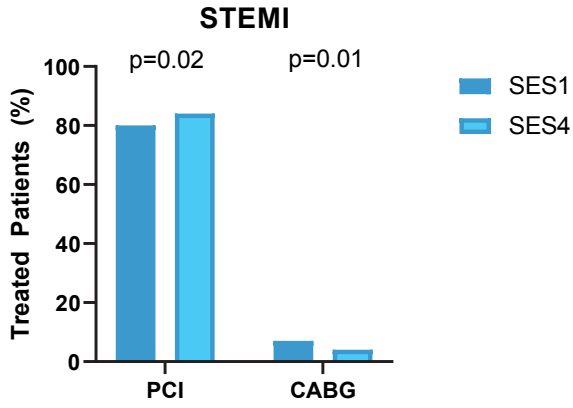


Figure 1a. Total P-CI and CABG in STEMI stratified by SES.

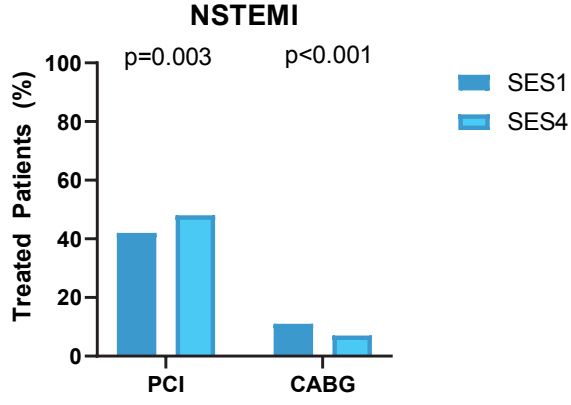


Figure 1b. Total PCI and CABG in NSTEMI stratified by SES.

Medication Usage by SES

Table 3 and figure 2 show medication use by STEMI and NSTEMI patients stratified by SES. Following STEMI, SES1 patients more frequently used complete optimal medical therapy as compared to SES4 patients (52% vs. 46%, P=0.01). The higher rate of medication use by SES1 patients was driven by a higher use of aspirin (84% vs. 76%, P<0.001), P2Y12-inhibitors (80% vs. 76%, P=0.03), betablockers (64% vs. 54%, P<0.001) and statins (84% vs. 77%, P<0.001). Following NSTEMI, 39% of SES1 patients used complete optimal medical therapy as compared to 40% of SES4 patients (P=NS). The only difference in NSTEMI patients concerned P2Y12-inhibitors with a lower use in SES1 patients (72% in SES1 vs. 76% in SES4, P=0.01).

Table 3. OMT and individual medication use among STEMI and NSTEMI patients by SES.

STEMI	**SES1**	**SES4**	**p-value**
OMT(N,%)	455(52)	274(46)	0.01
ASA(N,%)	728(84)	453(76)	<0.001
P2Y12(N,%)	699(80)	453(76)	0.03
BB(N,%)	557(64)	323(54)	<0.001
ACE/AT2(N,%)	653(75)	423(71)	NS
STAT(N,%)	734(84)	461(77)	<0.001
NSTEMI			
OMT(N,%)	466(39)	413(40)	NS
ASA(N,%)	984(82)	881(85)	NS
P2Y12(N,%)	856(72)	794(76)	0.01
BB(N,%)	705(59)	641(62)	NS
ACE/AT2(N,%)	844(71)	725(70)	NS
STAT(N,%)	992(83)	870(84)	NS

ACE/AT2 = angiotensin converting enzym/angiotensin II recepter blocker; ASA = Aspirin-specie; BB = Betablocker; OMT = Optimal Medical Treatment; P2Y12 = Thienopyridine antagonists; SES = socioeconomic status; Stat = Statin

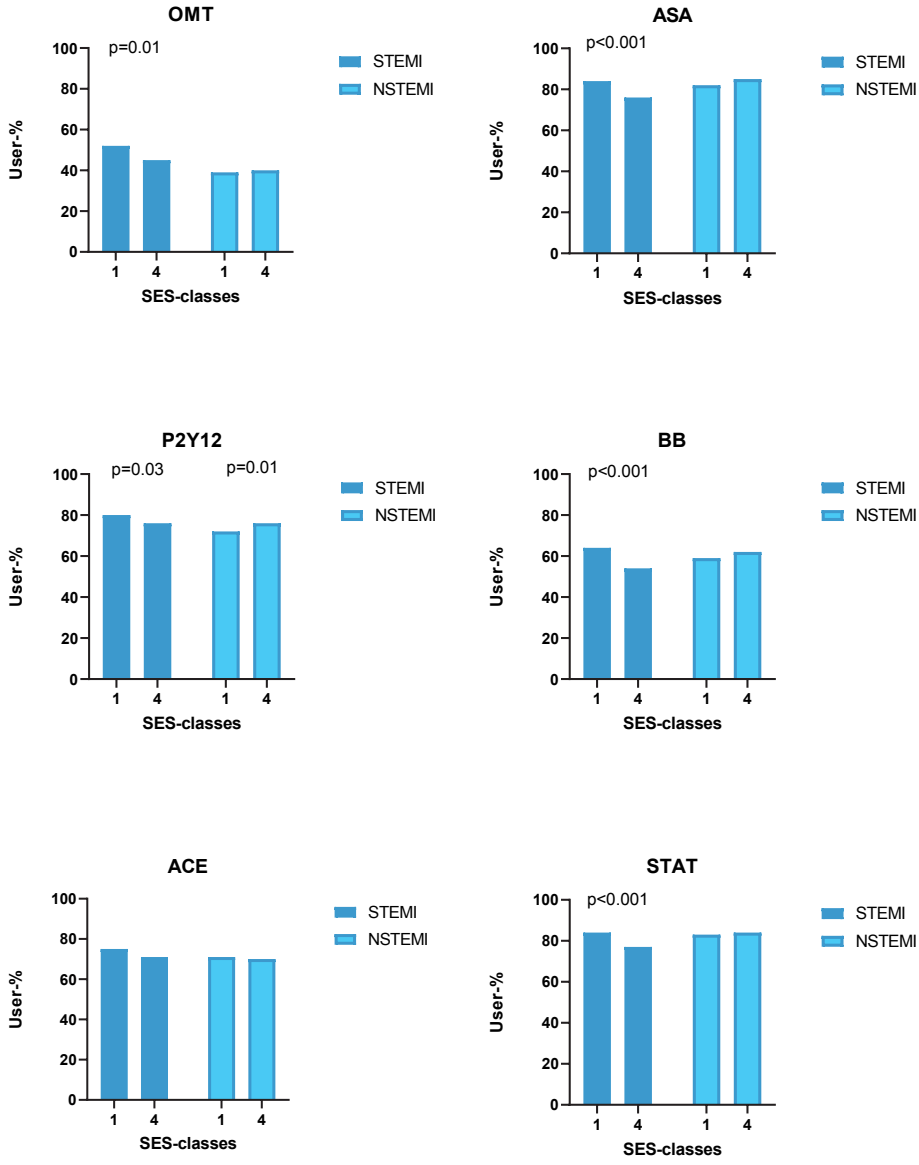


Figure 2. OMT and individual medication use among STEMI and NSTEMI patients by SES.

Discussion

The main findings of the current study, analyzing STEMI and NSTEMI care among low and high SES patients with the use of claims data, can be summarized as follows. At first, in both STEMI and NSTEMI patients, SES1 patients were less frequently treated by PCI and more frequently by CABG as compared to SES4 patients. At second, the use of optimal medical therapy is overall moderate in both SES1 and SES4 patients. Following STEMI, SES1 patients more frequently use complete optimal medical therapy as compared to SES4. Following NSTEMI, there is no difference in the rate of complete optimal medical therapy use. Lastly, combining claims data and area specific socioeconomic statistics, can be an efficient method to analyze cardiac care on a loco-regional level in a unique way.

A main finding of the current study is that low SES patients with either a STEMI or a NSTEMI, are treated by CABG more frequently than high SES patients. High CABG frequencies among low SES patients most probably are the result of more complex coronary lesions, resulting in the need for a CABG in this patient category.

Previous studies have shown that low SES patients overall exhibit more risk factors (smoking) and comorbidities (including hypertension, hypercholesterolemia and diabetes) at presentation resulting in multivessel disease rather than one-vessel disease (18-20). The relatively high frequency of CABGs in the low SES patients suggests that this population has an unhealthier life-style.

Thereby, the findings of the current study provide rationale for a conjoined initiative of cardiologists, family physicians, health care insurance companies and policy makers to improve life style in low SES regions.

In the current study, the use of optimal medical care is modest, both among STEMI and NSTEMI patients as well as among low and high SES patients. This finding is in line with previous Dutch (10, 12, 21), British and American studies (22-24), all stressing the need for increased awareness and improvement on this topic. When addressing individual medication use after STEMI in SES classes, foremost aspirin, betablockers and statins are used more frequently by low SES patients than by high SES STEMI patients. In NSTEMI patients, low and high SES patients show an overall comparable low usage pattern.

Although some previous studies show that low SES has a negative effect on medical adherence(25, 26), others show a negative effect of high SES(27, 28), or no effect of SES on medical adherence(29). The reason for the observed difference in our study is difficult to distill, as no clinical data such as allergies or side effect patterns were used. A lower use of cardioprotective medication in high SES STEMI patients can be related to an unwillingness

to take medication because of doubts or fear of side-effects, observed in higher educated patients(23, 30). It could however also be related to a healthier life-style and less prevalent risk-factors. The fact that, in the current study, high SES STEMI patients less frequently use optimal medical therapy is an important finding for the hospitals participating in the current study.

As medical adherence is indispensable for survival after myocardial infarction, initiatives focusing on medication adherence in the high SES patients in the outpatient follow-up by cardiologist and primary care physicians are warranted.

Future Perspectives

The use of financial claims data to analyze healthcare at a system level has recently gained attention. In the present study, for the first time, these claims data are combined with area specific socioeconomic statistics. Thereby, the study illustrates that in this way treatment patterns and healthcare use in specific regions and specific patient groups can be analyzed. This type of research substantially differs from previously performed "causality studies" with claims data assessing the impact of low SES on mortality or adverse events after myocardial infarction (19, 31-33).

The current findings in myocardial infarction patients, stress the importance of developing primary prevention programs in low SES regions. In addition, it provides rationale for developing programs to improve medical adherence after myocardial infarction among inhabitants of high SES regions. Conceptually, developing specific programs for specific inhabitants of specific regions may increase the effectiveness of these programs and contribute to a more useful spending of scarce healthcare resources.

Limitations

Some limitations should be considered when interpreting the results. First, the study uses observational data. Second, the used SES value is a ZIP-code average: some SES4 patients might live in an SES1 area and vice versa. Third, the used definition of SES is on an area bound-level, not on an individual level. Fourth, the level of clinical details is limited. Accordingly, completeness of revascularization, ventricular function or infarct size are not included and commonly used risk scores (e.g. GRACE risk score) cannot be applied to our study population. Fifth, the claims databases are gradually filled over a period of 2 years. Accordingly, the coverage of the 2018 and later databases were not available when this study was conducted. Lastly, the total amount of CABGs in our population could be underestimated by the fact that one off-site PCI center was included.

Conclusion

Combined analysis of claims data and area specific socioeconomic statistics can provide unique insight on how to improve myocardial infarction care for low and high SES patients. The relatively high CABG frequency among low SES patients stresses the importance of primary prevention programs in low SES regions.

The relatively low rate of complete optimal medical therapy justifies the development of programs to improve medical adherence among high SES patients.

Conflicts of Interest

none declared.

Funding

none received.

References

1. Braveman PA, Cubbin C, Egerter S, Chideya S, Marchi KS, Metzler M, et al. Socioeconomic status in health research: one size does not fit all. Jama. 2005;294(22):2879-88.
2. Pathirana TI, Jackson CA. Socioeconomic status and multimorbidity: a systematic review and meta-analysis. Australian and New Zealand journal of public health. 2018;42(2):186-94.
3. Kaplan GA, Keil JE. Socioeconomic factors and cardiovascular disease: a review of the literature. Circulation. 1993;88(4 Pt 1):1973-98.
4. Emberson JR, Whincup PH, Morris RW, Walker M. Social class differences in coronary heart disease in middle-aged British men: implications for prevention. International journal of epidemiology. 2004;33(2):289-96.
5. Rose G, Marmot MG. Social class and coronary heart disease. British heart journal. 1981;45(1):13-9.
6. Diez Roux AV, Merkin SS, Arnett D, Chambless L, Massing M, Nieto FJ, et al. Neighborhood of residence and incidence of coronary heart disease. The New England journal of medicine. 2001;345(2):99-106.
7. Gerber Y, Weston SA, Killian JM, Therneau TM, Jacobsen SJ, Roger VL. Neighborhood income and individual education: effect on survival after myocardial infarction. Mayo Clinic proceedings. 2008;83(6):663-9.
8. Yusuf S, Joseph P, Rangarajan S, Islam S, Mente A, Hystad P, et al. Modifiable risk factors, cardiovascular disease, and mortality in 155 722 individuals from 21 high-income, middle-income, and low-income countries (PURE): a prospective cohort study. Lancet (London, England). 2020;395(10226):795-808.
9. Rosengren A, Smyth A, Rangarajan S, Ramasundarahettige C, Bangdiwala SI, AlHabib KF, et al. Socioeconomic status and risk of cardiovascular disease in 20 low-income, middle-income, and high-income countries: the Prospective Urban Rural Epidemiologic (PURE) study. The Lancet Global health. 2019;7(6):e748-e60.
10. Eindhoven DC, Hilt AD, Zwaan TC, Schalij MJ, Borleffs CJW. Age and gender differences in medical adherence after myocardial infarction: Women do not receive optimal treatment - The Netherlands claims database. Eur J Prev Cardiol. 2017:2047487317744363.
11. Eindhoven DC, van Staveren LN, van Erkelens JA, Ikkersheim DE, Cannegieter SC, Umans V, et al. Nationwide claims data validated for quality assessments in acute myocardial infarction in the Netherlands. Netherlands heart journal : monthly journal of the Netherlands Society of Cardiology and the Netherlands Heart Foundation. 2017.
12. Ten Have P, Hilt AD, Paalvast H, Eindhoven DC, Schalij MJ, Beeres S. Non-ST-elevation myocardial infarction in the Netherlands: room for improvement! Netherlands heart journal : monthly journal of the Netherlands Society of Cardiology and the Netherlands Heart Foundation. 2020;28(10):537-45.

13. Kompas Volksgezondheid Noord en Oost Gelderland: Sociaal economische status [website]. http://www.kvnog.nl2017 [Available from: http://www.kvnog.nl/onderwerpen-voorst/bevolking-voorst/sociaaleconomische-status.
14. Wingen M OF. Sociaaleconomische status en verschillende gezondheidsaspecten van ouderen. Tijdschrift voor Gezondheidswetenschappen. 2009;87:109-17.
15. Collet JP, Thiele H, Barbato E, Barthélémy O, Bauersachs J, Bhatt DL, et al. 2020 ESC Guidelines for the management of acute coronary syndromes in patients presenting without persistent ST-segment elevation. European heart journal. 2020.
16. Ibanez B, James S, Agewall S, Antunes MJ, Bucciarelli-Ducci C, Bueno H, et al. 2017 ESC Guidelines for the management of acute myocardial infarction in patients presenting with ST-segment elevation: The Task Force for the management of acute myocardial infarction in patients presenting with ST-segment elevation of the European Society of Cardiology (ESC). European heart journal. 2018;39(2):119-77.
17. Jneid H, Addison D, Bhatt DL, Fonarow GC, Gokak S, Grady KL, et al. 2017 AHA/ACC Clinical Performance and Quality Measures for Adults With ST-Elevation and Non-ST-Elevation Myocardial Infarction: A Report of the American College of Cardiology/American Heart Association Task Force on Performance Measures. Circulation Cardiovascular quality and outcomes. 2017;10(10).
18. Gaalema DE, Elliott RJ, Morford ZH, Higgins ST, Ades PA. Effect of Socioeconomic Status on Propensity to Change Risk Behaviors Following Myocardial Infarction: Implications for Healthy Lifestyle Medicine. Progress in cardiovascular diseases. 2017;60(1):159-68.
19. Koren A, Steinberg DM, Drory Y, Gerber Y. Socioeconomic environment and recurrent coronary events after initial myocardial infarction. Annals of epidemiology. 2012;22(8):541-6.
20. Schultz WM, Kelli HM, Lisko JC, Varghese T, Shen J, Sandesara P, et al. Socioeconomic Status and Cardiovascular Outcomes: Challenges and Interventions. Circulation. 2018;137(20):2166-78.
21. Hoedemaker NPG, de Winter RJ, Hof AV, Kolkman E, Damman P. Optimal Medical Therapy Prescription in Patients with Acute Coronary Syndrome in the Netherlands: A Multicenter Pilot Registry. American journal of cardiovascular drugs : drugs, devices, and other interventions. 2020.
22. Hall M, Dondo TB, Yan AT, et al. Association of clinical factors and therapeutic strategies with improvements in survival following non–st-elevation myocardial infarction, 2003-2013. Jama. 2016;316(10):1073-82.
23. Murphy A, Palafox B, O'Donnell O, Stuckler D, Perel P, AlHabib KF, et al. Inequalities in the use of secondary prevention of cardiovascular disease by socioeconomic status: evidence from the PURE observational study. The Lancet Global health. 2018;6(3):e292-e301.
24. Hickson RP, Robinson JG, Annis IE, Killeya-Jones LA, Korhonen MJ, Cole AL, et al. Changes in Statin Adherence Following an Acute Myocardial Infarction Among Older Adults: Patient Predictors and the Association With Follow-Up With Primary Care Providers and/or Cardiologists. J Am Heart Assoc. 2017;6(10).

25. Wallach-Kildemoes H, Andersen M, Diderichsen F, Lange T. Adherence to preventive statin therapy according to socioeconomic position. European journal of clinical pharmacology. 2013;69(8):1553-63.
26. Rasmussen JN, Gislason GH, Rasmussen S, Abildstrom SZ, Schramm TK, Køber L, et al. Use of statins and beta-blockers after acute myocardial infarction according to income and education. Journal of epidemiology and community health. 2007;61(12):1091-7.
27. Citarella A, Kieler H, Sundström A, Linder M, Wettermark B, Berglind IA, et al. Family history of cardiovascular disease and influence on statin therapy persistence. European journal of clinical pharmacology. 2014;70(6):701-7.
28. Warren JR, Falster MO, Fox D, Jorm L. Factors influencing adherence in long-term use of statins. Pharmacoepidemiology and drug safety. 2013;22(12):1298-307.
29. Selmer R, Sakshaug S, Skurtveit S, Furu K, Tverdal A. Statin treatment in a cohort of 20 212 men and women in Norway according to cardiovascular risk factors and level of education. British journal of clinical pharmacology. 2009;67(3):355-62.
30. Ullberg T, Glader EL, Zia E, Petersson J, Eriksson M, Norrving B. Associations between Ischemic Stroke Follow-Up, Socioeconomic Status, and Adherence to Secondary Preventive Drugs in Southern Sweden: Observations from the Swedish Stroke Register (Riksstroke). Neuroepidemiology. 2017;48(1-2):32-8.
31. Jakobsen L, Niemann T, Thorsgaard N, Thuesen L, Lassen JF, Jensen LO, et al. Dimensions of socioeconomic status and clinical outcome after primary percutaneous coronary intervention. Circulation Cardiovascular interventions. 2012;5(5):641-8.
32. Alter DA, Chong A, Austin PC, Mustard C, Iron K, Williams JI, et al. Socioeconomic status and mortality after acute myocardial infarction. Annals of internal medicine. 2006;144(2):82-93.
33. Rasmussen JN, Rasmussen S, Gislason GH, Buch P, Abildstrom SZ, Køber L, et al. Mortality after acute myocardial infarction according to income and education. Journal of epidemiology and community health. 2006;60(4):351-6.

Appendix 1. Included zip-codes of analyzed PCI centers.

Leeuwarden Medisch Centrum (on-site PCI center)

- 8411 – 8495
- 8601 – 8651
- 8851 – 8584
- 8701 – 8773
- 8800 – 8896
- 8911 – 8941
- 9001 - 9089
- 9100 – 9178
- 9251 - 9265
- 9257 – 9269
- 9271 – 9298
- 9851 - 9853
- 9950

Leiden University Medical Center (on-site PCI center)

- 2171 - 2191
- 2201 - 2254
- 2311 – 2361

Noordwest Ziekenhuisgroep – Alkmaar (off-site PCI center)

- 1483 – 1486
- 1536
- 1631 - 1652
- 1711 - 1797
- 1811- 1873
- 1901 – 1992
- 2071 - 2082

PART TWO

HUMAN FACTORS SCIENCE IN CARDIOVASCULAR RESEARCH - PATIENT AND PROFESSIONAL PERSPECTIVES OF CARE

CHAPTER IV

VALUE BASED HEALTHCARE IN CARDIAC CARE - THE ADDITIONAL VALUE OF HUMAN FACTORS SCIENCE

A.D. Hilt, MD; R.W.C. Scherptong, MD, PhD.

Published
Tijdschrift voor Human Factors; 45 (4) 2020: 10-13.

Abstract

Developing patient-centered cardiovascular healthcare is eminent for an ever-growing, aging patient population. Value Based Healthcare (VBHC) research is becoming increasingly important in that matter, which questions the relevance (i.e. value) of contemporary evidence-based interventions in relation to *patients'* health status and personal preferences.

In cardiology, daily care consists of standardized complex care-tracks with diverse treatment options. The best possible care for a patient is based on contemporary scientific evidence and weighed by professionals. However, to assess the 'value' of care as perceived by the patient, is often difficult.

Human Factors (HF) science poses a useful addition in VBHC research. Via system analysis, such as combining observations and interviews into mapping a 'patient journey', it highlights the interaction between patient and professional both on *technical* and *non-technical* aspects of daily care. Value in that sense is uncovered by highlighting key points of interaction between patient and professional, with a focus on the patient experience and perspective.

This paper illustrates the added value of HF science into contemporary VBHC research in cardiology by discussing several example studies. It emphasizes the strength of it in determining value of care via a system analysis.

Introduction

Heart disease has a high mortality rate and morbidity burden worldwide, with the majority of total disease burden due to *coronary artery disease* (Kahn, 2020). Thankfully, survival of patients with coronary artery disease has increased since the second half of the 20th century (Fox et al., 2007).

The introduction of clinical electrocardiography by Willem Einthoven in 1901, the use of medication, cardiac surgery and percutaneous interventions have decreased mortality roughly from 50% in the 1950's, down to 2% in 2020 (O'Gara et al., 2013; Thygesen et al., 2012). Large randomized controlled clinical trials (RCT) and meta-analyses have been the hallmark of cardiovascular research to improve patients' health status (Lopes et al., 2019; Windecker et al., 2014). *Value* of care in that sense is determined through low mortality rates, fewer adverse events such as post-procedural bleeding, or medication-related side effects for example. Although important for patients' survival, this definition of *value* is rather one-dimensional in character, seen from the perspective of nowadays patients.

A 'bi-directional' focus on *value* in healthcare is embedded in the concept of 'Value Based Healthcare' (VBHC) which has become subject of growing interest in healthcare research (Porter, 2008; Porter et al., 2007). It incorporates the patient's perspective on determining value; it questions the need of certain evidence-based choices in relation to the relative benefit for the patient (Porter et al., 2007). In general, it attempts to transform care to become more 'patient-centered'. However, the complexity of cardiac care makes it difficult to determine what defines 'value' for patients.

Human Factors (HF) science, at the intersection of psychology, biology and engineering, poses an interesting field to shape VBHC research in cardiac care further. It combines qualitative and quantitative research methods like interviews, observations and questionnaires to gain perspective of patients within predefined care-tracks (Russ et al., 2013). Essentially, it helps to understand what defines 'value' from a patient perspective. In this paper, we discuss how HF science can contribute to the introduction and development of VBHC in cardiac care. To illustrate this novel approach, several example studies are discussed (Hilt, Kaptein, et al., 2020; Hilt, Mamaqi Kapllani, et al., 2020).

Value of Healthcare

The definition of "health" by The World Health Organization (WHO) in 1948 is "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity." Three aspects of health are interchangeably linked; physical-, mental and social aspects of health(Huber et al., 2011).

First, physical health reflects the ability of individuals to maintain physiological homeostasis during changing conditions ("allostasis"), for instance an increase in heart rate while running. Illness develops when physiological mechanisms fail during harmful circumstances, such as blood clot formation during smoking, resulting in myocardial infarction. Second, mental health is the sense of how individuals coherently manage and adapt to changing circumstances to improve their subjective well-being. And last, social health projects both physical and mental health aspects in life in general; how does one manage life when there is interaction with other living objects and environments (Huber et al., 2011). Healthcare interventions, preventive or curative, have outcomes across all these aspects of health.

Outcomes, as stated by Porter, are multi-layered (Porter et al., 2007). The result of an intervention is not only 'dead or alive' (Tier 1) but also the occurrence of complications or return to daily life after clinical care (Tier 2) and the sustainability of health during life in general (Tier 3) (Porter et al., 2007). Healthcare professionals (both physicians andnon-physicians) define "value" of an outcome, in comparison to outcome as found in evidence-based studies. However, weighing outcome-tiers may differ between patient and professional.

Value Based Healthcare (VBHC) attempts to prioritize the patients' perspective of value by "the creation and operation of a health system that explicitly prioritizes health outcomes which matter to patients, relative to the cost of achieving this outcome" (Porter et al., 2004; Putera, 2017). Research in this domain questions the relevance of certain evidence-based interventions and outcomes with regard to patient-specific health aspects and personal preferences. A well-known example is a patient-reported outcome measure (PROM); patients are actively asked to fill out questionnaires, to reflect on received care after clinical admission (Wiering et al., 2017).

Questionnaires are, however, only developed for a single construct and rarely reflect all aspects of a care-track, let alone what a patient perceives as 'valuable'. The effect of interventions on outcomes in a care-track (i.e., performance) should be assessed from a broad system perspective in order to determine its value for patients.

Human Factors Science

HF science assesses human performance in complex systems for promoting safety and efficiency (Flin, 2009; Saleem et al., 2009). In healthcare, HF science is mainly applied for two purposes: i) reducing the cognitive and physical load of professionals and ii) promoting safe, efficient and high quality care to patients (Karsh et al., 2006; Saleem et al., 2009). To achieve both purposes, diverse research methods are used, for designing efficient, reliable and safe healthcare systems, supporting both professional and patient.

HF specialists and researchers gather data about human characteristics and human interaction with and within systems (Saleem et al., 2009). The strength of HF science lies in the combination of specialists from different disciplines, working together towards a common goal.

For example, in a previous study we assessed the dynamics of teamwork and team culture on safety during surgery, by applying HF questionnaires from the aviation industry in the surgical theatre (Hilt, Kaptein, et al., 2020). Identically, creating a patient-journey is often used by HF specialists to determine the experience a patient has in a care-track (Trebble et al., 2010), created by a combination of observations, interviews or questionnaires. Furthermore, this unravels the interaction with care, from a patient-perspective. These methods are in line with common VBHC research such as PROMs, but offer a broader scientific approach to assess system performance.

From Care-Track to Patient Journey – HF Science in Cardiac Care

In cardiology, there is a broad spectrum of treatments for diverse health conditions, such as acute myocardial infarction, heart failure or cardiac rhythm disorders. An example of determining value of care by applying HF research in VBHC in cardiology is to improve the care-track for myocardial infarction (MI) patients (Hilt, Mamaqi Kapllani, et al., 2020). The MISSION! program is a standardized care-track for MI-patients in a large tertiary hospital in the Netherlands (Liem et al., 2007).

It has three pillars of care: i) rapid transport of MI patients to a hospital for treatment, ii) four consecutive outpatient visits during 12 months to monitor cardiac function and intervene when needed and iii) secondary prevention of new cardiac events by promoting cardiac health with long-term treatment with multiple medications and lifestyle changes. Professionals educate patients on their disease, sharing extensive spoken and written information. The effectivity of information exchange is, however, subject of debate.

To investigate the process of information exchange and determine improvements for patients, we conducted an observational study in close collaboration with design engineers from the Faculty of Industrial Design Engineering of the Delft University of Technology. Patient journey mapping was used to assess how patients perceive patient information and education resources offered in the MISSION! Program.

Twelve patients were asked to elaborate on their experience within the MISSION! program, regarding education and information exchange during outpatient visits. Observations, interviews and questionnaires were used to map out the patient experience regarding information exchange.

It was found that, contrary to professionals' belief, information shared was regarded too extensive, technical and generic by patients (Hilt, Mamaqi Kapllani, et al., 2020). Most strikingly, medication, which is one of the hallmarks of secondary prevention in cardiology, was seen as a hurdle to recovery due to side-effects rather than a catalyst to good health. As a consequence, patients stated that they did not see added value of taking medication to improve their health. 'Health' was described as 'continuing my daily life' or 'be able to play with my dog again', and not primarily 'lowering my cholesterol or improving my heart condition'. In contrast, professionals stated that the amount of information shared was too little and that they wanted to teach more anatomical understanding and elaborate more on medication importance. This nicely illustrates the difference in perspective of how patients see their condition with an illness and what they define as important. Medication non-adherence is a common problem in the medical field, with side-effects and lack of information being frequent reasons (Naderi et al., 2012; Scott et al., 2003). The system approach as described above specifically highlights the mismatch between performance (extensive information shared), outcome (patients still lack information about medication) and value (professionals want to educate more, patients want less but more personal information). By focusing on the patient experience, it offers guidance on how to improve medication understanding and possible medication adherence in the MISSION care-track.

To overcome the above-described issue, the introduction of a mixed reality application has been proposed (figure 1). Ultimately, this application can be used to unite patients' and professionals' perspectives on medication education and foster interaction between both regarding this topic.

Figure 1. Example of a Mixed Reality application to understand medication after myocardial infarction.

Conclusion

The aforementioned HF approach can be applied to many topics in healthcare, not restricted to cardiology or to information exchange only. Nor is HF science restricted to understanding only patient-professional interaction, but professional – professional interaction as well. To alter healthcare in line with VBHC and shape care that prioritizes patients' perspectives and their value of care, HF science offers vital specialists and methods.

As a scientific discipline, it offers assessment of healthcare as a whole, in a constructive, multidimensional fashion. Ultimately shaping it to optimize performance, alter outcomes positively and create value for professional and patient in line with their preferences.

In our opinion, we would welcome a hybrid (academic) hospital, where medical professionals collaborate with human factors specialists on a daily basis. Healthcare professionals thus becoming aware of the possibilities HF science has to offer. VBHC in that sense, can be shaped continuously, with multidimensional input, from a 'concept', to a new 'standard of care'.

References

Flin, R., Winter, J., Sarac, C., & Raduma Tomas, M. A. . (2009). *Human Factors in Patient Safety: Review of Topics and Tools*. Retrieved from Consensus document:

Fox, K. A., Steg, P. G., Eagle, K. A., Goodman, S. G., Anderson, F. A., Jr., Granger, C. B., . . . Gore, J. M. (2007). Decline in rates of death and heart failure in acute coronary syndromes, 1999-2006. *Jama, 297*(17), 1892-1900. doi:10.1001/jama.297.17.1892

Hilt, A. D., Kaptein, A. A., Schalij, M. J., & van Schaik, J. (2020). Teamwork and Safety Attitudes in Complex Aortic Surgery at a Dutch Hospital: Cross-Sectional Survey Study. *JMIR Hum Factors, 7*(2), e17131. doi:10.2196/17131

Hilt, A. D., Mamaqi Kapllani, K., Hierck, B. P., Kemp, A. C., Albayrak, A., Melles, M., . . . Scherptong, R. W. C. (2020). Perspectives of Patients and Professionals on Information and Education After Myocardial Infarction With Insight for Mixed Reality Implementation: Cross-Sectional Interview Study. *JMIR Hum Factors, 7*(2), e17147. doi:10.2196/17147

Huber, M., Knottnerus, J. A., Green, L., van der Horst, H., Jadad, A. R., Kromhout, D., . . . Smid, H. (2011). How should we define health? *Bmj, 343*, d4163. doi:10.1136/bmj.d4163

Kahn, T. (2020). World Health Organization - Cardiovascular Diseases. Retrieved from https://www.who.int/health-topics/cardiovascular-diseases/#tab=tab_1

Karsh, B. T., Holden, R. J., Alper, S. J., & Or, C. K. (2006). A human factors engineering paradigm for patient safety: designing to support the performance of the healthcare professional. *Qual Saf Health Care, 15 Suppl 1*(Suppl 1), i59-65. doi:10.1136/qshc.2005.015974

Liem, S. S., van der Hoeven, B. L., Oemrawsingh, P. V., Bax, J. J., van der Bom, J. G., Bosch, J., . . . Schalij, M. J. (2007). MISSION!: optimization of acute and chronic care for patients with acute myocardial infarction. *Am Heart J, 153*(1), 14.e11-11. doi:10.1016/j.ahj.2006.10.002

Lopes, R. D., Hong, H., Harskamp, R. E., Bhatt, D. L., Mehran, R., Cannon, C. P., . . . Alexander, J. H. (2019). Safety and Efficacy of Antithrombotic Strategies in Patients With Atrial Fibrillation Undergoing Percutaneous Coronary Intervention: A Network Meta-analysis of Randomized Controlled Trials. *JAMA Cardiol, 4*(8), 747-755. doi:10.1001/jamacardio.2019.1880

Naderi, S. H., Bestwick, J. P., & Wald, D. S. (2012). Adherence to drugs that prevent cardiovascular disease: meta-analysis on 376,162 patients. *Am J Med, 125*(9), 882-887.e881. doi:10.1016/j.amjmed.2011.12.013

O'Gara, P. T., Kushner, F. G., Ascheim, D. D., Casey, D. E., Jr., Chung, M. K., de Lemos, J. A., . . . Yancy, C. W. (2013). 2013 ACCF/AHA guideline for the management of ST-elevation myocardial infarction: a report of the American College of Cardiology Foundation/American Heart Association Task Force on Practice Guidelines. *Circulation, 127*(4), e362-425. doi:10.1161/CIR.0b013e3182742cf6

Porter, M. E. (2008). Value-based health care delivery. *Ann Surg, 248*(4), 503-509. doi:10.1097/SLA.0b013e31818a43af

Porter, M. E., & Teisberg, E. O. (2004). Redefining competition in health care. *Harv Bus Rev, 82*(6), 64-76, 136.

Porter, M. E., & Teisberg, E. O. (2007). How physicians can change the future of health care. *Jama, 297*(10), 1103-1111. doi:10.1001/jama.297.10.1103

Putera, I. (2017). Redefining Health: Implication for Value-Based Healthcare Reform. *Cureus, 9*(3), e1067-e1067. doi:10.7759/cureus.1067

Russ, A. L., Fairbanks, R. J., Karsh, B. T., Militello, L. G., Saleem, J. J., & Wears, R. L. (2013). The science of human factors: separating fact from fiction. *BMJ Qual Saf, 22*(10), 802-808. doi:10.1136/bmjqs-2012-001450

Saleem, J. J., Russ, A. L., Sanderson, P., Johnson, T. R., Zhang, J., & Sittig, D. F. (2009). Current challenges and opportunities for better integration of human factors research with development of clinical information systems. *Yearb Med Inform*, 48-58.

Scott, J. T., & Thompson, D. R. (2003). Assessing the information needs of post-myocardial infarction patients: a systematic review. *Patient Educ Couns, 50*(2), 167-177. doi:10.1016/s0738-3991(02)00126-x

Thygesen, K., Alpert, J. S., Jaffe, A. S., Simoons, M. L., Chaitman, B. R., White, H. D., . . . Mendis, S. (2012). Third universal definition of myocardial infarction. *Circulation, 126*(16), 2020-2035. doi:10.1161/CIR.0b013e31826e1058

Trebble, T. M., Hansi, N., Hydes, T., Smith, M. A., & Baker, M. (2010). Process mapping the patient journey: an introduction. *Bmj, 341*, c4078. doi:10.1136/bmj.c4078

Wiering, B., de Boer, D., & Delnoij, D. (2017). Patient involvement in the development of patient-reported outcome measures: a scoping review. *Health Expect, 20*(1), 11-23. doi:10.1111/hex.12442

Windecker, S., Stortecky, S., Stefanini, G. G., da Costa, B. R., Rutjes, A. W., Di Nisio, M., . . . Jüni, P. (2014). Revascularisation versus medical treatment in patients with stable coronary artery disease: network meta-analysis. *Bmj, 348*, g3859. doi:10.1136/bmj.g3859

CHAPTER V

TEAMWORK AND SAFETY ATTITUDES IN COMPLEX AORTIC SURGERY AT A DUTCH HOSPITAL: CROSS-SECTIONAL SURVEY STUDY

A.D. Hilt, MD; A.A. Kaptein, PhD; M.J. Schalij, MD, PhD; J. van Schaik, MD

Published
JMIR Hum Factors. 2020 Apr 8;7(2):e17131

Abstract

Background

Improving teamwork in surgery is a complex goal and difficult to achieve. Human factors questionnaires such as the Safety Attitudes Questionnaire(SAQ) can help understand medical teamwork and may aid in this task.

Objective

To assess local team- and safety culture in a cardiovascular surgery setting to understand how purposeful teamwork improvements can be reached.

Methods

Two cardiovascular surgical teams performing complex aortic treatments were assessed; a endovascular treatment team (ETT) and an open treatment team (OTT). Both teams answered an online version of the SAQ-NL consisting of 30 questions related to 6 different domains of safety (teamwork climate, safety climate, job satisfaction, stress recognition, perceptions of management, and working conditions). In addition, one open question was posed to gain more insight into the completed questionnaires.

Results

The SAQ-NL was completed by 23 (100%) ETT members and 13 (100%) OTT members. Team buildup was comparable for both teams (60% males and 50% physicians). All participants worked ≥10 years in healthcare. SAQ-NL mean scores were comparable between both teams, important differences were found between the physicians and non-physicians of the ETT. Non-physicians were less positive about the safety climate, job satisfaction and working climate domains than physicians ($p<.05$).

Additional education on performed procedures, more conjoined team training as well as a hybrid OR were suggested by participants as important areas of improvement.

Conclusion

Non-physicians of a local team performing complex endovascular aortic aneurysm surgery perceive safety climate, job satisfaction and working conditions less positive than physicians of the same team. Open questions suggested this is related to lack of adequate conjoined training, education, and an adequate operating room. With added open questions, the SAQ-NL appears to be an assessment tool which allows developing strategies that are instrumental in improving quality of care.

Abbreviations

CMAQ	Cockpit Management Attitudes Questionnaire
CRM	Crew Resource Management
ET(T)	Endovascular Treatment (Team)
FMAQ	Flight Management Attitudes Questionnaire
HF	Human Factors
ICU	Intensive Care Unit
ICUMAQ	Intensive Care Unit Management Attitudes Questionnaire
JS	Job Satisfaction
LUMC	Leiden University Medical Centre
OT(T)	Open Treatment (Team)
OR	Operating Room
PoM	Perceptions of Management
SAQ	Safety Attitudes Questionnaire
SAQ-NL	Safety Attitudes Questionnaire Dutch Edition
SC	Safety Climate
SR	Stress Recognition
TC	Teamwork Climate
tSTEPPS	Team Strategies and Tools to Enhance Performance and Patient Safety
WC	Working Conditions
WHO	World Health Organization

Introduction

The World Health Organization (WHO) states that knowledge on human factors and especially non technical skills, are crucial in developing safe environments for patients(1). A 2017 analysis of the Dutch healthcare system shows that non-technical aspects of work are understudied in professional training(2, 3). Non-technical dimensions of teamwork such as communication, stress-awareness, and shared decision making, all contribute to the effectiveness of teamwork. Importantly, failing to invest in these issues may have negative effects on patient safety and clinical outcome (4-6). The challenge lies in how to identify, analyse and improve these non-technical skills.

In aviation and offshore industries for example, awareness of non-technical skills is crucial in daily work. Training and improving non-technical skills are often part of corporate policies, with proven effects on safety (7, 8). Similarly, positive results are observed in healthcare, although the number of studies is scarce (9, 10). Core to improving non-technical skills is understanding the safety culture and climate within a team. This can be assessed through questionnaires, such as the Safety Attitudes Questionnaire (SAQ)- a medical human factors (HF) questionnaire that has been validated in different medical domains. In 2016 the SAQ was validated in the Dutch language (SAQ-NL)(11, 12).

Although often used to assess an *ex ante* baseline and the *ex post* effect of team trainings, the use of the SAQ-NL as a diagnostic tool to identify what exactly needs changing within a team, and adjust subsequent training accordingly, is not common.

The outcome of complex aortic aneurysm surgery is highly dependent on team dynamics. Aortic aneurysms are defined as 'complex' when important side branches are included in the aneurysm. This necessitates inclusion of these side branches in the vascular reconstruction, making the procedure high-risk. Open, as well as endovascular complex aortic reconstructions are associated with high mortality and morbidity rates. Both treatments are conducted by multidisciplinary teams. In the current study, the SAQ-NL was used as a diagnostic tool to examine teamwork and safety climate in two types of teams; an open treatment team and an endovascular treatment team. The aim of this study was to understand, and to ultimately help improve, teamwork conditions and safety climate in this high-risk setting. Primarily it was hypothesized that (1) the SAQ-NL provides insight into how teamwork and safety is perceived by different team members, and (2) that this knowledge may help guide future teamwork improvement strategies.

Methods

Terminology

Pinpointing safety culture and safety climate within a medical department is difficult, especially because they are not mutually exclusive. The *safety culture* of an organisation is the product of individual and group values, traditions, perceptions and competences that determine the commitment to, and the style and proficiency of, an organization's health and safety management(13). An organisation's safety culture is the context in which personal safety attitudes develop, persist, and are promoted(8). It's like a 'script' that is taught to every employee, and continuously formed and (re)shaped not only by themselves, but also by their fellow 'actors' in the work setting. This concept has been used widely since the 1980s in aviation, as well as industrial settings such as power plants and offshore environments.

The *safety climate* is the manifestation of that safety culture in the behaviour and attitudes of professionals, for instance during surgical procedures. When one would make a 'snap-shot' of such environment, certain behavioural cues would be seen. For example, a surgeon being focussed on the patient and on his or her tools, the scrub-nurse seeing a drop in blood pressure and the anaesthetist reacting accordingly. This 'snap-shot' with all the interactions between professionals can be seen as the *climate* people are working in.

This *climate* (the play or the day-to-day atmosphere when working) is directly influenced by the departments *culture* (the script which consists of perceptions, beliefs, traditions). For example, when convention holds that nurses do not speak up when things go wrong, this negatively impacts safety climate, and often leads to errors and eventually diminished patient safety(14). Measuring perceptions of safety and teamwork in a specific setting at a certain point in time (i.e.; during a surgical procedure), provides insight into the *safety climate* as well as the *safety culture*.

Put differently; it allows for the assessment of how every actor plays their role and while doing so, to what extent they are influenced by others and the script used. Figure 1 gives an overview of the used terminology.

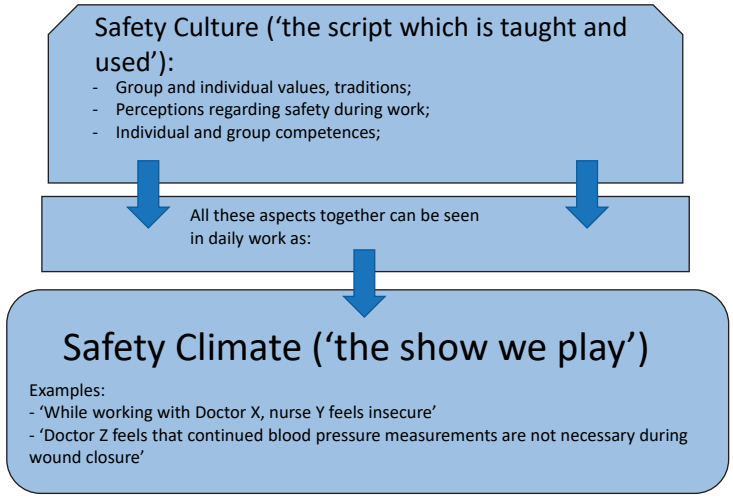


Figure 1. Safety culture and safety climate.
Copyright: A.D. Hilt

Design

The current study followed a cross-sectional survey design.

Study setting

The Leiden University Medical Centre (LUMC) is one of eight university hospitals in the Netherlands. For this study, two complex aortic aneurysm treatment teams were evaluated; one conducting the endovascular treatment (ET), and the other conducting the standard open treatment (OT). Assessment of the two teams has two reasons. Firstly, the endovascular treatment is relatively new to this hospital (since 2013).Refinement of non-technical skills is of great interest in this setting, since it has been shown that this improves patient safety and outcome(10, 15). Secondly, the introduction of the endovascular treatment demanded a shift in work environment for part of the team.

The OT-team (OTT) continues to work in the familiar environment of their operating theatre, whereas the ET-team (ETT) has to perform their procedures in an angiography suite - an environment where many team members are not used to working. For daily workflow of the ETT, it is important to understand how this shift in environment influences this. An outline of a routine ETT and OTT procedure is shown in multimedia appendix 1.

Study population

The ETT consists of 23 team members and has a larger diversity of radiology personnel, surgical staff and a supplier specialist. The OTT consists of 13 team members with predominantly surgical staff and perfusionists, the latter being not included in the ETT. Noticeably, a supplier specialist is present in the ETT, but not the OTT. The specific role of the supplier specialist lies in participating in the discussion of stent-type, and design, as well as on site product advice during the procedure. The supplier specialist is a standard, crucial, team member of the ETT.

Additionally, it should be noted that 2 vascular surgeons, 1 neurologist, and 1 clinical neurophysiology technician are part of both teams. The partial overlap of members of different teams is common in medical settings. All 4 interviewees with dual team membership were able to clearly distinguish between the two teams in answering our questions. In all further analyses, vascular surgeons, thoracic surgeons, radiologists, anaesthetists and neurologists are referred to as 'physicians', whereas scrub nurses, anaesthetic nurses, clinical neurophysiology technicians, radiology technicians, specialist suppliers and perfusionists are referred to as 'non-physicians. Table 1 summarizes the physician and non-physicians composition of both teams, as well as healthcare-tenure and team-tenure.

Human Factors and the Safety Attitudes Questionnaire (SAQ)

Research into Human Factors (HF) aims to understand how humans function in different environments, in order to improve human performance and safety within these environments (16). Human Factors research has become a core part of major industries such as aviation and the offshore industry, mainly because of the high dependence on human performance and its effect on safety. Teamwork safety has been extensively evaluated in aviation through HF-questionnaires, originally through the cockpit management attitudes questionnaire (CMAQ)(7, 17).

This questionnaire assessed the perceptions concerning safety climate and teamwork among personnel working on an aircraft. This was later refined into the Flight Management Attitudes Questionnaire (FMAQ) (7).

In the medical domain, ICUs were the first to adopt a medical version of the FMAQ; the ICUMAQ(17). Developed by Sexton et al., the SAQ is a refinement of the ICUMAQ for a healthcare setting. It has proven its psychometric and clinical quality in different clinical settings, as well in Dutch (SAQ-NL)(11, 17, 18). The SAQ assesses 30 items in six domains: safety climate (SC), teamwork climate (TC), job satisfaction (JS), stress recognition (SR), perceptions of management (PoM), and working conditions (WC). The 30 items are each assessed on a 5-point Likert scale: disagree strongly, disagree slightly, neutral, agree slightly, agree strongly.

The WHO indicates that the SAQ is a valuable human factors instrument to asses medical teamwork dynamics in a standardized fashion(1). For the current study, the strong methodological foundation of the SAQ and its usability in the field were the main reasons to use it. Additionally, to gain insight into teamwork, safety attitudes and the meaning of the SAQ-NL outcomes, respondents were asked to answer the following open question: "What are your top three recommendations for improving patient safety in this clinical area"? A web based survey of the SAQ-NL (Google Forms™, Google) was sent to all ETT and OTT members (multimedia appendix 2).

Statistics

Frequency tables for gender, professional positions, team tenure and general healthcare tenure are generated to give an overview of both teams. Response patterns are shown in percentages. For normally distributed categorical data a *chi square*-test was used to calculate statistical differences. For each SAQ dimension, mean scores and standard deviations were calculated per team (ETT and OTT); per professional group (physicians and non-physicians); and per department. An unpaired *t* test was used to calculate differences between SAQ-NL mean scores for ETT and OTT teams.

A univariate ANOVA test was performed to evaluate whether there was a significant difference between average SAQ-NL scores among professional groups; the ETT and OTT ; as well as the departments. Data of the open ended questions were displayed in a descriptive manner, content analysis was used to analyse these. Two authors (ADH and JvS) labelled responses according to major that emerged from the data. Cronbach's alpha (α) was calculated for all SAQ-dimensions of our sample. For analysis, SPSS Statistics version 23 (IBM Corp., Armonk, NY, USA) was used. A *P*-value <.05 was considered significant.

Biases

Teamwork and safety are delicate subjects, leading to a risk of response bias. Examples of response bias are question order bias or social desirability bias. The use of a self-administered questionnaire via an online survey is known to minimize the latter effect(19). All questionnaire data was available only to the main researcher (ADH), who has no professional position in the ETT or OTT.

Ethical considerations

Dutch law, no ethical approval was needed to conduct this study. All participants gave consent for participating in the study and the use of their pseudo-anonymized data.

Results

Demographics

The ETT consists of 23 members of which 13(59%) are male with a total of 11(50%) physicians. The OTT consists of 13 members of which 8(61%) are male with a total of 7(53%) physicians, but not significantly different (p=.6 and p=.5, table 2). Team tenure ≥5 years was more prevalent in the ETT (55% of team members) than in the OTT (23% of team members), but not statistically different (*P*=.16, table 2). Both teams have a large proportion of members working ≥10 years in healthcare (ETT vs OTT; 86% vs 92%, *P*=.3). Long (≥50 hours) working weeks are more prevalent in the OTT than in the ETT, this difference however, was not significant (50% vs 23%, *P*=.5).

Table 1. Overview of team composition; ETT vs OTT

Teams			
ETT(N=23)	**N**	**HT**	**TT**
Radiologist	2	≥10 years	≥5 years
Thoracic surgeon	1	≥10 years	4 years
Anesthesist	3	≥10 years	≥5 years
Vascular surgeon	4	≥10 years	4 years
Neurologist	1	≥10 years	3 years
Radiology technician	5	≥10 years	≥5 years
Scrub nurse	3	8 years	≥5 years
Nurse anesthesist	1	≥10 years	≥5 years
Clinical neurophysiology technician	2	≥10 years	4 years
Supplier specialist	1	8 years	≥5 years
OTT(N=13)	**N**	**HT**	**TT**
Thoracic surgeon	1	≥10 years	3 years
Anesthesist	2	≥10 years	1 year
Vascular surgeon	3	≥10 years	≥5 years
Neurologist	1	≥10 years	4 years
Scrub nurse	2	9 years	4 years
Nurse anesthesist	1	≥10 years	4 years
Clinical neurophysiology technician	1	≥10 years	4 years
Perfusionist	2	≥10 years	≥5 years

ETT = Endovascular Treatment Team; HT = average healthcare tenure in years; N/A = not applicable;
OTT = Open Treatment Team; TT = average team tenure in years

Table 2. Demographics

	ETT	OTT	P-value
Total (N)	23	13	N/A
Male, (N,%)	13(60%)	8(61%)	P=.6
Physician (N,%)	11(48%)	7(53%)	P=.5
≥5 years team tenure (N, %)	12(55%)	3(23%)	P=.16
≥10 years healthcare tenure (N, %)	19(86%)	12(92%)	P=.3
≥50 Weekly workhours (N,%)	5(23%)	6(50%)	P=.5
Response (N, %)	23(100%)	13(100%)	N/A

ETT = endovascular treatment team

OTT = open treatment team

Mean Safety Attitudes Questionnaire-NL scores: ETT vs OTT teams

An overview of mean SAQ-NL mean scores with standard deviations (SD) per domain is shown in table 3 and figure 2. Higher means were observed for the OTT, however an independent samples *t* test showed that for all SAQ-NL domains, no statistically significant differences existed between the ETT and OTT.

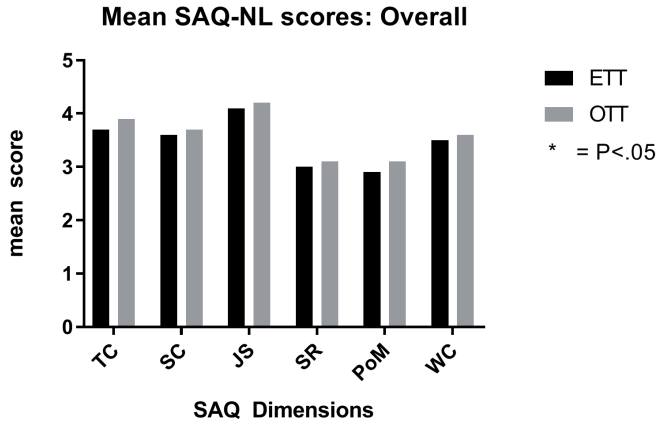
Mean scores on the SAQ-dimensions for respectively ETT and OTT were; 3.7±0.37 vs 3.9± 0.31(*P*=.40) for Teamwork Climate(TC), 3.6±0.43 vs 3.7±0.31(*P*=.65) for Safety climate (SC), 4.1±0.5 vs 4.2± 0.46(*P*=.39) for Job satisfaction (JS), 3.0±0.73 vs 3.1±0.92(*P*=.84) for Stress recognition (SR), 2.9±0.66 vs 3.1±0.51(*P*=.44) for Perceptions of Management (PoM), and 3.5±0.64 vs 3.6±0.70(*P*=.69) for Working conditions (WC). For our sample, all SAQ-domains had a reliability of $\alpha \geq .70$ (acceptable) with the exception of the TC domain (α=.58, poor).

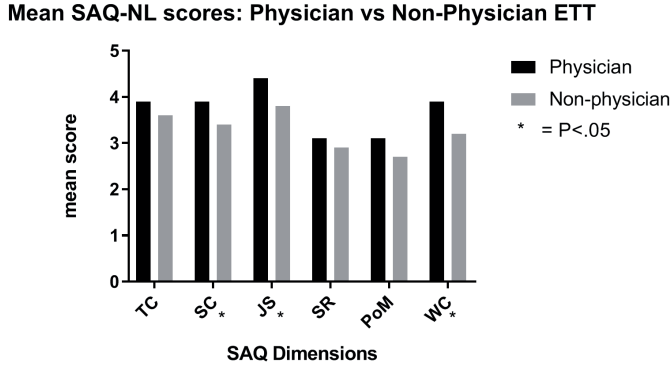
Table 3. SAQ Means scores and Standard Deviations (SD).

	TC	SC	JS	SR	PoM	WC
Team						
ETT (N=23)	3.7(0.37)	3.6(0.43)	4.1(0.50)	3.0(0.73)	2.9(0.66)	3.5(0.64)
OTT(N=13)	3.9(0.31)	3.7(0.31)	4.2(0.46)	3.1(0.92)	3.1(0.51)	3.6(0.70)
Position						
Non-physician ETT	3.6(0.43)	3.4(0.35)	3.8(0.41)	2.9(0.61)	2.7(0.67)	3.2(0.68)
Physician ETT	3.9(0.31)	3.9(0.34)	4.4(0.33)	3.1(0.86)	3.1(0.64)	3.9(0.37)
Non-physician OTT	3.8(0.40)	3.7(0.33)	4.0(0.47)	3.0(0.93)	2.9(0.43)	3.5(0.54)
Physician OTT	3.9(0.23)	3.7(0.33)	4.4(0.39)	3.1(0.98)	3.2(0.52)	3.7(0.83)
Department						
Surgery ETT	3.8(0.35)	3.7(0.39)	4.0(0.56)	3.1(0.62)	2.9(0.86)	3.3(0.56)
Anesthesiology ETT	3.9(0.26)	4.0(0.32)	4.4(0.51)	2.6(1.12)	3.0(0.00)	4.1(0.17)
Radiology ETT	3.7(0.45)	3.4(0.41)	4.1(0.46)	3.2(0.49)	2.5(0.39)	3.2(0.79)
Neurology ETT	3.4(0.2)	3.5(0.59)	4.0(0.40)	3.4(0.76)	3.6(0.53)	4.0(0.33)
Industry ETT	4.4(0.00)	4.1(0.00)	4.2(0.00)	2.0(0.00)	3.6(0.00)	4.0(0.00)
Surgery OTT	3.9(0.30)	3.7(0.38)	4.3(0.46)	3.0(1.01)	3.0(0.51)	3.5(0.39)
Anesthesiology OTT	3.6(0.34)	3.7(0.1)	4.3(0.61)	2.8(0.90)	2.8(0.00)	3.4(0.96)
Radiology OTT	n/a	n/a	n/a	n/a	n/a	n/a
Neurology OTT	4.0(0.00)	3.7(0.40)	4.1(0.42)	3.8(0.35)	3.7(0.42)	4.7(0.47)
Industry OTT	n/a	n/a	n/a	n/a	n/a	n/a
Overlapping members (N=4)						
Vascular surgeon W (ETT)	4.2(n/a)	4.2(n/a)	4.6(n/a)	2.3(n/a)	2.4(n/a)	3.7(n/a)
Vascular surgeon W (OTT)	4.2(n/a)	4.2(n/a)	5.0(n/a)	1.8(n/a)	3.4(n/a)	4.0(n/a)
Vascular surgeon X (ETT)	3.4(n/a)	3.5(n/a)	4,2(n/a)	3.8(n/a)	2.4(n/a)	3.4(n/a)
Vascular surgeon X (OTT)	4.2(n/a)	3.2(n/a)	4.4(n/a)	3.7(n/a)	2.6(n/a)	3.3(n/a)
Neurologist Y (ETT)	3.6(n/a)	4.1(n/a)	4.4(n/a)	4.3(n/a)	3.8(n/a)	4.3(n/a)
Neurologist Y (OTT)	4.0(n/a)	4.0(n/a)	4.4(n/a)	4.0(n/a)	4.0(n/a)	5.0(n/a)
Clin.neurophys.technician Z (ETT)	3.4(n/a)	3,3(n/a)	4.0(n/a)	3.3(n/a)	3.0(n/a)	3.7(n/a)
Clin.neurophys.technician Z (OTT)	4.0(n/a)	3.4(n/a)	3.8(n/a)	3.5(n/a)	3.4(n/a)	4.3(n/a)

TC = teamwork climate; SC = safety climate; JS = job satisfaction; SR = stress recognition; PoM = perceptions of management; WC = working conditions.

ETT = Endovascular Treatment Team; OTT = Open Treatment Team; n/a = not applicable; Non-physicians = all non-physician's, i.e. nurses, technicians etc.





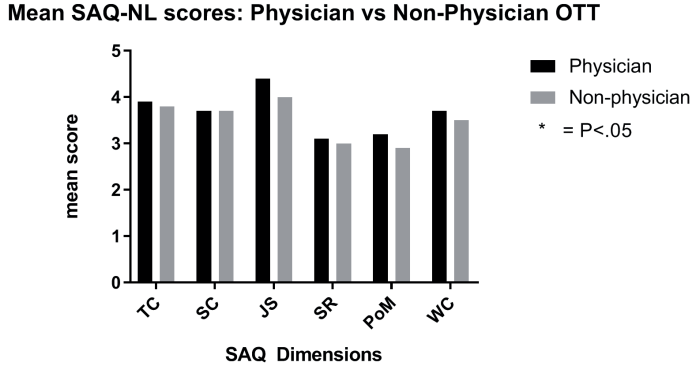


Figure 2. SAQ-NL mean scores per team and professional position.

Legend figure 2: TC: Teamwork Climate, SC: Safety Climate, JS: Job Satisfaction, SR: Stress Recognition, PoM: Perceptions of Management, WC: Working Climate

Mean Safety Attitudes Questionnaire-NL scores: physician vs non-physicians (ETT vs OTT)

Univariate ANOVA showed that for the ETT, there are significant differences between physician and non-physicians on mean scores for the SC, JS and WC domain; physicians were significantly more positive about safety climate, job satisfaction and working conditions compared to non-physicians.

Respectively, SC, JS and WC mean scores for physicians vs non-physicians were; 3.9±0.34 vs 3.4±0.35 (*P*=.002), 4.4±0.33 vs 3.8±0.41(*P*=.001) and 3.9±0.37 vs 3.2±0.68 (*P*=.008), figure 2. For the ETT, the specialist supplier did not score significantly different from the other non-physicians (table 3); there was a slight trend towards higher TC (P=.08) and SC (P=.07) scores. For the OTT, besides a slight trend towards higher mean scores in physicians for the JS domain (3.7±0.83 vs 3.5±0.54, *P*=.12), no significant differences between physicians and non-physicians scores for all domains were found.

Mean Safety Attitudes Questionnaire-NL scores: department differences (ETT vs OTT)

Univariate ANOVA and independent *t* tests showed no statistical differences between members of different departments (i.e. radiology, surgery, neurology, industry and anesthesiology) in the ETT and OTT.

Mean Safety Attitudes Questionnaire-NL scores sub-analysis: overlapping team members

Three physicians and one technician filled out both the ETT and OTT questionnaires. These mean SAQ-NL scores are also shown in table 3 (overlapping members). An independent *t* test showed no significant differences between the ETT and OTT for any of the SAQ-NL domains in this group. Despite a slight trend towards lower job satisfaction in non-physicians (*P*=.18), no significant differences were found for all domains comparing physicians and non-physicians in ETT and OTT both through univariate ANOVA. When eliminating these four participants from the total ETT and OTT physician vs non-physicians analysis, univariate ANOVA showed identical results for the ETT; safety climate(P<.002), job satisfaction(P<.001) and working climate(P<.008) mean scores were significantly lower in non-physicians than physicians in the ETT but not in the OTT.

Open Ended Questions

Of the ETT, 21(91%) respondents together provided 50 comments. Of the OTT 7(53%) respondents together provided 14 comments. For the ETT, 5 themes were identified through content analysis; comments related to peri-procedural planning, dynamics during procedures (technical, non-technical aspects), facilities present in the OR and patient privacy (multimedia appendix 3). In total 23 out of 50(46%) comments were related to teamwork between non-physicians and physicians.

Non-physicians expressed their desire to be more involved in the surgical process (12 out of 23(53%) comments); individual examples were: '*...more open communication about the patients' status during surgery' , '... more clarification of the surgical steps taken'* or *'... more debriefing after performed surgery'.*

Physicians found education of non-physicians an important issue (10 out of 23(43%) comments), individual examples were: '*… more time for extra training', '... more team members should attend the conjoined pre-surgery meetings', '…there should be more post-surgery evaluations together' and '... more open communication at different stages in surgery should be applied towards all*'. Additionally, the need for a hybrid operating room (fit for both open and endovascular treatment) was stressed (11 out of 50(22%) comments); *"...a hybrid OR where all the radiology and surgery devices are available is a must'.*

For the OTT, 2 major themes were identified; comments related to peri-procedural planning and dynamics during procedures (non-technical aspects). In total 6 out of 14(42%) comments were education related; non-physicians wanted to be educated more (4 out of 6(67%)comments), individual examples: '*… there should be more clinical classes about this procedure done by the anesthetist and surgeons'* and '*… there should be more dedicated trainings and preparation'.*

Physicians also expressed a desire for more education of non-physicians in the different phases of surgery (2 out of 6(34%) comments), individual examples: '*... if there are lessons learned during procedures, we should conjointly evaluate them'* and *'... clinical evaluations after surgery should be evaluated with the whole team'*. An overview of relevant themes for both ETT and OTT with example remarks is added as multimedia appendix 3.

Discussion

The results of this study can be summarized as follows: (1) for the ETT, physicians are more positive about the safety climate -, job satisfaction - and working conditions than non-physicians; (2) conjoined training sessions, education and post-procedural evaluation, and a hybrid OR are important topics for future improvements for both physicians and non-physicians of the ETT; and (3) using the SAQ-NL with the addition of open ended questions is an instrumental way of assessing the safety culture and climate of two surgical teams and to propose strategies to improve this further.

The findings of our local study suggest that there is room for improvement in teamwork within the ETT. Regarding safety climate-, job satisfaction- and working climate- domains, physicians are more positive than non-physicians which is not observed in the OTT. These outcomes are specified by the answers to the open questions. Especially the remarks regarding more conjoined education on procedures and the wish for a hybrid OR give a good explanation for the lower scores on the job satisfaction- and working conditions domains, and possibly the safety climate domain within the non-physicians group. Higher safety climate, job satisfaction and working conditions scores express aspects of the overall perceptions regarding commitment to safety, the work experience and the quality of the work environment (i.e. equipment, staffing), respectively. It is striking that this was different from the OTT.

A reasonable explanation for lower job satisfaction and working conditions scores in the ETT may be that non-physicians need to operate outside of their own habitat, in an environment (the angiography suite) which they are not familiar with, and do not know as well as the OR. This setup is due to the absence of adequate radiological facilities in the OR. This condition results in non-physicians having to move large amounts of instruments and materials from the OR to the angiography suite.

Having to work outside of their familiar environment, and having to move surgical equipment is not necessary for OTT members, who operate in the OR where all materials are close at hand. Qualitative results suggest that building a hybrid OR must be prioritized to raise ETT scores to the level of OTT scores. A hybrid OR is a fully functional surgical theatre that is equipped with advanced medical imaging devices such as fixed C-arms, CT scanners or MRI scanners. These imaging devices enable complex minimally-invasive surgery as well as ‘hybrid’ procedures where minimally-invasive techniques are combined with conventional ‘open’ surgery. The perceived need for more education and adequate working conditions could also explain the lower safety climate score in non-physicians of the ETT.

For future improvements, one suggestion would be cross-functional teaching between radiology technicians and scrub nurses; a more explicit definition of roles and use of equipment ; and instruction of team members by physicians. SAQ-NL outcomes can be used after these improvements to measure the effect of these changes in working circumstances on teamwork.

Implications for Surgical Procedures

Previous studies have shown the effectiveness of using the SAQ as a measure to assess teamwork in different medical settings, largely focusing on measuring the effect of team trainings on daily work(20, 21). The SAQ-NL has not been solely used as a diagnostic tool.

Although no overall differences were found in our study between both the ETT and OTT as a whole, there were important differences within the ETT. Physicians were more positive than non-physicians. Through open ended questions, important themes for improvement of daily procedures were found. Differences between physicians and non-physicians are not new(10, 22). This is however still an important finding, especially for a large tertiary referral hospital. Our findings are not only useful for patient-facing employees, but also for team managers.

These findings stress not only the need for facilitating conjoined training and education, but also to direct this more specifically towards the needs of the employees. An example of the latter is 'slowing down during surgery', which enables team members to ask questions at certain key points during the surgery process(23).

Safety Attitudes Questionnaire-NL Outcomes

Improving healthcare team culture and teamwork safety is not straightforward, and thorough assessments of workflow and interactions between different professionals are time consuming.

While improvements are necessary, trying to change the entire healthcare system at once is doomed to fail because of the complex nature of this working environment. It's questionable what the relevance of, for instance, a national teamwork assessment is. Assessing teamwork among thousands of people having no direct interaction with each other. Therefore, as proposed by Sexton et al., it is especially important to put effort in analysis of the working environment of patient-facing employees and focus on local settings(18). Attitudinal surveys on a local (team) level can be a valuable addition to this.

The present study shows that small teams can be fruitfully assessed using the SAQ-NL. Firstly, the strength of using the SAQ-NL in small teams is that a complete response rate is more easily obtained. Secondly, the clinical implications of the study outcomes can be used immediately. For example, regarding the education-related remarks, a focus on more education during procedures can be started during the next surgery. The SAQ-NL could subsequently be used to monitor how such changes would influence a team's safety attitudes. Lastly, the SAQ-NL is a useful tool in a cross-professional setting.

Due to the intertwinement of work, the specialist supplier for example cannot be left out of the ETT analysis. The SAQ-NL in this sense is not restricted to particular professions.

Future perspectives; Human Factors and team analysis

Assessing team-processes such as safety climate through the SAQ-NL, is a valuable addition to team analysis. A recent meta-analysis by Schmutz et al assessed the impact of team process-analysis on team performance(24). It showed that teams who are aware of processes during daily work, were almost 3 times more likely to achieve high performance than teams who were not. In line with this meta-analysis and as we hypothesized, we recognize the SAQ-NL as a valuable diagnostic tool for team process analysis. Mainly to assess and create awareness of processes among team members that define their daily work.

With the knowledge of what needs attention during daily teamwork, a next step could be Human Factors (HF) trainings such as Crew Resource Management (CRM) or Team Strategies and Tools to Enhance Performance and Patient Safety (TeamSTEPPS)(25). Both are proven to be effective in altering team performance through HF principles. They teach participants that people have certain strengths and weaknesses which can impact daily work in a good or bad way(16, 26-28).

The SAQ is often used to monitor the effects of these HF-training. O'Dea et al. proposed in their meta-analysis that, while plausible, it is difficult to unambiguously link changes in team behaviour or SAQ-outcomes to a particular training(29). Starting with a diagnostic approach with the SAQ of what needs attention in a team before commencing training however, the effect of CRM or TeamSTEPPS could be understood better during the course of training. For our sample, a CRM or TeamSTEPPS training could aim at improving communication during crucial steps of the ETT procedures, in order to assure shared understanding between physicians and non-physicians and hereby increase the safety climate.

Limitations

Our study has several limitations. Firstly, it is debatable what the (clinical) meaning/ implication is of the difference between sections of the Likert scale in daily work. When looking at the ETT outcomes between non-physicians and physicians for example, the difference (Δ) for the job satisfaction domain is 0.6 and working conditions 0.7. What this (statistically significant) difference implies solely from the questionnaire's outcome, is not directly clear. However, using open ended questions helps understand this difference. Secondly, we are well aware that there is overlap in respondents filling out the SAQ-NL for both ETT and OTT.

In this small group no differences were found between physicians and non-physicians for both ETT and OTT. Correcting all data for this group did not alter the main outcomes. Thirdly, the original SAQ and SAQ-NL showed good psychometric properties and a good reliability (average Cronbach's alpha of .76). In our study the reliability was generally acceptable ($\alpha \geq .70$) with the exception of the teamwork climate- domain which had a rather poor internal reliability ($\alpha = .58$). This is however highly dependent on the number of subjects participating in the study and the number of items per dimension. Further use of the SAQ-NL and research in this setting should be stressed to evaluate the psychometric properties of the SAQ-NL.

Conclusion

Non-physicians of a local team performing endovascular aortic aneurysm surgery perceive safety climate; job satisfaction; and working conditions less positively than physicians on the same team. Open ended questions specified this to be related to a lack of adequate conjoined training; education; and an adequate operating room. The SAQ-NL can be a first step in developing strategies to improve quality of care.

Contributions

ADH and JvS conceived of the presented idea. JvS provided input from earlier study of the ETT(15), ADH, AAK and JvS developed the theory, ADH performed the data collection and analysis. AAK, MJS and JvS supervised the research and critically reviewed the findings. ADH and JvS drafted the manuscript. All authors discussed the results and contributed to the final manuscript.

Conflict of interest

None.

Disclosures

None.

Multimedia appendix 1. Typical ETT procedure day.

ETT procedure day	
0730hours	Preparation angiosuite • Radiology material collection from angiosuite supply room (radiology assistant) • Surgery material collection. Moving material from OR to angiosuite (scrub nurse) • Anesthesia material collection. Moving material from OR to angiosuite (anesthesiological team)
0745hours	Technical briefing/material check (interventional radiologist, vascular surgeon, radiology assistant, anesthesiologist, scrub nurse, supplier specialist)
0815hours	Patient briefing in angiosuite (Patient, interventional radiologist, vascular surgeon, radiology assistant, anesthesiologist, scrub nurse, clinical neurophysiologist)
0820hours	Start anesthesia, neuromonitoring preparation (anesthesiologist, clinical neurophysiologist)
0845hours	Surgical preparation • Radiological material (radiology assistant) • Surgical material (scrub nurse) • Sterile draping (vascular surgeon, scrub nurse, radiology assistant)
0900hours	Surgical cut-down (vascular surgeon, scrub nurse)
0915hours	Start endovascular procedure. Flexible process which might differ greatly from one procedure to another depending on patient, anatomy, stent type, technical/anesthesiological or surgical problems encountered. Usually several 'stop moments' or 'time-outs' used for team discussion where needed. (Interventional radiologist, vascular surgeon, anesthesiologist, clinical neurophysiologist, supplier specialist, scrub nurse, radiology assistant)
……	Finalization of the procedure
0015hours	Team de-briefing as wounds are closed (whole team)
0030hours	Preparing patient for transport to ICU (anesthesiological team)
0045hours	Transport to, and briefing at ICU (anesthesiologist, vascular surgeon, interventional radiologist)
0100hours	Return of surgery and anesthesia material to OR (scrub nurse, anesthesiological team)

OTT procedure day	
0730hours	Preparation operating room • Surgery material collection on site (scrub nurse) • Anesthesia material collection on site (anesthesiological team) • Perfusion material collection on site (perfusion team)
0800hours	Start anesthesia, neuromonitoring preparation (anesthesiologist, clinical neurophysiologist)
0845hours	Team briefing in OR (thoracic surgeon, vascular surgeon, anesthesiologist, scrub nurses, clinical neurophysiologist, perfusionist)
0900hours	Surgical preparation • Surgical material (scrub nurse) • Sterile draping (thoracic surgeon, vascular surgeon, scrub nurse)
0915hours	Start surgical procedure. Flexible process which might differ greatly from one procedure to another depending on patient, anatomy, technical/ anesthesiologic or surgical problems encountered. Usually several 'stop moments' or 'time-outs' used for team discussion where needed. (thoracic surgeon, vascular surgeon, anesthesiologist, perfusionist, clinical neurophysiologist, scrub nurse)
……	Finalization of the procedure
0015hours	Team de-briefing as wounds are closed (whole team)
0045hours	Preparing patient for transport to ICU (anesthesiologic team)
0100hours	Transport to, and briefing at ICU (anesthesiologist, thoracic surgeon, vascular surgeon)

"Angiosuite" = radiology depratment intervention room with primarily radiological equipment, ETT = endovascular treatment team; ICU = intensive care unit; OR = (surgical) operation room; OTT = open treatment team

Multimedia Appendix 2: Safety Attitudes Questionnaire-NL

Below the original English questions are the validated Dutch counterparts. The open question was not in the original SAQ-NL.

Teamwork climate

1. Nurse input is well received in this clinical area.
De inbreng van verpleegkundigen wordt op mijn unit op prijs gesteld.

2. In this clinical area, it is difficult to speak up if I perceive a problem with patient care.
Op mijn unit is het moeilijk om het uit te spreken als ik merk dat er een probleem is met de patiëntenzorg.

3. Disagreements in this clinical area are resolved appropriately (i.e., not *who* is right, but *what* is best for the patient).
Meningsverschillen op mijn afdeling worden op een goede manier opgelost (d.w.z. niet wie heeft er gelijk, maar wat is het beste voor de patiënt).

4. I have the support I need from other personnel to care for patients.
Ik krijg de ondersteuning die ik nodig heb van staf-artsen om voor patiënten te kunnen zorgen.

5. It is easy for personnel here to ask questions when there is something that they do not understand.
Medewerkers op mijn unit kunnen gemakkelijk vragen stellen als er iets is dat ze niet begrijpen.

6. The physicians and nurses here work together as a well-coordinated team.
De artsen en de rest van het team hebben hier een goede samenwerking.

Safety Climate

7. I would feel safe being treated here as a patient.
Als ik hier als patiënt zou worden behandeld, zou ik me veilig voelen.

8. Medical errors are handled appropriately in this clinical area.
Medische fouten worden goed afgehandeld op de afdeling.

9. I know the proper channels to direct questions regarding patient safety in this clinical area.
Ik weet aan wie ik vragen kan stellen als het gaat om de patiëntveiligheid op de afdeling waar ik werk.

10. I receive appropriate feedback about my performance.
Ik krijg goede feedback op mijn functioneren.

11. In this clinical area, it is difficult to discuss errors.
Op de unit waar ik werk is het lastig om fouten te bespreken.

12. I am encouraged by my colleagues to report any patient safety concerns I may have.
Ik word door mijn collega's aangemoedigd al mijn bedenkingen wat patiëntveiligheid betreft te melden.

13. The culture in this clinical area makes it easy to learn from the errors of others.
De cultuur op mijn unit maakt het makkelijk om van fouten van anderen te leren.

Job Satisfaction

14. I like my job.
Ik ben enthousiast over mijn baan.

15. Working here is like being part of a large family.
Het werken in dit ziekenhuis voelt als deel uit maken van een grote familie.

16. This is a good place to work.
Dit ziekenhuis is een goede plek om te werken.

17. I am proud to work in this clinical area.
Ik ben trots dit ik in dit ziekenhuis werk.

18. Morale in this clinical area is high.
Het moreel op deze afdeling is hoog.

Stress Recognition

19. When my workload becomes excessive, my performance is impaired.
Wanneer mijn werkdruk te hoog wordt, dan lijdt mijn functioneren daaronder.

20. I am less effective at work when fatigued.
Als ik vermoeid ben dan verricht ik routinetaken minder goed.

21. I am more likely to make errors in tense or hostile situations.
Ik ben meer geneigd om fouten te maken in een gespannen of bedreigende situatie.

22. Fatigue impairs my performance during emergency situations.
Vermoeidheid hindert mijn functioneren tijdens acute situaties.

Perceptions of management
23. Management supports my daily efforts.
Het ziekenhuismanagement helpt me bij mijn dagelijkse bezigheden.

24. Management doesn't knowingly compromise patient safety.
Het ziekenhuismanagement brengt de veiligheid van de patiënten niet bewust in gevaar.

25. Problem personnel are dealt with constructively by our unit / hospital management.
Dit ziekenhuis gaat constructief om met minder goed functionerend personeel.

26. I get adequate, timely info about events that might affect my work, from unit / hospital management.
Ik krijg voldoende, tijdige informatie over gebeurtenissen in het ziekenhuis die invloed kunnen hebben op mijn werk.

27. The levels of staffing in this clinical area are sufficient to handle the number of patients.
We hebben genoeg personeel om de werklast aan te kunnen.

Working conditions
28. This hospital does a good job of training new personnel.
Dit ziekenhuis is goed in het trainen van nieuw personeel.

29. All the necessary information for diagnostic and therapeutic decisions is routinely available to me.
Ik beschik steeds over alle informatie die nodig is voor diagnostische en therapeutische beslissingen.

30. Trainees in my discipline are adequately supervised.
Degenen die opgeleid worden in mijn discipline krijgen voldoende begeleiding.

Open question
What are your top three recommendations for improving patient safety in this clinical area? (complex endovascular aortic treatment)
Wat zijn jouw top drie aanbevelingen om patiëntveiligheid te verbeteren binnen deze setting (complexe endovasculaire aortabehandelingen)

Multimedia appendix 3: Themes and open ended question answers SAQ-NL analysis ETT vs OTT.

Teams	Examples
ETT themes	
Peri procedural planning	".. sufficient numbers of scrub nurses are needed for safe procedures.." (Scrub nurse) " ..good preparation of all team members and OR-room.." (Radiology technician) " ..enough procedures should be planned to keep everyone up-to-date and well-trained."(Thoracic surgeon)
Dynamics during procedure – technical aspects	" .. monitor patient vitals more closely and keep track consistently."(Scrub nurse) "...radiology technicians and scrub nurses should teach each other the steps they undertake during the procedure..." (Scrub nurse)
Dynamics during procedure – non technical aspects	"...keep track of the steps that are taken during the procedure and discuss what happens next."(Clinical neurophysiological technician) ".. there should be more conjoint post-discussions on the procedure.." (Vascular surgeon)
Facilities of surgical theatre	"..a hybrid OR where all the radiology and surgery devices are available is a must.." (Vascular surgeon, scrub nurse, radiology technician, radiologist)
Patient privacy	"..availability of patient data to non-medical personnel/ industry is hampered by modern Dutch law.." (Specialist supplier)
OTT themes	
Peri-procedural planning	"... sometimes it's difficult to plan all the waiting patients.." (Vascular surgeon) " .. there should be a limited number of surgeons at the table.." (Perfusionist) ".. we should facilitate spectators from other specialities.." (Vascular surgeon) "..we should gather post-operative problems and discuss them more.." (Anesthesist) "..there should be more procedures to keep our skills up-to-date." (Thoracic surgeon)
Dynamics during procedure – non technical aspects	".. there should be a limited number of surgeons at the table to streamline communications.." (Perfusionist) ".. education on surgical steps for nurses should be mandatory.." (Scrub nurse) "..ICU personnel should be educated on these procedures as well.."(Vascular surgeon) "..we should do proper introductions of all team members present before the procedure starts.." (Scrub nurse)

Definitions of themes:

Peri procedural planning - all work involved around the surgical procedure including preparation and discharge of the patient, but also preparation of materials etc.

Dynamics during procedure – technical aspects – all steps involved during the procedure that encompass use of equipment (surgical, radiological, neurophysiological) within the OR during the procedure (ETT or OTT).

Dynamics during procedure – non technical aspects – all steps involved during the procedure that encompass communication between team members within the OR during the procedure (ETT or OTT).

Facilities of surgical theatre – all aspects of the operating theatre that support functionality (like quick access to equipment) during procedures (ETT or OTT).

Patient privacy – all aspects of correct and safe use of patient medical data in line with Dutch law, for example patient rights, safe storage of data and availability of data to third parties.

References

1. Flin R, Winter, J., Sarac, C., & Raduma Tomas, M. A. . Human Factors in Patient Safety: Review of Topics and Tools. Consensus document: WHO; 2009.
2. Klopotowska. J SB, de Bruijne. M, Wagner. C. "Tweede evaluatie van het VMS Veiligheidsprogramma." (Second evaluation of the VMS Safety Program). Utrecht; NIVEL, 2016.
3. Langelaan M, Broekens, M.A., Bruijne, M.C., Groot, J.F., Moesker, M.J., Porte, P.J., Schutijser, B., Singotani, R., Smits, M., Zwaan, L., Asscheman, H., Wagner, C., . "Monitor zorggerelateerde schade 2015/2016: dossieronderzoek bij overladen patienten in Nederlandse ziekenhuizen. (Monitor health care-related damage 2015/2016: case research of deceased patients in Dutch hospitals)". Utrecht: NIVEL; 2017.
4. Kim SE, Kim CW, Lee SJ, Oh JH, Lee DH, Lim TH, et al. A questionnaire survey exploring healthcare professionals' attitudes towards teamwork and safety in acute care areas in South Korea. BMJ open. 2015;5(7):e007881.
5. Institute of Medicine Committee on Quality of Health Care in A. In: Kohn LT, Corrigan JM, Donaldson MS, editors. To Err is Human: Building a Safer Health System. Washington (DC): National Academies Press (US) Copyright 2000 by the National Academy of Sciences. All rights reserved.; 2000.
6. Warnack E, Pachter HL, Choi B, DiMaggio C, Frangos S, Klein M, et al. Postinjury Complications: Retrospective Study of Causative Factors JMIR Hum Factors. 2019;6(3):e14819.
7. Helmreich RL, Merritt AC, Wilhelm JA. The Evolution of Crew Resource Management Training in Commercial Aviation. The International Journal of Aviation Psychology. 1999;9(1):19-32.
8. Mearns K, Whitaker S, Flin R. Safety Climate, Safety Management Practice and Safety Performance in Offshore Environments. Safety Science2003. 641-80 p.
9. Pal A, Lal R, Frizelle F. Aviation-based teamwork skills work for surgeons: time for an 'aviation bundle'? ANZ journal of surgery. 2018;88(12):1231-5.
10. Haerkens MH, Kox M, Lemson J, Houterman S, van der Hoeven JG, Pickkers P. Crew Resource Management in the Intensive Care Unit: a prospective 3-year cohort study. Acta anaesthesiologica Scandinavica. 2015;59(10):1319-29.
11. Haerkens MH, van Leeuwen W, Sexton JB, Pickkers P, van der Hoeven JG. Validation of the Dutch language version of the Safety Attitudes Questionnaire (SAQ-NL). BMC health services research. 2016;16(a):385.
12. Ajlan AM, Harsh GRt. The human factor and safety attitudes in neurosurgical operating rooms. World neurosurgery. 2015;83(1):46-8.
13. Mardon RE, Khanna K, Sorra J, Dyer N, Famolaro T. Exploring relationships between hospital patient safety culture and adverse events. Journal of patient safety. 2010;6(4):226-32.
14. Christian CK, Gustafson ML, Roth EM, Sheridan TB, Gandhi TK, Dwyer K, et al. A prospective study of patient safety in the operating room. Surgery. 2006;139(2):159-73.
15. Stevens M, van Schaik J. Implementing new technologies for complex care: The role of embeddedness factors in team learning. 2020;66(1-2):112-34.

16. Russ AL, Fairbanks RJ, Karsh BT, Militello LG, Saleem JJ, Wears RL. The science of human factors: separating fact from fiction. BMJ quality & safety. 2013;22(10):802-8.
17. Sexton JB, Thomas EJ, Helmreich RL. Error, stress, and teamwork in medicine and aviation: cross sectional surveys. BMJ (Clinical research ed). 2000;320(7237):745-9.
18. Sexton JB, Helmreich RL, Neilands TB, Rowan K, Vella K, Boyden J, et al. The Safety Attitudes Questionnaire: psychometric properties, benchmarking data, and emerging research. BMC health services research. 2006;6:44.
19. Nederhof AJ. Methods of coping with social desirability bias: A review. Eur J Soc Psychol. 1985;15(3):263-80.
20. Savage C, Gaffney FA, Hussain-Alkhateeb L, Olsson Ackheim P, Henricson G, Antoniadou I, et al. Safer paediatric surgical teams: A 5-year evaluation of crew resource management implementation and outcomes. International journal for quality in health care : journal of the International Society for Quality in Health Care. 2017;29(6):853-60.
21. Smiley K, Ofori L, Spangler C, Acquaah-Arhin R, Deh D, Enos J, et al. Safety Culture and Perioperative Quality at the Volta River Authority Hospital in Akosombo, Ghana. World journal of surgery. 2019;43(1):16-23.
22. Makary MA, Sexton JB, Freischlag JA, Holzmueller CG, Millman EA, Rowen L, et al. Operating room teamwork among physicians and nurses: teamwork in the eye of the beholder. Journal of the American College of Surgeons. 2006;202(5):746-52.
23. Moulton CA, Regehr G, Mylopoulos M, MacRae HM. Slowing down when you should: a new model of expert judgment. Academic medicine : journal of the Association of American Medical Colleges. 2007;82(10 Suppl):S109-16.
24. Schmutz JB, Meier LL, Manser T. How effective is teamwork really? The relationship between teamwork and performance in healthcare teams: a systematic review and meta-analysis. BMJ open. 2019;9(9):e028280.
25. Buljac-Samardzic M, Doekhie KD, van Wijngaarden JDH. Interventions to improve team effectiveness within health care: a systematic review of the past decade. Human resources for health. 2020;18(1):2.
26. O'Connor P, Campbell J, Newon J, Melton J, Salas E, Wilson KA. Crew Resource Management Training Effectiveness: A Meta-Analysis and Some Critical Needs. Int J Aviat Psychol. 2008;18(4):353-68.
27. Haerkens MH, Jenkins DH, van der Hoeven JG. Crew resource management in the ICU: the need for culture change. Annals of intensive care. 2012;2(1):39.
28. Sorra J, Khanna K, Dyer N, Mardon R, Famolaro T. Exploring relationships between patient safety culture and patients' assessments of hospital care. The Journal of nursing administration. 2014;44(10 Suppl):S45-53.
29. O'Dea A, O'Connor P, Keogh I. A meta-analysis of the effectiveness of crew resource management training in acute care domains. Postgraduate medical journal. 2014;90(1070):699-708.

CHAPTER VI

PERSPECTIVES OF PATIENTS AND PROFESSIONALS ON INFORMATION AND EDUCATION AFTER MYOCARDIAL INFARCTION WITH INSIGHT FOR MIXED REALITY IMPLEMENTATION: CROSS-SECTIONAL INTERVIEW STUDY

A.D. Hilt, MD*; K. Mamaqi Kapllani, MEng*; B.P. Hierck, MD, PhD; A.C. Kemp BSc; A. Albayrak, MEng, PhD; M. Melles, MEng, PhD; M.J. Schalij, MD, PhD; R.W.C. Scherptong, MD, PhD
*: both authors contributed equally to the manuscript

Published
JMIR Hum Factors. 2020 Jun 23;7(2):e17147

Abstract

Background

Patient education is crucial in the secondary prevention of cardiovascular disease. Novel technologies such as mixed reality expand the possibilities for providing visual support in this process. However, research on this technology in the patient domain is scarce.

Objective

The aim of this study was to understand how patients perceive information provided after myocardial infarction and examine if mixed reality can be supportive in this process.

Methods

Twelve patients that experienced myocardial infarction and six health care professionals were enrolled in the study. Clinical, demographic, and qualitative data were obtained through semi-structured interviews, with a main focus on patient experiences within the hospital and the knowledge they gained about their disease. These data were then used to map a susceptible timeframe to identify how mixed reality can contribute to patient information and education.

Results

Knowledge transfer after myocardial infarction was perceived by patients as too extensive, not personal, and inconsistent. Notably, knowledge on anatomy and medication was minimal and was not recognized as crucial by patients, whereas professionals stated the opposite. Patient journey analysis indicated the following four critical phases of knowledge transfer: at hospital discharge, at the first outpatient visit, during rehabilitation, and during all follow-up outpatient visits. Important patient goals were understanding the event in relation to daily life and its implications on resuming daily life. During follow up, understanding physical limitations and coping with the condition and medication side effects in daily life emerged as the most important patient goals. The professionals' goals were to improve recovery, enhance medication adherence, and offer coping support.

Conclusion

There is a remarkable difference between patients' and professionals' goals regarding information and education after myocardial infarction. Mixed reality may be a practical tool to unite perspectives of patients and professionals on the disease in a more even manner, and thus optimize knowledge transfer after myocardial infarction. Improving medication knowledge seems to be a feasible target for mixed reality. However, further research is needed to create durable methods for education on medication through mixed reality interventions.

Introduction

Coronary artery disease is a major cause of mortality in developed countries, leading to roughly 1.5 million deaths annually worldwide (1,2). Improvements in early recognition of the disease and treatment have significantly decreased the mortality rate after myocardial infarction over the last few decades (3). However, increased complexity in treatment and long-term care makes educating patients about their disease a challenge for health care professionals. Guiding patients through complex terminology, pathophysiological concepts, and extensive treatment options in a limited time frame is a stressful and demanding process for both the health care professionals and patients (4).

Improvements have been made regarding patient information and education through extensive written information, informational videos, or digitalized “how does it look” visual models (5-8). Attempts at improving education in patients following myocardial infarction are scarce and have mainly focused on care processes and anatomical knowledge (9-11).
With rapid development of new technologies such as virtual reality (12) or more recent mixed reality modalities (3) patient information and education approaches have also been changing (14-16). Mixed reality creates interactive digital three-dimensional (3D) projections that are viewed through a head-mounted display such as Microsoft Hololens. With the introduction of this new technology, the possibilities to support daily care increase, in particular regarding improvements in anatomical knowledge. However, this adds another layer of complexity to the care process. The question therefore remains as to how to best establish the added value of implementing a new technology such as mixed reality in the educational process on a patient level.

To optimize the process of patient information and education after myocardial infarction, information should add to the sustainability of health and disease prevention (17). The latter aspect is a particular cornerstone of myocardial infarction care (1). Toward this end, the aim of this study was to assess how patients perceive patient information and education resources offered after myocardial infarction without the use of a mixed reality app.

A secondary aim was to identify targets for mixed reality within the domain of patient information and education after myocardial infarction.

Methods

Design

This was a cross-sectional interview study. Ethical approval for the project was obtained through the local medical ethics committee of Leiden University Medical Centre (protocol number P18.132).

Study Population

Twelve consecutive patients who visited the dedicated outpatient clinic for patients after myocardial infarction were asked to participate in the study. The patients were at various stages in their recovery, ranging between 1 and 12 months after the initial myocardial infarction. In addition, two cardiologists, two nurse specialists, one psychologist, and one sexologist were included in the study to obtain the professional stakeholders' point of view. Demographic data such as age, gender, occupation, and time of interviewing (1, 3, 6, or 12 months after myocardial infarction) were collected.

Additionally, clinical demographics such as comorbidities (smoking, hypertension, diabetes mellitus), initial diagnosis (ST-elevation myocardial infarction (STEMI) or nonST-elevation myocardial infarction (NSTEMI)), culprit lesion of the myocardial infarction, maximum troponin levels at admission, and left ventricular ejection fraction (LVEF%) at hospital discharge were collected from the electronic medical record.

Semi-structured Interviews and Questionnaires

In line with existing value-based health care literature, generic Patient Reported Outcome Measure tools were used in the current study (18). First, we evaluated whether patients felt that the information provided during clinical care was sufficient, if they understood what medications they were taking, and the purpose of the medication. Second, we assessed the extent of knowledge the patients had about their disease and the effect on cardiac function.

We conducted semi-structured interviews to assess patients' knowledge about personal myocardial infarction characteristics. A list of investigator created open questions was used to conduct the interviews. The first part of the interview included questions related to social and demographic factors. The second part of the interview consisted of questions related to myocardial infarction-specific knowledge. The last part of the interview included the Generic Short Patient Experiences Questionnaire (GS-PEQ). This questionnaire was originally developed to be used in multiple health care settings to evaluate the patient experience through standardized questions in addition to other qualitative measures such as semistructured interviews (19). According to the aim of this study, the GS-PEQ was used to gain insight in patients' opinions about their experience during clinical care.

Since one of the core features of mixed reality is visualizing complex 3D models to interact with, it is relevant to understand if patients have a basic understanding of cardiac anatomy. Therefore, the level of knowledge about coronary artery disease was tested. Two forms were used: one that showed a representation of the coronary arteries, in which the patients could label the vessels that were occluded/obstructed in their case (figure 1), and the other included two diagrams representing the simplified cardiac anatomy of the heart on which patients could label the area affected and how it is related with pump function, if applicable (figure 2). All interviews were audio-recorded and subsequently transcribed.

Semistructured Interview With Professionals

To gain insights into the process and map the professionals' perspective on information provision during the patient journey, semistructured interviews were conducted with professionals engaged in the treatment of patients with myocardial infarction. A list of investigator created questions was used to guide the interviews, which were adapted according to the specific professional activities. The main focus of the interviews was to identify the materials professionals use to interact with patients, the dynamics of the consultations they conduct, and how and when they consider the need to educate patients.

Analysis

Content Analysis

Content analysis was used to structure all of the qualitative data from the interviews, which were summarized through descriptive statistics and examples of general comments. Numerical data are presented as means (SD) and categorical data are presented as proportions. GS-PEQ outcomes were used to structure the patient journey (see further description below); these outcomes were then used for the establishment of themes relevant to both professionals and patients.

Patient Journey Analysis

A patient experience journey was created via a standardized approach to analyze the patient experience within the dedicated care track of myocardial infarction treatment, with specific attention paid to knowledge transfer between professionals and patients (21). For this purpose, the patients underwent observations during outpatient visits at our department, and were then interviewed subsequently with the researchers and were asked to fill out questionnaires consecutively. Patient journey mapping is a frequently used method among design engineers, but is relatively new in the medical domain.

This approach combines several methods to best understand the patient's experience by dividing the management of a specific condition, or process such as education, into a series of consecutive steps or events (21). The mapping is performed using data collected from semistructured interviews, questionnaires, and observations. Combining these data, the result of the final patient journey offers a description of the dedicated care track as seen by professionals and experienced by the patient. In this study, the patient journey analysis included descriptions of the main event (myocardial infarction), acute treatment and total duration of treatment, the environment in which treatment takes place, and interactions with professionals. Importantly, this analysis can highlight the key points of knowledge transfer, materials of interaction, patient concerns, patient goals, professional goals, and guide eventually possible mixed reality interventions throughout the patient experience when treated for myocardial infarction.

Results

Demographics of the Study Population

A total of 12 patients and 6 professionals were interviewed in this study. There were 9/12 (75%) and 3/6 (50%) men in the patient and professional group, respectively. The average age of the patients and health care professionals was 62.7 (SD 10.4) years and 43.2 (SD 9.6) years, respectively. Among the patients, there were 2/12 (17%) current smokers, and the remaining 10 (83%) had stopped smoking after myocardial infarction. Six (50%) patients suffered from hypertension and 2/12 (16%) had diabetes. The majority of patients (10/12, 83%) suffered from a STEMI, with a common culprit vessel being the left anterior descending artery (6 patients, 50%, Table 1). The average LVEF at discharge after myocardial infarction was 49.8% (SD 6.8%) and the average maximum troponin release was 8140.3 ng/L (SD 13.623).

Table 1. Demographic overview of the patients.

Sex	Age (years)	Profession	Interview time after MI[a]	Smoking	HT[b]	DB[c]	LVEF (%)[d]	Tmax[e] (ng/L)	Type of MI	Culprit vessel
Female	61	Administrative assistant	1 month	stopped	yes	yes	39	10,553	STEMI[f]	LAD[g]
Male	62	Lawyer	1 month	stopped	no	no	58	50,000	STEMI	LAD
Male	74	Vice principal	3 months	stopped	no	no	58	1160	STEMI	RCA[h]
Male	52	Manager	3 months	stopped	yes	no	58	1504	NSTEMI[i]	RCA
Male	57	Foreman	6 months	yes	yes	no	48	8389	STEMI	LAD
Female	63	Nurse	6 months	stopped	yes	no	58	20	STEMI	RCA
Male	54	Engineer	6 months	stopped	no	no	44	5659	STEMI	LAD
Male	56	Information technology consultant	6 months	stopped	yes	no	50	5308	STEMI	RCA
Male	64	Dentist	12 months	yes	no	yes	49	3990	STEMI	LAD
Male	78	Architect	12 months	stopped	no	no	45	2078	NSTEMI	D1[j]
Male	82	Truck driver	12 months	stopped	no	no	48	8406	STEMI	RCx[k]
Female	49	Housewife	12 months	stopped	yes	no	42	622	STEMI	LAD

[a]MI: myocardial infarction, [b]HT: hypertension, [c]DB: diabetes mellitus, [d]LVEF: left ventricular function at infarction (%), [e]Tmax: maximal troponin release, [f]STEMI: ST-elevation myocardial infarction, [g]LAD: left anterior descending artery, [h]RCA: right coronary artery, [i]NSTEMI: nonST-elevation myocardial infarction, [j]D1: diagonal branch, [k]RCx: circumflex artery.

General Experience

Six (50%) patients (all men) indicated that the information shared (written or spoken, presented in analog or digital format) was too extensive and repetitive, whereas one male patient stated that more information was needed. Overall, the patients indicated that clinicians were able to provide them with sufficient care, specifically regarding information on their diagnosis. However, 9/12 (75%; 2 women, 7 men) patients noted that they were not involved in specific decisions regarding their treatment process. Only one male patient reported that the given treatment was incorrect according to his own judgement (Table 2).

Table 2. Generic Short Patient Experiences Questionnaire (GS-PEQ) (N=12).

Question	Agree (n, %)
Did the clinician talk to you in a way that was easy to understand?	12 (100)
Do you have confidence in the clinicians' professional skill?	9 (75)
Did you get sufficient information about your diagnosis?	11 (92)
Did you perceive the treatment as adapted to your situation?	11 (92)
Were you involved in decisions regarding your treatment?	3 (25)
Did you perceive the institution's work to be well organized?	12 (100)
Did you have to wait before you were admitted for services at the institution?	12 (100)
Overall, was the help and treatment you received at the institution satisfactory?	11 (92)
Did you benefit from the care given at the institution?	11 (92)
Do you believe that you were in any way given incorrect treatment?	1 (8)

From the professionals' perspective, optimal timing for information exchange is perceived at the first visit at 1 month after myocardial information (6/6, 100%). All professionals (6/6, 100%) also stated that they wish to educate patients in a understandable and complete manner, although the timeframe is perceived to be too short in the outpatient setting.

Medication Usage

Six of the 12 (50%, 2 women, 4 men) patients were unaware of the type of medication they were taking and its purpose. In addition, 10/12 (83%, 3 women, 7 men) patients considered the medication to influence their recovery in a negative manner.

From the professionals' perspective, written and hand-drawn educational information were stated as the most frequently used materials for both providing medication information and anatomical knowledge transfer (6/6, 100%), followed by video (3/6, 50%) and Microsoft PowerPoint presentations (1/6, 17%). Accurate insight on medication ("what medication do you use and why?") among patients was perceived to be poor by professionals; 4/6 (85%) of the professionals stated that they frequently encounter this problem in the outpatient setting. The professionals equally stated a desire to educate patients on the cardioprotective function as completely as possible (6/6, 100%).

Anatomical Knowledge

Regarding anatomical knowledge, 4/12 (33%, 1 woman, 3 men) patients were aware of the culprit vessel (Figure 1, Table 3) and 4/12 (33%, 1 woman, 3 men) knew the affected site (Figure 2, Table 4). Only 2/12 (17%, both men) patients knew the area of the heart that was affected by the culprit lesion: 10/12 (83%, 3 women, 7 men) patients had no knowledge of the relationship between the diseased (culprit) vessel and the effect on their heart. Six (50%, 1 woman, 5 men) of the patients noted that this type of information was not relevant to them. Examples of comments given by patients are shown in Textbox 1.

Table 3. Culprit lesion knowledge (also see Figure 1).

Patient	Culprit lesion	Correctly shown in figure?
1	*LAD*[a]	*No*
2	*LAD*	*Yes*
3	*RCA*[b]	*No*
4	*RCA*	*No*
5	*LAD*	*No*
6	*RCA*	*No*
7	*LAD*	*Yes*
8	*RCA*	*Yes*
9	*LAD*	*No*
10	*D1*[c]	*Yes*
11	*RCx*[d]	*No*
12	*LAD*	*No*

[a]LAD: left anterior descending artery, [b]RCA: right coronary artery, [c]D1: left anterior descending artery diagonal branch, [d]RCx: circumflex artery.

Table 4. Affected site knowledge (see Figure 2).

Patient	Correct site shown
1	*No*
2	*No*
3	*No*
4	*No*
5	*Yes*
6	*No*
7	*Yes*
8	*Yes*
9	*No*
10	*No*
11	*No*
12	*Yes*

Textbox 1. Example patient comments related to information exchange with professionals.

- **Overall information exchange**

"Too much information to comprehend at once"

"I really don't need to know all what they tell me"

"I really wanted to know way more than they tell me"

- **Medication-related information**

"I have no idea what I am taking"

"I am in charge over my body and I want to live a great life without medication"

"So many pills! That is a big problem for me, but what can I do?"

"I have different kind of colors and sizes, don't know what they do"

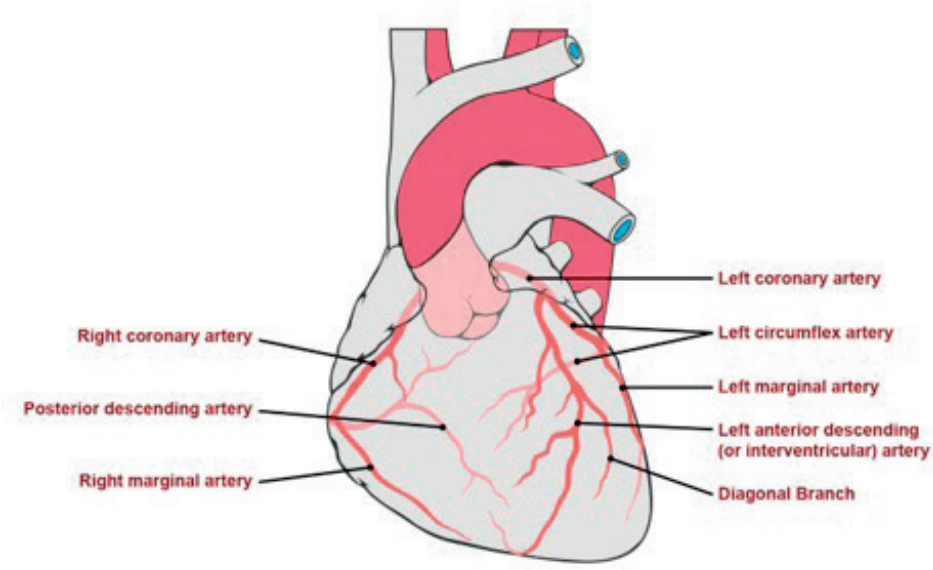


Figure 1. Representation of coronary arteries. Patients were asked the following: "Could you please tick on the boxes which of your arteries have been affected, if any? Also, on the left illustration, draw the parts affected after the myocardial infarction."

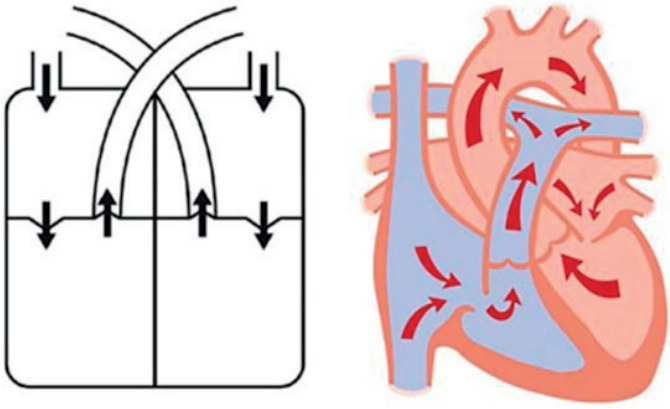


Figure 2. Representation of heart blood circulation (left) and the main parts of the heart (right). Patients were asked: "Could you please tick on the boxes corresponding to the parts of your heart that have been affected, if any? Also, draw the affected parts on the left illustration."

All professionals (6/6, 100%) stated that there should be more time available to educate patients on an anatomical understanding of myocardial infarction.

Patient Experience Journey: Care Track and Opportunities for Mixed Reality

Information Exchange Goals

Figure 3 shows the key elements regarding knowledge transfer after myocardial infarction, and Multimedia Appendix 5 provides a full overview of the patient journey. The patient journey includes the goals of both patients and professionals at each step of the care track. Key points regarding information transfer were assessed at hospital discharge, during the first outpatient visit, and during the rehabilitation initiation. Information exchange during these phases is currently performed using drawings, the post-myocardial infarction care track information booklet, and videos (Figure 3).

Index Event and Admission

Information transfer goals

Patient	Professional
• Understand what happened. • Understand recovery process. • Understand impact on daily life.	• Pathology knowledge. • Importance of medication. • Call 911 when necessary.

Possible MR targets

Models with a focus on:

- Cardiac function importance of medication use.
- Consequences in daily life.
- Riskfactor impact.

Current media use: booklets, dragwings.

First Outpatient Visit

Information transfer goals

Patient	Professional
• Understand current condition. • Understand side effects. • Coping in daily life.	• Initiate proper recovery. • Enhance medication adherence. • Psychological guidance.

Possible MR targets

Models with a focus on:

- Recovery of the heart.
- Importance of medication use.
- Medication side effects.
- Riskfactor impact.

Current media use: booklets, dragwings.

Rehabilitation

Information transfer goals

Patient	Professional
• Recover physical level as before MI. • Understand impairment of physical fitness.	• Enhance heart recovery. • Medication adherence. • Optimal physical fitness.

Possible MR targets

Models with a focus on:

- Recovery of the heart.
- Importance of medication use.
- Limitations in physical fitness.

Current media use: booklets, dragwings, video.

Follow-up Outpatient Visit

Information transfer goals

Patient	Professional
• Understand current condition. • Cope with/resolve side effects. • Coping in daily life.	• Prolong survival. • Enhance medication adherence. • Prepare for discharge to GP.

Possible MR targets

Models with a focus on:

- Total recovery of the heart.
- Importance of medication use.

Current media use: booklets, dragwings, video.

Figure 3. Overview of patient experience regarding knowledge transfer and mixed reality (MR) possibilities.

Discharge and First Outpatient Visit

Patient goals at discharge were understanding what happened, what the current condition is, and how it affects their daily life. Professionals focus on describing the event, relating it to risk factors, and stressing the importance of seeking attention when similar symptoms that may indicate a myocardial infarction are experienced.

Goals at the first outpatient visit were the same as those at discharge with the addition of understanding the side effects of medications as well as coping with the disease in daily life. Professionals focus on optimal recovery through optimal medication adherence, stressing the importance of rehabilitation and providing psychological guidance when needed. Mixed reality can help to visually support the patient's clinical state when they leave the hospital, as well as stressing the importance of medication, risk factor impacts such as smoking, and possible side effects of medication that are to be expected (Figure 3).

Rehabilitation and Outpatient Follow Up

During rehabilitation, patient goals focus on physical fitness in terms of understanding the impairment of the disease and reaching the pre-myocardial infarction level of fitness. Professionals focus on increasing physical fitness through exercise and support recovery by stressing medication adherence.

During outpatient follow up, patient goals focus on adjusting to the current health condition in daily life and understanding the potential side effects that may occur. Professionals focus mainly on prolonging survival by optimizing medication adherence and lifestyle as well to prepare patients for eventual discharge to the family physician. Mixed reality can visually support the physical condition of patients by showing the current state of heart function and its effect on physical fitness, along with the state of recovery the heart and highlighting the long-term importance of medication on survival.

Discussion

Principal Findings

Overall, the results of the current study demonstrate that patients and clinical staff have very different opinions about the overall information shared during outpatient clinical visits, anatomical knowledge, and medication. First, patients reported that the information shared was too extensive and superfluous, whereas staff members stated a desire to share more information. Second, patients perceived medication as a hurdle toward their recovery, whereas professionals viewed the medication as an important part of their recovery. Third, the anatomical knowledge of patients was minimal regarding the culprit lesion and its effect on cardiac function. The patient journey in this regard showed that patients transition from a state of uncertainty to a state of confidence; however, the lack of knowledge remains and reassurance by health care providers is regarded as important.

Patient Information Education After Myocardial Infarction

Throughout the year following myocardial infarction, patients see roughly 4 clinical specialists and often also see a psychologist or sexologist, all of whom elaborate on the same concept of myocardial infarction.

However, our outcomes suggest that patient knowledge of simple anatomical and physiological concepts of heart disease remains minimal. Furthermore, patients regard medication as a hurdle toward recovery although it is the hallmark of secondary prevention in cardiovascular care. Scott et al (22) found that patients ranked explanation of anatomical and pathophysiological concepts as well as medication information as of high importance after myocardial infarction; however, the effect of teaching these aspects to patients regarding their long-term survival is not known. It is also questionable if teaching of these concepts is essential to reach the goal of preventing new myocardial infarction, and evidence in this regard is lacking.

Our patients received identical information after myocardial infarction; however, they seem to have gained little understanding from this education, and mainly perceived the information provided as too extensive, which was not considered to be in line with their own goals. Therefore, our study highlights room for improvement in patient information education after myocardial infarction.

Professional goals (prevention of new myocardial infarction) and patient goals (living a normal life) differ to a striking degree (Figure 3). Although the necessity of teaching anatomical and pharmacological concepts might be debatable, patient care regarding information exchange should be in line with the goals of patients to support patient-centered care (18).

To unite these goals, the interaction between a patient and professional needs to be assessed and reevaluated based on the results of our study. When this information exchange is goal-oriented, learning and adoption of new information will be more effective, as stated by the cognitive load theory proposed by Sweller (23). This theory states that the methods of information exchange should promote a low extraneous cognitive load (ie, presentation of information). Conventional methods (ie, booklets) create high levels of extraneous load, whereas visual methods create a low extraneous load (23). Therefore, use of a mixed reality app might effectively aid in generating a low extraneous load and offer a new method of learning. This warrants further research, particularly if implementation of mixed reality for patient information education can lead to improvement of medication adherence.

Identifying Targets for Mixed Reality

As seen in the patient journey analysis, there are certain points at which mixed reality may provide solutions in patient information exchange. Certain targets might provide less information, but will nonetheless be aligned with actual patient data, including guidance on the effect of medication on their current health condition.

Mixed reality has been recently popularized by the development of Google Glass and subsequently Microsoft HoloLens, released in March 2016 (15). HoloLens can project interactive 3D images in the field of vision of the user and recognize the environment owing to the presence of four environment-sensing cameras, a depth camera, and a light sensor. Apart from recognizing the environment, HoloLens also memorizes it, thereby reducing the time required for the next interaction. HoloLens can also recognize human gestures to enable interaction and teamwork around the same projected objects, owing to integration of human understanding software such as spatial sound, gaze tracking, gesture input, and voice support (24).

Table 5 provides an overview of the different types of media available for mixed reality and their usability, along with a summary of usability and capabilities.

The main capabilities of HoloLens to be considered in the outpatient setting are: (i) recognize and interact with the environment, to choose the best environment for the interventions and base the design accordingly; (ii) project 3D images that can rotate, scale, or move; and (iii) encourage teamwork by enabling doctors and patients to collaborate through synchronization of doctor and patient images in space, giving them an opportunity to collaboratively study the model. Through these capabilities, mixed reality creates new ways of collaboration between the patient and professional. Recent studies have tested mixed reality for medical training (16) and as a surgical assistive technology (25). For medical students, especially those with lower visual-spatial abilities, mixed reality was shown to significantly improve 3D knowledge acquisition (26).

However, no apps currently exist that use mixed reality specifically to educate myocardial infarction patients or to improve their experience during the treatment after myocardial infarction.

Table 5. Media types and usefulness in patient education.

Usability and capability	Mixed Reality (HoloLens)	Augmented Reality	Virtual Reality	Video	Text and Images
Interaction between two or more users	Full	Partial	Partial	No	No
Movement	Yes	Yes	Yes	Partial	No
Environment aware	Yes	Partial	No	No	No
Device needed	Yes	Yes (phone)	Yes (phone)	Yes (TV, computer, or phone)	No

Our results indicate that mixed reality may be of aid in compiling patient-specific data in one model such as a simplified model of the heart and coronary anatomy using radiographic and ultrasound data. This may be used at the end of the hospital stay when patients are fit to go home, and when uncertainties are present. A mixed reality intervention at discharge can provide a crude overview of myocardial infarction and the importance of medication and education on minimizing risk factors such as smoking.

This technology can be used consecutively throughout all outpatient visits, compiling cardiac function in the model and thereby offering the possibility to use one model consecutively. Furthermore, mixed reality can be used to explain the effects of medication on long-term survival.

Medication as a Specific Target for Mixed Reality

The patients included in our study perceived medication as a hurdle toward recovery. They indicated that this is mainly coupled to side effects but also that the beneficial effects are unclear (despite all information provided). Optimal medical therapy after myocardial infarction is the cornerstone of cardioprotective care and is essential in preventing new events (12). This has been stressed by both the European and American cardiology societies (27). However, nonadherence to medication is a common problem (28). Through the years, attempts have been made to improve this limitation; however, it remains a challenge to create sustainable interventions (29). The patient journey analysis suggested that reassurance is important for patients to understand their condition such as whether or not they are physically fit.

Clear explanation of medication benefits on their health and daily life may resolve the lack of understanding of medication effects and potentially lower the need for reassurance.

Tailoring education to patient-specific features and needs such as medication adherence seems to be effective, which has been proposed in other studies. Nieuwkerk et al (20) demonstrated that by clarifying the effect and importance of statins visually, low-density lipoprotein cholesterol levels can be reduced along with an increase in the intake of statins. A randomized study conducted by Jones et al (30) in 2015 showed that providing visual education after myocardial infarction improved illness and medication perceptions in the intervention group. A similar approach may be feasible in patients after myocardial infarction that are offered a new form of education through mixed reality. A model could be developed, not focusing on anatomy per se but rather on statin use and the effect on the patient's cardiovascular health, such as by demonstrating atherosclerosis in coronary vessels, which is targeted by statin therapy (1). The effect of such a mixed reality intervention could be measured according to assessing medication beliefs and illness perceptions.

Further research is needed to test our assumptions. Importantly, the implementation and evaluation of a mixed reality app in the elderly should be undertaken. With increasing age, potential users will be between 60 and 80 years old, which is accompanied by different forms of disabilities (ie, impaired vision, hearing, or cognitive function) that can complicate use. However, mixed reality seems to be an accessible and feasible tool in the elderly, as highlighted by Rohrbach et al (31) in patients with Alzheimer disease. Since patients with Alzheimer disease comprise a complex patient group, it is feasible to assume that patients with no cognitive impairments might also benefit from mixed reality apps. In this era of rapidly evolving technology that brings new opportunities regarding patient information education, it is important to thoroughly evaluate how these technologies can be used in a changing medical setting and with what goal in mind, especially given the sparsity of research on the topic.

Limitations

There are certain limitations to our study. First, all interviews were conducted in a group of patients and professionals belonging to a single hospital. Using a different group of professionals and patients from different hospitals and social backgrounds, different outcomes may be generated concerning patient information education. Second, and following this point, the small study size could have led to overestimating the assumptions such as the problems patients have with medication. Further investigation on this subject is therefore warranted. Third, observational interview studies have inherent biases (such as responder bias or social desirability bias). This can also be corrected using a larger-scale study.

Conclusion

We identified a remarkable difference between the goals of patients and health care professionals regarding information and education after myocardial infarction. Mixed reality may be a practical tool to unite the perspectives of patients and professionals on the disease in a more even manner, and thus optimize knowledge transfer after myocardial infarction. Medication understanding seems to be a feasible target for mixed reality. However, further research is needed to develop durable methods for education on medication through mixed reality.

Acknowledgments

We would like to thank Mrs. J.W.M. Plevier for her support and help in conducting the literature search at the Walaeus library of Leiden University Medical Center.

Authors' Contributions

AH, KK, RS, AA, and MM conceived of the study. AH, KK, RS, AA, and MM developed the theory, and AH, KK, and CK performed the data collection and analysis. BH, RS, AA, MM, and MS supervised the research and critically reviewed the findings. AH and KK drafted the manuscript. All authors discussed the results and contributed to the final manuscript.

References

1. Roffi M, Patrono C, Collet JP, Mueller C, Valgimigli M, Andreotti F, et al. 2015 ESC Guidelines for the management of acute coronary syndromes in patients presenting without persistent ST-segment elevation: Task Force for the Management of Acute Coronary Syndromes in Patients Presenting without Persistent ST-Segment Elevation of the European Society of Cardiology (ESC). European heart journal. 2016;37(3):267-315.
2. Amsterdam EA, Wenger NK, Brindis RG, Casey DE, Ganiats TG, Holmes DR, et al. 2014 AHA/ACC Guideline for the Management of Patients With Non–ST-Elevation Acute Coronary Syndromes: A Report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines. Journal of the American College of Cardiology. 2014;64(24):e139-e228.
3. Nabel EG, Braunwald E. A tale of coronary artery disease and myocardial infarction. The New England journal of medicine. 2012;366(1):54-63.
4. Westermann GM, Verheij F, Winkens B, Verhulst FC, Van Oort FV. Structured shared decision-making using dialogue and visualization: a randomized controlled trial. Patient education and counseling. 2013;90(1):74-81.
5. Kaphingst KA, Persky S, McCall C, Lachance C, Loewenstein J, Beall AC, et al. Testing the effects of educational strategies on comprehension of a genomic concept using virtual reality technology. Patient education and counseling. 2009;77(2):224-30.
6. Becker A, Herzberg D, Marsden N, Thomanek S, Jung H, Leonhardt C. A new computer-based counselling system for the promotion of physical activity in patients with chronic diseases--results from a pilot study. Patient education and counseling. 2011;83(2):195-202.
7. Harless WG, Zier MA, Harless MG, Duncan RC, Braun MA, Willey S, et al. Evaluation of a virtual dialogue method for breast cancer patient education. Patient education and counseling. 2009;76(2):189-95.
8. Zissiadis Y, Harper E, Kearney E. Impact of more intensive written information in patients having radical radiation therapy: results of a prospective randomized phase III trial. Radiotherapy and oncology : journal of the European Society for Therapeutic Radiology and Oncology. 2010;96(2):254-8.
9. Kuo MC, Chang P. Developing a visualized patient-centered, flow-based and objective-oriented care path of cardiac catheterization examination. Studies in health technology and informatics. 2009;146:879-80.
10. Otto CM. Communicating with our patients for shared decision making. Heart (British Cardiac Society). 2018;104(6):451-3.
11. Kaufman BG, Kim S, Pieper K, Allen LA, Gersh BJ, Naccarelli GV, et al. Disease understanding in patients newly diagnosed with atrial fibrillation. Heart (British Cardiac Society). 2018;104(6):494-501.
12. Montalescot G, Sechtem U, Achenbach S, Andreotti F, Arden C, Budaj A, et al. 2013 ESC guidelines on the management of stable coronary artery disease: the Task Force on the

management of stable coronary artery disease of the European Society of Cardiology. Eur Heart J. 2013;34(38):2949-3003.
13. Helmreich RL, Merritt AC, Wilhelm JA. The Evolution of Crew Resource Management Training in Commercial Aviation. The International Journal of Aviation Psychology. 1999;9(1):19-32.
14. Bork F. [Interactive augmented reality systems : Aid for personalized patient education and rehabilitation]. Der Unfallchirurg. 2018.
15. Biglino G, Capelli C, Wray J, Schievano S, Leaver LK, Khambadkone S, et al. 3D-manufactured patient-specific models of congenital heart defects for communication in clinical practice: feasibility and acceptability. BMJ open. 2015;5(4):e007165.
16. Wang S, Parsons M, Stone-McLean J, Rogers P, Boyd S, Hoover K, et al. Augmented Reality as a Telemedicine Platform for Remote Procedural Training. Sensors (Basel, Switzerland). 2017;17(10).
17. Porter ME. What is value in health care? The New England journal of medicine. 2010;363(26):2477-81.
18. Fitzpatrick R, Davey C, Buxton MJ, Jones DR. Evaluating patient-based outcome measures for use in clinical trials. Health technology assessment (Winchester, England). 1998;2(14):i-iv, 1-74.
19. Sjetne IS, Bjertnaes OA, Olsen RV, Iversen HH, Bukholm G. The Generic Short Patient Experiences Questionnaire (GS-PEQ): identification of core items from a survey in Norway. BMC health services research. 2011;11:88.
20. Nieuwkerk PT, Nierman MC, Vissers MN, Locadia M, Greggers-Peusch P, Knape LP, et al. Intervention to improve adherence to lipid-lowering medication and lipid-levels in patients with an increased cardiovascular risk. The American journal of cardiology. 2012;110(5):666-72.
21. Trebble TM, Hansi N, Hydes T, Smith MA, Baker M. Process mapping the patient journey: an introduction. BMJ (Clinical research ed). 2010;341:c4078.
22. Scott JT, Thompson DR. Assessing the information needs of post-myocardial infarction patients: a systematic review. Patient education and counseling. 2003;50(2):167-77.
23. Sweller J. Cognitive Load During Problem Solving: Effects on Learning. 1988;12(2):257-85.
24. Chen H, Lee AS, Swift M, Tang JC. 3D Collaboration Method over HoloLens™ and Skype™ End Points. Proceedings of the 3rd International Workshop on Immersive Media Experiences; Brisbane, Australia. 2814350: ACM; 2015. p. 27-30.
25. Sauer IM, Queisner M, Tang P, Moosburner S, Hoepfner O, Horner R, et al. Mixed Reality in Visceral Surgery: Development of a Suitable Workflow and Evaluation of Intraoperative Use-cases. Annals of surgery. 2017;266(5):706-12.
26. Bogomolova K, van der Ham IJM, Dankbaar MEW, van den Broek WW, Hovius SER, van der Hage JA, et al. The effect of stereoscopic Augmented Reality visualization on learning anatomy and the modifying effect of visual-spatial abilities: a double-center randomized controlled trial. Anatomical sciences education. 2019.
27. Fihn SD, Gardin JM, Abrams J, Berra K, Blankenship JC, Dallas AP, et al. 2012 ACCF/AHA/ACP/AATS/PCNA/SCAI/STS Guideline for the diagnosis and management of patients with stable ischemic heart disease: a report of the American College of Cardiology Foundation/American

Heart Association Task Force on Practice Guidelines, and the American College of Physicians, American Association for Thoracic Surgery, Preventive Cardiovascular Nurses Association, Society for Cardiovascular Angiography and Interventions, and Society of Thoracic Surgeons. J Am Coll Cardiol. 2012;60(24):e44-e164.

28. Naderi SH, Bestwick JP, Wald DS. Adherence to drugs that prevent cardiovascular disease: meta-analysis on 376,162 patients. The American journal of medicine. 2012;125(9):882-7.e1.
29. Briesacher BA, Andrade SE, Fouayzi H, Chan KA. Comparison of drug adherence rates among patients with seven different medical conditions. Pharmacotherapy. 2008;28(4):437-43.
30. Jones AS, Ellis CJ, Nash M, Stanfield B, Broadbent E. Using Animation to Improve Recovery from Acute Coronary Syndrome: A Randomized Trial. Annals of behavioral medicine : a publication of the Society of Behavioral Medicine. 2016;50(1):108-18.
31. Rohrbach N, Gulde P, Armstrong AR, Hartig L, Abdelrazeq A, Schroder S, et al. An augmented reality approach for ADL support in Alzheimer's disease: a crossover trial. Journal of neuroengineering and rehabilitation. 2019;16(1):66.

CHAPTER VII

DEVELOPMENT OF A PATIENT-ORIENTED HOLOLENS APPLICATION TO ILLUSTRATE THE FUNCTION OF MEDICATION AFTER MYOCARDIAL INFARCTION

Alexander D. Hilt, MD; Beerend P. Hierck, MD, PhD; Joep Eijkenduijn, MSc; Fons J. Wesselius, MSc; Armagan Albayrak, MEng, PhD; Marijke Melles, MEng, PhD; Martin J. Schalij, MD, PhD; Roderick W.C. Scherptong, MD, PhD.

Published
European Heart Journal - Digital Health,
Volume 2, Issue 3, September 2021, Pages 511–520

Abstract

Background

Statin treatment is one of the hallmarks of secondary prevention after myocardial infarction. Adherence to statins tends to be difficult and can be improved by patient education. Novel technologies such as Mixed Reality (MR) expand the possibilities to support this process.

Objective

To assess if an MR medication-application supports patient education focused on function of statins after myocardial infarction.

Methods

A human centered design-approach was used to develop an MR statin tool for Microsoft HoloLens™. Twenty two myocardial infarction patients were enrolled; twelve tested the application, ten patients were controls. Clinical, demographic, and qualitative data were obtained. All patients performed a test on statin knowledge. To test if patients with a higher tendency to become involved in virtual environments affected test outcome in the intervention group, validated Presence- and Immersive Tendency Questionnaires (PQ and ITQ) were used.

Results

Twenty two myocardial infarction patients (STEMI, 18/22, 82%) completed the study. Ten out of twelve (83%) patients in the intervention group improved their statin knowledge by using the MR application (median 8 points, IQR 8). Test improvement was mainly the result of increased understanding of statin mechanisms in the body and secondary preventive effects.

A high tendency to get involved and focused in virtual environments was moderately positive correlated with better test improvement ($r=0.57$, $P<0.05$) The median post- test score in the control group was poor (median 6 points, IQR 4).

Conclusions

An MR statin education application can be applied effectively in myocardial infarction patients to explain statin function and importance.

List of abbreviations

ADL	Activities of Daily Living
AR	Augmented Reality
DT	Design Thinking
ITQ	Immersive Tendencies Questionnaire
IQR	Inter Quartile Range
MI	Myocardial Infarction
MR	Mixed Reality
NSTEMI	Non ST-Elevation Myocardial Infarction
PQ	Presence Questionnaire
STEMI	ST- Elevation Myocardial Infarction

Introduction

Global mortality and morbidity due to coronary artery disease is high; roughly 85% of all cardiovascular deaths is due to myocardial infarction alone(1). Hypercholesterolemia is an important risk factor in the development of coronary atherosclerosis, and an important determinant of recurrent myocardial infarction(2). Statin treatment is the hallmark of secondary cardiovascular disease prevention, however statin *adherence* among patients remains a challenge(3, 4). Non-adherence to statins increases the risk of new cardiovascular events drastically(5).

Statin non-adherence is commonly related to both unintentional (practical) and intentional (motivational) barriers(4, 6, 7). Sociodemographic patient factors, negative media coverage, and the nocebo effect are contemporary factors that negatively affect statin adherence(8, 9). To improve statin adherence, patient education is essential(10). Visual anatomy or pathophysiology models can support healthcare professionals in this process(11-14).

Visual education of myocardial infarction patients is commonly done via conventional methods in the outpatient setting, such as booklets or online videos. Nonetheless, improvements regarding visual education have been made over the years (15, 16).

With rapid development of new technologies such as augmented- and mixed reality (AR/MR)(17, 18), options in visual patient education are expanding(19, 20). MR creates interactive digital three-dimensional (3D) holographic projections, overlaying virtual objects on the real-world environment. While augmented reality only overlays objects, MR anchors virtual objects to the real world, fostering interaction between user and virtual object. For medical students, MR technology supports education and improves learning(18, 21). Papers with a focus on patient education with extended realities such as virtual- or augmented reality become more present in daily clinical care(22-24). However, education through MR is scarce and non-existent in clinical cardiology to date. Interestingly, a recent study found that statin education might be a feasible target for an MR application in myocardial infarction patients(25).

The aim of the present study was to develop and test the feasibility of an MR statin education application in the outpatient setting of myocardial infarction patients. It was hypothesized that an interactive MR model is effective in transferring knowledge about the function of statins after myocardial infarction. Furthermore, it was hypothesized that patients who become easily focused and immersed within virtual environments would benefit the most from this technology(26).

Methods

This non-randomized controlled observational study is part of a project investigating the clinical application of MR in myocardial infarction patients. Ethical approval for the project was obtained through the local medical ethics committee of Leiden University Medical Center (protocol number P18.132).

General Study Design

An overview of the study design is presented in figure 1. Twenty two patients who visited the dedicated myocardial infarction outpatient clinic were asked to participate in the study; twelve underwent the intervention, ten patients were used as a control group.

For the intervention group, inclusion criteria were; patients, of 18 years or older i) who had either a ST-elevation myocardial infarction (STEMI) or non ST-elevation myocardial infarction (NSTEMI) and were treated in our center, ii) were one month after initial myocardial infarction, and iii) without impaired vision or hearing which could interfere with using the application. Patients were excluded if they had participated in the previous study in our center concerning MR use in the outpatient setting(25). Informed consent was collected prior to study participation. Demographic data such as age, gender and occupation were collected. Initial diagnosis (STEMI/NSTEMI), pharmaceutical data such as type of statin used, dosage and possible side effects were collected from the electronic medical record. An MR model was shown to all patients in the intervention group in the outpatient clinic via a first generation Microsoft™ HoloLens™. The procedure was guided by a research assistant. Patients were instructed to follow HoloLens audio cues and use all functionalities of the application for one hour. General comments on application-use were simultaneously collected by the assistant. Patients in the intervention group filled out a pre-test on statin knowledge and the Immersive Tendency Questionnaire (ITQ, see below) before using the MR model. The pre-test score was deemed 'test-score after conventional education' (T=0, figure 1). The ITQ assesses if a patient has either a high or low tendency to become focused in virtual environments. After using the model, the Presence Questionnaire (PQ) was filled out; this assesses if the MR model generates high levels of focus for what is shown (statin function). The post-test (T=1, figure 1) consisted of a telephone interview with a focus on statin knowledge.

A control group was used to determine the general effect of conventional statin education via a nurse on statin knowledge in myocardial infarction patients. For the control group, inclusion criteria were: patients, of 18 years or older i) who had either a STEMI or NSTEMI and were treated in our center, ii) were discharged one month prior to study begin or longer and had received conventional education from a specialized nurse at hospital discharge and during outpatient follow-up.

All control patients were naïve for the purpose of the study and completed the post-test via telephone at either 1, 6 or 12 months after discharge. This post- test score (T=0, figure 1) was deemed 'test score after conventional education'. Patients were excluded if they had participated in the previous study in our center concerning MR use in the outpatient setting(25).

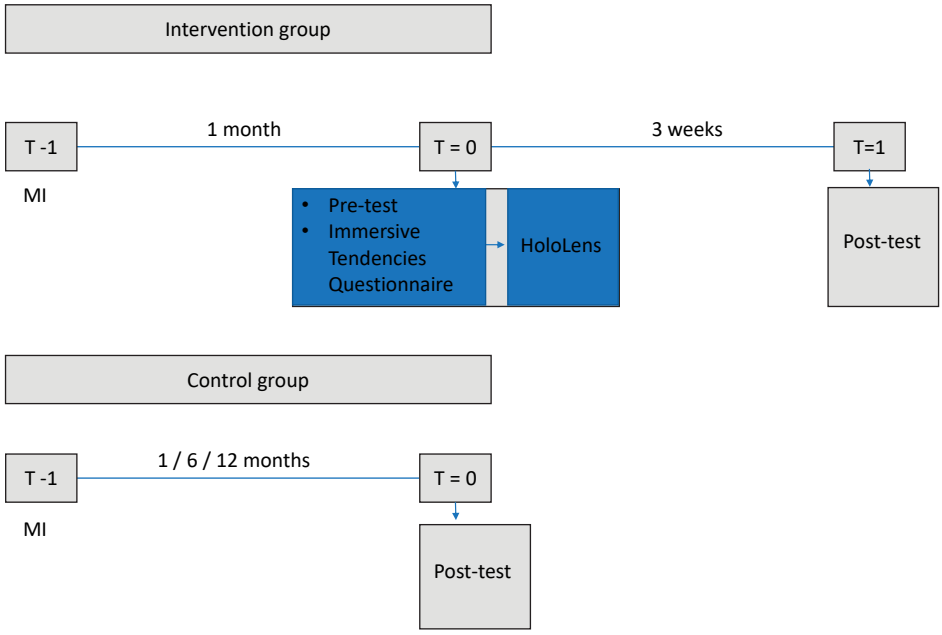


Figure 1. Study overview (intervention- and control group).

Caption: intervention group patients completed a pre-test on statin knowledge after conventional education (T=0) and a questionnaire on immersive tendencies before using the HoloLens application. After using the HoloLens, a presence questionnaire was filled out. Three weeks later, all patients completed the post-test on statin knowledge via phone. All control group patients underwent the post-test via telephone, after they had received the conventional education (T=0) via a specialized nurse, 1, 6 or 12 months after their initial myocardial infarction.

Development of the Mixed Reality Model

The 'double-diamond' human centered design approach, as introduced by the British Design Council in 2005, was used to create the application(27-29). This approach maps the divergent and convergent stages of a design process, showing different modes of design thinking in a structured manner (Figure 2A-D). The first phase (Figure 2A) comprised the preceding study and concluded that statin therapy might be a feasible target for an MR application (25). For the next phase, a correct anatomical 3D heart model (Figure 1B) was obtained online to develop further into a first prototype (Figure 2C). The final phase (Figure 2D) concerns the development of a commercially available product and, as such is not part of the current study. For prototype development, in addition to the patient perspective(25), interviews with two specialized nurses and two cardiologists frequently attending myocardial

infarction patients in the outpatient setting of our hospital, were used to define the essential educational topics regarding statin function to be shown in the model.

This concluded that, to understand statin function, the model should contain animations of; i) cholesterol particles in the blood, ii) atherosclerosis in the coronary vessels, iii) an effect of cholesterol on atherosclerosis, and iv) an effect of statins on cholesterol particles and thus atherosclerosis. Additionally, the effect of atherosclerosis on blood flow and an effect of blood flow on oxygen distribution in the heart was incorporated.

The prototype was built using a set of tools to create an MR model in Blender 2.79, Microsoft ™ Visual studio community 2017, Mixed Reality Toolkit (Version 2017.4.0.0) and Unity, a game development tool, in which 3D or 2D models are programmed using C# or JavaScript(30). The model was stored on a first generation Microsoft™ HoloLens™, Development Edition with a Windows 10 update (Version 10.0.17763.134). With the Microsoft™ HoloLens™, interactive 3D holographic models can be freely handled via hand gestures. Additionally, within the prototype, the user could activate different animations such as 'show cholesterol particles', 'blood flow' or 'show atherosclerosis' in the coronary vessels. When 'statin function' was activated, the amount of cholesterol particles would decrease and the severity of atherosclerosis would decrease. Eight educational audio cues were recorded and build into the model (appendix 1). The final version of the prototype (C) was used in the present study. A video of the model is added as a supplementary file (video appendix 1).

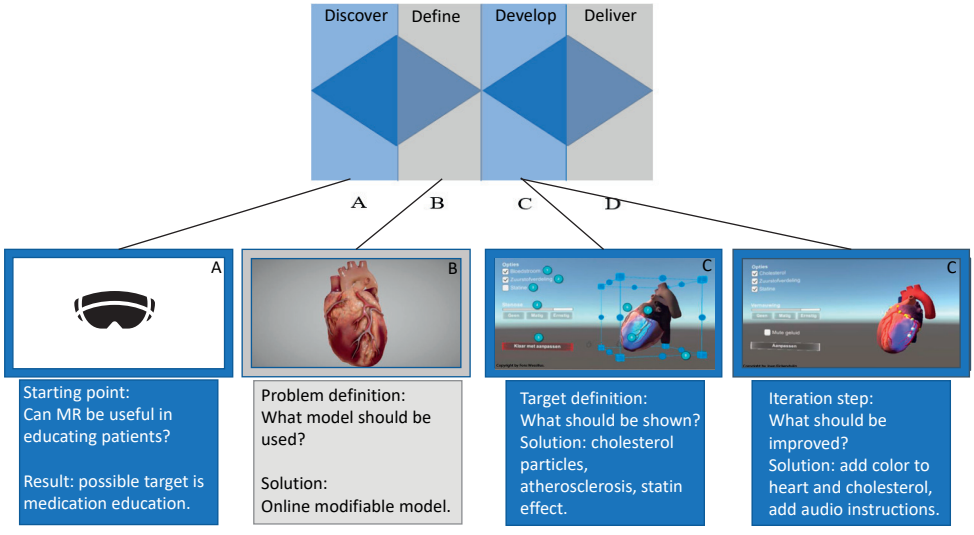


Figure 2. Double Diamond method.

Caption: the double diamond design approach is a standardized method to assess a problem through diverse divergent- and convergent steps (A – C) and ultimately deliver a solution (D).

Assessment of Knowledge on Statin Function

Patient's understanding of statins was tested via a pre- and post-test. The pre-test consisted of five questions regarding statin-effects in the body: i) 'what substances in the body are affected by statins?', ii) 'in what part of the body do statins work/have their function?', iii) 'which side effects do statins commonly give?', iv) 'how long do statins stay active in the body?' and v) 'how fast do statins work in the body?'. Correct answers, or answers containing elements as 'cholesterol/LDL', 'lower cholesterol and/or prevent new cardiovascular events', 'muscular- and gastro intestinal complaints', 'a month' and 'within one or two hours' were rewarded 10 points maximally (appendix 3).

The post-test consisted of one open question for which, identically, 50 points could be scored maximally: 'Could you elaborate in your own words, what the function of statins is in the body and what negative effects can occur because of it'. Each correct part of the answer was rewarded with 10 points, equal to the pre-test (appendix 3). Both pre- and post-test were identical regarding contents.

Control patients only took the post-test. All test outcomes were separately scored by researchers ADH and JE and compared afterwards to reach consensus. The test improvement (difference in pre- and post- test score) was calculated for each patient.

Measurement of Presence and Immersive tendencies

Patients' personal tendency to become focused and immersed within the MR model and its visualizations, were investigated via validated Immersive Tendency-, and Presence Questionnaires (ITQ and PQ)(26). Both questionnaires are used to characterize the likelihood of subjects to become fully focused within a virtual environment(31, 32). The ITQ quantifies a person's individual tendency to become focused in virtual environments.

High cumulative scores (minimum 18 – maximum 126) represent a high tendency to become easily immersed in virtual environments. The PQ quantifies the amount of focus a person experiences on objects or tasks, *generated by* a digital application. The higher the cumulative score (minimum 22 - maximum 154), the higher the focus for the objects shown in the MR model (see appendix 2).

For this study, two questions regarding haptic feedback were removed from the original PQ as this feature was not present in our application. Both ITQ and PQ scores were compared and correlated with the changes in test results, to determine if these device and patient characteristics showed a relationship with test improvement.

Analysis

Non-normally distributed ITQ, PQ and pre- and post-test numerical data are presented as absolute numbers with medians and Inter Quartile Range (IQR). A Spearman Rank test for correlation was calculated for non-normally distributed data; correlation coefficients (r) between Immersive Tendency and test improvement, as well as Presence and test improvement were calculated. Content analysis was used to structure all qualitative data; authors ADH and JE categorized responses to major themes that emerged from the data. For analysis, SPSS Statistics for Windows, version 23.0 (IBM Corp), was used. A *P*-value of less than .05 was considered significant.

Results

Study Population - Demographics

Twenty two myocardial infarction patients were enrolled in the study; the intervention group consisted of 9/12 (75%) males. Median age was 60.0 (IQR 9,5) years. The control group consisted of 5/10 (50%) males, median ages was 63.0 (IQR 5) years. All patients in the intervention group were tested at one month after initial myocardial infarction. Patients in the control group, were recruited at variable time-points after the initial MI: 1 month (n=3), 6 months (n=3) and 12 months (n=4). The majority of patients (18/22, 82%) suffered initially ST-elevation myocardial infarction (STEMI) (table 1 and 2).

Most patients used Atorvastatin 40 milligrams once daily (16/22, 73%), with an average duration of 1,5 (SD 0.6) years since the initial myocardial infarction. Muscle cramps (7/22, 32%) and fatigue (2/22, 10%) were frequent encountered side effects. Three (3/22, 14%) patients had personally terminated statin therapy during outpatient follow up; 19/22 (86%) of patients self-reported full adherence to statins (table 1 and 2). In comparison to the intervention group, the control group consisted of slightly more; NSTEMI patients (20% vs 17%, p=.82), females (50% vs 25%, p=.37) and therapeutically adherent patients (100% vs 75%, p=0.08) with a higher median age (63 years, IQR 5 vs 60 years, IQR 5, p=.1). These differences were however not statistically different.

Table 1. Demographics (intervention group)

Patient	Age(y)	Sex	Education	Type of MI	Statin	Daily Dosage	Side effects	Adherence
P001	60	F	Middle school	STEMI	Simvastatin	40	None	Complete
P002	39	M	BSc	STEMI	Atorvastatin	40	None	Complete
P003	62	M	MSc	STEMI	Atorvastatin	40	None	Complete
P004	72	M	Msc	STEMI	Atorvastatin	20	Muscle Cramp	Complete
P005	60	M	Highschool	STEMI	Atorvastatin	40	Fatigue, GI-cramps	Complete
P006	55	M	Highschool	STEMI	Atorvastatin	40	Fatigue	Complete
P007	50	M	Middle school	NSTEMI	Rosuvastatin	5	Muscle Cramp	Incomplete*
P008	60	F	Highschool	STEMI	Rosuvastatin	5	Muscle Cramp	Incomplete*
P009	67	F	Highschool	NSTEMI	Atorvastatin	40	None	Incomplete*
P010	44	M	Middle school	STEMI	Atorvastatin	40	Muscle Cramps	Complete
P011	58	M	BSc	STEMI	Rosuvastatin	10	Tingling sensation	Complete
P012	72	M	MSc	STEMI	Atorvastatin	40	None	Complete

BSc= bachelor of science; F= female; GI= gastrointestinal; M= male; MG= milligram; MI = myocardial infarction; NSTEMI = non ST elevation myocardial infarction; STEMI = ST elevation myocardial in farction.

Incomplete* = patients discontinued statin therapy single handed

Table 2. Demographics (control group)

Participant	Age(y)	Sex	Education	Type of MI	Statin	Daily Dosage(mg)	Side effects	Adherence	Months after MI
P013	61	F	Unknown	STEMI	Atorvastatin	40	None	Complete	1
P014	62	M	MSc	STEMI	Atorvastatin	40	None	Complete	1
P015	66	F	BSc	NSTEMI	Atorvastatin	80	Muscle Cramps	Complete	1
P016	64	M	Highschool	STEMI	Atorvastatin	80	None	Complete	6
P017	61	F	Unknown	STEMI	Atorvastatin	40	None	Complete	6
P018	69	F	MSc	STEMI	Atorvastatin	40	Muscle Cramps	Complete	6
P019	76	M	MSc	NSTEMI	Atorvastatin	40	None	Complete	12
P020	55	M	BSc	STEMI	Atorvastatin	40	None	Complete	12
P021	61	F	BSc	STEMI	Atorvastatin	40	None	Complete	12
P022	66	M	Unknown	STEMI	Atorvastatin	40	Muscle Cramps	Complete	12

BSc= bachelor of science; F= female; M= male; MG= milligram; MI = myocardial infarction; MSc = master of science;

NSTEMI = non ST elevation myocardial infarction;

Test Results

Table 3 shows test results, ranked highest to lowest, with patients' ITQ and PQ scores for the intervention group. Median pre-test score was 13 out of 50 (IQR 17) points. The pre-test showed that 8 (67%) patients recalled that statins had *some* effect on cholesterol in the body, however 7 (60%) patients could not elaborate *what* the underlying mechanism was (i.e. lowering of cholesterol and reducing atherosclerosis, preventing new cardiovascular events). Median post-test score was 21 out of 50 (IQR 11) points; a median increase of 8 (IQR 8) points after three weeks (table 3). Test improvement was mainly related to an increase of understanding that statins have a lowering effect on cholesterol, positively affecting atherosclerosis in the coronary vessels and thereby preventing new cardiovascular events; 10/12 (83%) patients could explain that effect in their own words.

The control group scored a median post-test score of 6 out of 50 points (IQR 4)(table 4); the post-test showed that 8 (80%) patients recalled that statins had *some* effect on cholesterol in the body, however 8 (80%) patients could not elaborate *what* the underlying mechanism was (i.e. lowering of cholesterol and reducing atherosclerosis, preventing new cardiovascular events etc.).

Two patients had no knowledge of why they used statins. In comparison to the intervention group, the control group test score after conventional education (T=0, figure 1) was slightly lower (6 points vs 13 points, p=.02). Comparing all control-group and intervention-group patients at 1 month of follow up, median test scores were comparable (10 points vs 13 points, p=.4).

ITQ and PQ outcome

Table 3 shows ITQ and PQ outcomes. Median Immersive Tendency score was 63(IQR 26), median Presence score was 83(IQR 23). Highest ITQ scores were observed among 5 out of 6 (83%) best performing patients (highest test improvement).

Highest PQ scores were observed among 3 out of 6 (50%) best performing patients (highest test improvement). Immersive tendencies were moderately positive correlated with test improvement ($r=0.56$, $p<.05$), whereas presence was not correlated with test improvement ($r= 0.038$, $p=.4$).

Table 3. Test and questionnaire outcomes with ranks (intervention group).

Patient	Pre-test	Post-test	TI	Rank TI	ITQ	Rank ITQ	PQ	Rank PQ
P001	9	24	15	1	82	2	61	12
P003	12	26	14	2	67	6	88	4
P011	20	33	13	3.5	81	3	93	3
P012	7	20	13	3.5	84	1	80	8
P007	24	35	11	5	79	4	81	7
P009	17	26	9	6	52	10	86	5
P005	1	9	8	7.5	47	12	95	1
P004	15	23	8	7.5	56	8	70	11
P006	15	21	6	9	51	11	94	2
P008	9	12	3	10	74	5	77	9
P010	6	5	-1	11	54	9	84	6
P002	21	16	-5	12	59	7	72	10

ITQ = immersive tendencies questionnaire; PQ = presence questionnaire; TI = test improvement

Table 4. Post-test outcome (control group).

Participant	Post-test score	Months after MI
P013	6	1
P014	10	1
P015	15	1
P016	6	6
P017	6	6
P018	5	6
P019	10	12
P020	6	12
P021	12	12
P022	1	12

MI = myocardial infarction

Qualitative Outcome - User Comments on the HoloLens Application.

Forty three comments were shared. Four themes were identified through content analysis: i) general usability of the HoloLens, ii) visibility and understanding of statin function, iii) visibility of coronary atherosclerosis and iv) usability of the app in the cardiology department. Table 3 gives an overview of example excerpts.

Regarding *general HoloLens use,* 3/12 (25%) patients noted that the healthcare professional should control the app and three other commented that the added value of an MR was minimal in comparison to a video.

Statin function was overall clear to 8/12 (75%) of patients. *Atherosclerosis* was visible however underexposed in the app according to 6/12 (50%) patients; "…the narrowing of the blood vessels is clear to me and the effect of statins on it…", "…*how* atherosclerosis develops is missing from the app…" and "…you can't see the process of calcification in the vessels…".

Regarding *overall use during hospital admission*, 6/12 (50%) of patients noted that the app should be shown to patients right after myocardial infarction in the hospital; "…if I had seen this earlier I would have understood more why I was hospitalized…", "…

I think I would have understood my heart attack better if this was shown to me…" and "…a few days after treatment it would be good to see what led to the heart attack and how it could be prevented…" were typical comments. Overall, none of the intervention group patients mentioned cyber-sickness related complaints during use of the MR-application (table 3).

Table 3. Example excerpts.

Visibility and understanding statin function	"… this helps me understand what happened and what statins do…"
	"… the statin function is clear to me now…"
	"…it reaches the goal of letting me understand my medication…"
Visibility of coronary atherosclerosis	"…the diminished blood flow and stenosis can be more dramatic; this looks too 'cute'/'childish'.
	"… I want to know more about how a stenosis develops…"
	"…a text in the app saying that blood flow is diminished might be useful…"
	"… the direct effect of statins on stenosis is clear and very useful…"
	"… If I had seen this right after my infarction, it would have made understanding it much easier…"
General use of the app in the hospital	"..this is very useful in the overall outpatient care process, maybe with my own data…'
	"…I am too old for this; not for my generation…"
	"…this technology needs some practice…"
Overall usability of HoloLens technology	"…this is amazing!..."
	"…the goggles are too heavy…"
	"…the doctor should guide the patient with the model…"
Cybersickness	No complaints regarding nausea, motion sickness or loss of vision or disturbed vision were mentioned by the intervention group.

Discussion

Principal Findings

To summarize the findings of the current study, it primarily shows that after myocardial infarction, overall intervention and control group patients have limited understanding of statins. However, it shows that an MR model on statin function can be used in clinical practice: ten of twelve (83%) patients improved their statin knowledge after using the HoloLens application. Secondly, stated by patients, MR seems a feasible medium to extend the possibilities of visual education, especially during the clinical admission of myocardial infarction. This study provides insight in how a collaboration with patients leads to the development of optimized educational tools to implement in clinical practice after myocardial infarction.

Education on Statin Function and Health Behavior

Statin non-adherence is still a contemporary problem which is well illustrated in a recent randomized study by Wood et al, showing that, despite the small study sample, 50% of enrolled cardiovascular disease patients would not resume statin therapy because of experienced side effects(9).

Although patients primarily tend to discontinue statin therapy due to side effects, medical- or non- medical opinions and a lack of understanding the importance of the drug increase the problem further(33, 34). Healthcare professionals can improve statin adherence foremost by highlighting the importance of it.

The secondary preventive effect of statins after myocardial infarction is beyond dispute and stressed by all international guidelines (35, 36), still statin non-adherence is a common phenomenon in myocardial infarction patients(37, 38). A seventh of patients in our study discontinued statin therapy, which is comparable to scientific literature(38, 39).

In line with a previous study concerning patient education after myocardial infarction(25), our results identically shows that patients have minimal understanding of statins after myocardial infarction after conventional education, both in the interventional and control group. To overcome knowledge gaps, and become familiar with the disease and medication, patients rate visual aids of high importance in education after myocardial infarction(40).

The question remains if patient education improves statin adherence, as data in this matter is scarce and limited to smaller studies(11, 41). To improve statin adherence, patients' representation of the treatment should be met by the professional(42-44). When education is goal-oriented, for example promote statin adherence, adoption of new information into this behavior will be more effective. As stated by the cognitive load theory by Sweller(45),

this theory states that education becomes effective when the methods of information exchange (i.e. presentation of information) promotes low extraneous cognitive load. Conventional methods (i.e. booklets) in the outpatient setting of myocardial infarction patients create high levels of cognitive load, whereas visual methods, such as videos or the MR model, create low levels of cognitive load(45). The use of MR has been proven useful in medical education for students (18, 21) and professionals(46, 47) and it might be a feasible medium for patients as well as our study suggests. To test if this promotes long-term statin adherence, requires further study.

Future Development of MR in the Clinical Domain

The double-diamond human centered design approach used in this study is becoming more frequent in medical research(28, 29, 48). This structured method promotes scientific reasoning during the process of scientific research. Although often described in literature as a concept, studies describing development and utilization of an end-product are scarce. Our study is the first to use the double diamond approach to assess a clinical problem in myocardial infarction patients and hint at a solution with an MR device.

The majority of patients (83%) in our study improved their knowledge on statins by using the developed MR application, despite low levels of involvement and focus for digital environments. This implies that the MR app might be effective in myocardial infarction patients, regardless if a patient has a high or low tendency to become focused and immersed in digital environments. Half of participants stated they would have wanted to use this technology during the initial admission of their myocardial infarction, to understand the disease mechanisms and the long term effects of medication better.

Both findings add to the existing body of evidence that visualization might be a feasible method to educate myocardial infarction patients. Both offer insight in further development of MR technology in the clinical domain after myocardial infarction, which, to our knowledge, is not discussed in the literature so far. To develop the application further and test its clinical effectiveness, the double diamond approach can be utilized further to specify additional features. Although the technology takes some time to get adjusted to, this can be overcome by letting the physician take the lead. An MR application on a HoloLens can be shared between multiple HoloLenses, enabling a visual interactive collaboration between physician and multiple patients thus enabling group education for instance during rehabilitation. Additionally, the coupling with a desktop-version of the app could support the usability in the outpatient setting. The strength of MR technology lies in the possibility to see both physician and educational model without closing of the real world (as with Virtual Reality), thus minimizing fear of claustrophobia or simulator sickness.

Although a basic heart model was used for our prototype, visual ultrasound and angiographic data can be incorporated in the moving model, making the visualizations patient specific.

The same model can then be used to show for instance changes in left ventricular function over time or new found anomalies in the coronary anatomy after angiography. As suggested, MR promotes interactivity, irrespective of the age of the patient. A study by Rohrbach et al showed in octogenarian Alzheimer patients that a HoloLens application effectively supported activities of daily living in these patients(17). Overall, further testing and comparing this technology to contemporary educational methods such as booklets and videos, is eminent.

Limitations

There are certain limitations to our study that need to be taken into account when interpreting the results. Firstly, the assessed study group is small and only consisted of myocardial infarction patients. Unfortunately, including more patients was restricted due to the COVD-19 pandemic of 2020 and 2021. A larger study population with patients of diverse cardiovascular diseases requiring statin use, could strengthen our results further. Secondly, the majority of patients included in our study were below 65 years. Although a feasible medium in older patients, this MR app should be tested in octogenarians as well.

Thirdly, no longitudinal test scores were gathered in both control and intervention group. Fourthly, clinical end-points, such as patients' LDL value during follow-up, were measured during this study. Lastly, further *randomized* studies between conventional and novel technologies are needed to assess the added value in patient education.

Conclusion

An MR statin education application can be applied effectively in myocardial infarction patients to explain statin function and importance. The use of a MS HoloLens is feasible for this purpose, with no effect of individual immersive tendencies on the educational process observed. The present study offers insight into the direction and development of modern visual educational tools in cardiology.

References

1. Kahn T. World Health Organization - Cardiovascular Diseases: World Health Organization; 2020 [Available from: https://www.who.int/health-topics/cardiovascular-diseases/#tab=tab_1.
2. Ibanez B, James S, Agewall S, Antunes MJ, Bucciarelli-Ducci C, Bueno H, et al. 2017 ESC Guidelines for the management of acute myocardial infarction in patients presenting with ST-segment elevation: The Task Force for the management of acute myocardial infarction in patients presenting with ST-segment elevation of the European Society of Cardiology (ESC). European heart journal. 2018;39(2):119-77.
3. Sivashanmugarajah A, Fulcher J, Sullivan D, Elam M, Jenkins A, Keech A. Suggested clinical approach for the diagnosis and management of 'statin intolerance' with an emphasis on muscle-related side-effects. Internal medicine journal. 2019;49(9):1081-91.
4. Saxon DR, Eckel RH. Statin Intolerance: A Literature Review and Management Strategies. Progress in cardiovascular diseases. 2016;59(2):153-64.
5. Ibanez B, James S, Agewall S, Antunes MJ, Bucciarelli-Ducci C, Bueno H, et al. 2017 ESC Guidelines for the management of acute myocardial infarction in patients presenting with ST-segment elevation. Revista espanola de cardiologia (English ed). 2017;70(12):1082.
6. Abd TT, Jacobson TA. Statin-induced myopathy: a review and update. Expert opinion on drug safety. 2011;10(3):373-87.
7. Bellosta S, Corsini A. Statin drug interactions and related adverse reactions: an update. Expert opinion on drug safety. 2018;17(1):25-37.
8. Krüger K, Leppkes N, Gehrke-Beck S, Herrmann W, Algharably EA, Kreutz R, et al. Improving long-term adherence to statin therapy: a qualitative study of GPs' experiences in primary care. Br J Gen Pract. 2018;68(671):e401-e7.
9. Wood FA, Howard JP, Finegold JA, Nowbar AN, Thompson DM, Arnold AD, et al. N-of-1 Trial of a Statin, Placebo, or No Treatment to Assess Side Effects. The New England journal of medicine. 2020.
10. Fitzpatrick R, Davey C, Buxton MJ, Jones DR. Evaluating patient-based outcome measures for use in clinical trials. Health technology assessment (Winchester, England). 1998;2(14):i-iv, 1-74.
11. Jones AS, Ellis CJ, Nash M, Stanfield B, Broadbent E. Using Animation to Improve Recovery from Acute Coronary Syndrome: A Randomized Trial. Annals of behavioral medicine : a publication of the Society of Behavioral Medicine. 2016;50(1):108-18.
12. Williams B, Anderson AS, Barton K, McGhee J. Can theory be embedded in visual interventions to promote self-management? A proposed model and worked example. International journal of nursing studies. 2012;49(12):1598-609.
13. Devcich DA, Ellis CJ, Broadbent E, Gamble G, Petrie KJ. The psychological impact of test results following diagnostic coronary CT angiography. Health psychology : official journal of the Division of Health Psychology, American Psychological Association. 2012;31(6):738-44.

14. Perera AI, Thomas MG, Moore JO, Faasse K, Petrie KJ. Effect of a smartphone application incorporating personalized health-related imagery on adherence to antiretroviral therapy: a randomized clinical trial. AIDS patient care and STDs. 2014;28(11):579-86.
15. Kaphingst KA, Persky S, McCall C, Lachance C, Loewenstein J, Beall AC, et al. Testing the effects of educational strategies on comprehension of a genomic concept using virtual reality technology. Patient education and counseling. 2009;77(2):224-30.
16. Becker A, Herzberg D, Marsden N, Thomanek S, Jung H, Leonhardt C. A new computer-based counselling system for the promotion of physical activity in patients with chronic diseases--results from a pilot study. Patient education and counseling. 2011;83(2):195-202.
17. Rohrbach N, Gulde P, Armstrong AR, Hartig L, Abdelrazeq A, Schroder S, et al. An augmented reality approach for ADL support in Alzheimer's disease: a crossover trial. Journal of neuroengineering and rehabilitation. 2019;16(1):66.
18. Bogomolova K, van der Ham IJM, Dankbaar MEW, van den Broek WW, Hovius SER, van der Hage JA, et al. The Effect of Stereoscopic Augmented Reality Visualization on Learning Anatomy and the Modifying Effect of Visual-Spatial Abilities: A Double-Center Randomized Controlled Trial. Anatomical sciences education. 2020;13(5):558-67.
19. Biglino G, Capelli C, Wray J, Schievano S, Leaver LK, Khambadkone S, et al. 3D-manufactured patient-specific models of congenital heart defects for communication in clinical practice: feasibility and acceptability. BMJ open. 2015;5(4):e007165.
20. Wang S, Parsons M, Stone-McLean J, Rogers P, Boyd S, Hoover K, et al. Augmented Reality as a Telemedicine Platform for Remote Procedural Training. Sensors (Basel, Switzerland). 2017;17(10).
21. Bogomolova K, Hierck BP, Looijen AEM, Pilon JNM, Putter H, Wainman B, et al. Stereoscopic three-dimensional visualisation technology in anatomy learning: A meta-analysis. Medical education. 2020.
22. Bray L, Sharpe A, Gichuru P, Fortune PM, Blake L, Appleton V. The Acceptability and Impact of the Xploro Digital Therapeutic Platform to Inform and Prepare Children for Planned Procedures in a Hospital: Before and After Evaluation Study. Journal of medical Internet research. 2020;22(8):e17367.
23. Tait AR, Connally L, Doshi A, Johnson A, Skrzpek A, Grimes M, et al. Development and evaluation of an augmented reality education program for pediatric research. Journal of clinical and translational research. 2020;5(3):96-101.
24. Sezer S, Piai V, Kessels RPC, Ter Laan M. Information Recall in Pre-Operative Consultation for Glioma Surgery Using Actual Size Three-Dimensional Models. Journal of clinical medicine. 2020;9(11).
25. Hilt AD, Mamaqi Kapllani K, Hierck BP, Kemp AC, Albayrak A, Melles M, et al. Perspectives of Patients and Professionals on Information and Education After Myocardial Infarction With Insight for Mixed Reality Implementation: Cross-Sectional Interview Study. JMIR human factors. 2020;7(2):e17147.

26. Witmer BJ, Singer MJ. Measuring Presence in Virtual Environments: A Presence Questionnaire. Presence. 1998;7(3):225-40.
27. Eleven lessons: managing design in eleven globar brands - A study of the design process. London, 2005: The Design Council; 2007.
28. Ferreira FK, Song EH, Gomes H, Garcia EB, Ferreira LM. New mindset in scientific method in the health field: Design Thinking. Clinics (Sao Paulo, Brazil). 2015;70(12):770-2.
29. Melles M, Albayrak A, Goossens R. Innovating Health Care: Key Characteristics of Human-Centered Design. International journal for quality in health care : journal of the International Society for Quality in Health Care. 2020.
30. Unity - Game engine, tools and multiplatform. 2020 [Available from: https://unity.com/products.
31. Weibel D, Schmutz J, Pahud O, Wissmath B. Measuring Spatial Presence: Introducing and Validating the Pictorial Presence SAM. 2015;24(1):44-61.
32. Wissmath B, Weibel D, Schmutz J, Mast FW. Being present in more than one place at a time? Patterns of mental self-localization. Consciousness and cognition. 2011;20(4):1808-15.
33. Mauskop A, Borden WB. Predictors of statin adherence. Curr Cardiol Rep. 2011;13(6):553-8.
34. Campione JR, Sleath B, Biddle AK, Weinberger M. The influence of physicians' guideline compliance on patients' statin adherence: a retrospective cohort study. Am J Geriatr Pharmacother. 2005;3(4):229-39.
35. Kernan WN, Ovbiagele B, Black HR, Bravata DM, Chimowitz MI, Ezekowitz MD, et al. Guidelines for the prevention of stroke in patients with stroke and transient ischemic attack: a guideline for healthcare professionals from the American Heart Association/American Stroke Association. Stroke. 2014;45(7):2160-236.
36. Arnett DK, Blumenthal RS, Albert MA, Buroker AB, Goldberger ZD, Hahn EJ, et al. 2019 ACC/AHA Guideline on the Primary Prevention of Cardiovascular Disease: A Report of the American College of Cardiology/American Heart Association Task Force on Clinical Practice Guidelines. Circulation. 2019;140(11):e596-e646.
37. Hickson RP, Robinson JG, Annis IE, Killeya-Jones LA, Fang G. It's Not Too Late to Improve Statin Adherence: Association Between Changes in Statin Adherence from Before to After Acute Myocardial Infarction and All-Cause Mortality. J Am Heart Assoc. 2019;8(7):e011378.
38. Colantonio LD, Rosenson RS, Deng L, Monda KL, Dai Y, Farkouh ME, et al. Adherence to Statin Therapy Among US Adults Between 2007 and 2014. Journal of the American Heart Association. 2019;8(1):e010376.
39. Eindhoven DC, Hilt AD, Zwaan TC, Schalij MJ, Borleffs CJW. Age and gender differences in medical adherence after myocardial infarction: Women do not receive optimal treatment - The Netherlands claims database. European journal of preventive cardiology. 2018;25(2):181-9.
40. Scott JT, Thompson DR. Assessing the information needs of post-myocardial infarction patients: a systematic review. Patient education and counseling. 2003;50(2):167-77.
41. Nieuwkerk PT, Nierman MC, Vissers MN, Locadia M, Greggers-Peusch P, Knape LP, et al. Intervention to improve adherence to lipid-lowering medication and lipid-levels in patients with an increased cardiovascular risk. The American journal of cardiology. 2012;110(5):666-72.

42. O'Donovan CE, Painter L, Lowe B, Robinson H, Broadbent E. The impact of illness perceptions and disease severity on quality of life in congenital heart disease. Cardiol Young. 2016;26(1):100-9.
43. Rajpura JR, Nayak R. Role of illness perceptions and medication beliefs on medication compliance of elderly hypertensive cohorts. J Pharm Pract. 2014;27(1):19-24.
44. Hagger MS, Hardcastle SJ, Hu M, Kwok S, Lin J, Nawawi HM, et al. Effects of medication, treatment, and behavioral beliefs on intentions to take medication in patients with familial hypercholesterolemia. Atherosclerosis. 2018;277:493-501.
45. Sweller J. Cognitive Load During Problem Solving: Effects on Learning. 1988;12(2):257-85.
46. Bogomolova K, van der Ham IJM, Dankbaar MEW, van den Broek WW, Hovius SER, van der Hage JA, et al. The effect of stereoscopic Augmented Reality visualization on learning anatomy and the modifying effect of visual-spatial abilities: a double-center randomized controlled trial. Anatomical sciences education. 2019.
47. Sauer IM, Queisner M, Tang P, Moosburner S, Hoepfner O, Horner R, et al. Mixed Reality in Visceral Surgery: Development of a Suitable Workflow and Evaluation of Intraoperative Use-cases. Annals of surgery. 2017;266(5):706-12.
48. Badwan B, Bothara R, Latijnhouwers M, Smithies A, Sandars J. The importance of design thinking in medical education. Medical teacher. 2018;40(4):425-6.
49. Montalescot G, Sechtem U, Achenbach S, Andreotti F, Arden C, Budaj A, et al. 2013 ESC guidelines on the management of stable coronary artery disease: the Task Force on the management of stable coronary artery disease of the European Society of Cardiology. European heart journal. 2013;34(38):2949-3003.

VII

CHAPTER VIII

A PREOPERATIVE VIRTUAL REALITY APP FOR PATIENTS SCHEDULED FOR CARDIAC CATHETERIZATION: PRE-POST QUESTIONNAIRE STUDY EXAMINING THE FEASIBILITY, USABILITY AND ACCEPTABILITY

Jiska J. Aardoom, PhD*; Alexander D. Hilt, MD*;
Tamar Woudenberg MSc; Niels H. Chavannes, MD, PhD; Douwe E. Atsma, MD, PhD.

* Shared first authors

Published JMIR Cardio. 2022 Feb 22;6(1):e29473. doi: 10.2196/29473. PMID: 35191839;
PMCID: PMC8905473.

Abstract

Background

Pre- and post-operative anxiety is a common phenomenon and is associated with negative post-operative outcomes. Symptoms of post-traumatic stress disorder, such as fear, nightmares, and sleep deprivation, are prevalent in roughly 30-50% of patients following discharge from intensive care units after (cardiac) surgery. Preliminary evidence suggests a promising role of Virtual Reality (VR) in preventing of stress-related reactions using Stress Inoculation Training. Such training enables cognitive preparation of individuals for stressful situations, such as medical emergencies or treatments, thereby becoming more tolerant and resistant to stress, subsequently reducing the risk for potential negative psychological consequences. This study investigated a pre-operative VR-application ('Pre-View') in the context of better informing and preparing patients for cardiac catheterization.

Objective

To assess the feasibility, usability and acceptability of Pre-View in patients undergoing cardiac catheterization.

Methods

Eligible participants were adults scheduled for elective cardiac catheterization. Pre-View comprised an interactive virtual representation of the whole care process related to cardiac catheterization; from entering the hospital for admission to post-procedural stay and discharge. These processes were represented through 360° videos- and interactive photos. Self-report questionnaires were completed at baseline (i.e., pre-catheterization, after undergoing the VR-experience) and after cardiac catheterization. Outcome measures included user experience and satisfaction, VR-presence and immersive tendencies, and user-friendliness. Perceived effectiveness was exploratively assessed.

Results

Eight individuals with a mean age of 67 participated. Half of them underwent the VR-experience in the hospital, the other half at home. Participants reported high levels of presence in the virtual environment (Presence Questionnaire; M = 129.1, SD = 13.4). The usability of Pre-View was well evaluated (System Usability Score; M = 89.1, SD = 12.0), and patient satisfaction was high (Client Satisfaction Questionnaire; M = 27.1, SD = 3.2). Usability and satisfaction scores were higher for participants who underwent Pre-View at home versus those who underwent Pre-View in the hospital, although the latter group was significantly older; 72.8 versus 61.3 respectively. All participants reported Pre-View to be effective in terms of feeling better informed about the care process of cardiac catheterization.

Furthermore, most of participants (87.5%) reported Pre-View to be effective in terms of feeling better prepared for the cardiac catheterization, acknowledging the potential of Pre-View in reducing negative psychological consequences after catheterization.

Conclusions

The results provide initial support for the feasibility and acceptability of a pre-operative VR-application, creating a virtual environment that supports patient education and preparation for upcoming coronary catheterization. More studies are needed to further investigate the effects of VR as a tool to better prepare patients for medical procedures, its effectiveness in terms of reducing negative patient outcomes (e.g., anxiety, stress, post-operative recovery outcomes), and the generalizability of effects across different settings and patient populations.

Abbreviations

AAA:	Abdominal aortic aneurysm
CSQ-8:	Client satisfaction questionnaire
ITQ:	Immersive tendencies questionnaire
LUMC:	Leiden University Medical Centre
PQ:	Presence questionnaire
PTSD:	Post-traumatic stress disorder
SIT:	Stress inoculation training
SUS:	System usability scale
VR:	Virtual reality

Introduction

Coronary artery disease is one of three most common cardiovascular pathologies, playing a major role in mortality and morbidity worldwide (1). The occlusion of coronary vessels can lead to myocardial infarction and eventually death. Cardiac catheterization has evolved over many decades, decreasing the amount of deaths after acute myocardial infarction drastically as well as relieving anginal complaints in the elective setting (2). Overall, the clinical admission for such a procedure is short, however, psychological complaints regularly arise afterwards. Roughly 30 to 50% of patients has been found to suffer from depression and symptoms of Post-Traumatic Stress Disorder (PTSD), such as fear, nightmares, and sleep deprivation, following post-cardiac surgery (3-6). Such negative psychological outcomes can adversely impact patients' recovery (3, 7, 8). More specifically, studies have shown depression to be a strong risk factor for cardiac events, cardiac complications, and cardiac mortality following bypass surgery (3, 9, 10). Furthermore, lower levels of quality of life and psychological functioning in general have been demonstrated for subgroups of patients reporting symptoms of PTSD after bypass surgery (5).

Previous research has demonstrated pre-operative education to be a promising method to improve post-(cardiac)surgical outcomes, such as decreasing levels of anxiety and depression, improving recovery, and increasing patient satisfaction (11-15). Pre-operative patient education can be provided through verbal advice and written information. By informing and educating patients about the care process such as surgery- and hospital admission procedures, patients might feel more at ease and prepared for hospital admission and surgery accordingly.

The incorporation of multimedia tools has been suggested beneficial in terms of increasing patient satisfaction and perceived benefits and understanding treatments (16-18). New technology such as Virtual Reality (VR) (19) is a successful tool in the education of patients (16-18). Furthermore, VR could be used to desensitize patients for stressful events. Virtual Reality-exposure therapy is being increasingly used to treat PTSD and anxiety disorders (20-24). Furthermore, preliminary evidence suggests that VR can be successfully used to prevent stress-related reactions, such as PTSD, by means of Stress Inoculation Training (SIT). Such a training can help prepare individuals for stressful situations, such as combat or battlefield stressors, or medical emergencies or treatments, to reduce the risk for potential negative psychological consequences. When using VR during SIT, individuals can be pre-exposed to a stressor in a gradual and controlled manner. This is theorized to enable individuals to prepare themselves for the actual stressful event, thereby becoming more tolerant and resistant towards stress. Indeed, using VR in the context of SIT has for example been shown a promising approach to prepare military personnel for combat situations (25-28), enhancing resilience and potentially preventing PTSD-related symptoms.

In the current study, a VR-application ('Pre-View') was used to investigate whether VR can be a useful medium in the pre-operative management of cardiac patients undergoing elective cardiac catheterization. 'Pre-View' combines pre-operational education with virtually experiencing the care process for elective cardiac catheterization in a Dutch university medical center. By means of Pre-View, participants could virtually experience the whole process; from entering the hospital for admission until the moment of elective catheterization without showing the procedure itself, and to the post-procedural stay and discharge. The benefit of the VR-experience over written or verbal information only, is that the patient is in control of the information he or she receives. The patient decides where to look and where to go to, and the application adjusts to that correspondingly.

This increases the feeling of "being present" in the virtual environment, with presence referring to the subjective experience of being in a digital environment, while physically being in another (29). The sense and quality of this presence are considered an important factor for Virtual Reality Exposure Therapy to be effective (30). The quantification of presence can furthermore be used as an evaluative measure for the virtual experience (31).

The current pilot study aimed to assess the feasibility and acceptability of using VR-application 'Pre-View' as a medium to inform and prepare patients for their upcoming elective cardiac catheterization.

Methods

Participant Recruitment and Eligibility Criteria

Participants were recruited from the Cardiology department of the Leiden University Medical Centre (LUMC), where they were listed for elective cardiac catheterization. Patients were eligible to participate if 1) aged 18 years or older, 2) able to speak and understand the Dutch language, 3) scheduled for elective cardiac catheterization, 4) able to undergo a VR-experience, that is, not having impaired eyesight and a known history of epilepsy, and 5) not having underwent a previous cardiac catheterization. The study was approved by a local medical ethics committee of the LUMC (protocol number P19-068), and subsequently a declaration of no objection was obtained from a Medical Ethics Review Committee. Recruitment and enrollment of participants took place between January 6th and February 27th of 2020.

Procedure

Potentially eligible patients (i.e., aged 18 years or older and not having underwent previous cardiac catheterization) were approached and informed by e-mail and/or telephone by a research intern (author TW). When interested, patients received written information about the study and provided informed consent accordingly. Subsequently, the VR-experience was planned one or two weeks prior to the scheduled elective cardiac catheterization. Participants could choose to either undergo the VR-experience at home or in the hospital. In the hospital, participants were welcomed at the outpatient clinic for heart diseases in the LUMC. When participants chose to undergo the experience at home, the research assistant would visit the patient at home. Other than the location, the process of undergoing the VR-experience was identical. Patients were informed on how to use the VR-application, whereafter they could independently undergo the experience. The research assistant was present to assist in case of any technical difficulties. Directly after completion of the VR-experience, participants were asked to fill out a set of paper questionnaires assessing socio-demographic characteristics (i.e., age, gender), presence, immersive tendencies, and questions related to satisfaction and usability (for more details, see 'measures'). Patients' perceived effectiveness of Pre-View was assessed by means of a telephone call after the cardiac catheterization to enable patients to reflect on whether and how Pre-View may have supported them during the process of preparation for the surgery, as well as during and after the catheterization.

VR-experience 'Pre-View'

Patients underwent the VR-experience via a head-mounted display: the Oculus Rift Go™ device (figure 1). The headset was individually adjustable, even for participants wearing glasses. Within the VR-environment, patients were provided with an interactive representation of the whole care process related to the cardiac catheterization; they could experience, in general, the day of the heart catheterization. This encompassed the patient journey from entering the hospital for admission, to post-procedural stay. The procedure of the heart catheterization itself was not presented. However related processes were; patients were virtually being transferred in a hospital bed with wheels to the operating room, where the cardiologist would shortly explain the procedure. The experience was represented through both video and interactive photos, which had been captured and recorded during the development process of the VR-application. Topics like "What will happen on the ward? What clothing do I need? Which people are allowed to stay?", as well as topics like "What medication is given after the procedure?", "Can I eat before the surgery?" were addressed during the experience. The experience was fully interactive ; patients could to choose select objects or persons (e.g., nurse, cardiologist) to gain more information on relevant topics related to the care process at every stage of the stay. In order to do so, patients simply had to gaze a few seconds at the object or person to select it. Hence, there was no need to press a button on a controller physically.

For example, patients could gaze at the personnel around them when virtually lying in the hospital bed, after which an explanation would be given about the type of personnel (e.g., nurse, cardiologist) and what their role during the stay or catheterization would be (e.g., to perform the procedure, to assist, etc.).

Figure 1. Occulus Rift Go™ device.

Further interaction took place through short quizzes, for example, choosing the right floor in the virtual elevator when patients' need to find their way through the hospital towards the cardiology. A detailed overview of the total experience is presented in Table 1. An example of a 360° photo can be found in Multimedia Appendix 1. All shown images and videos were context-specific, meaning that they were captured and recorded in the LUMC, with actual LUMC-staff in order to enhance feelings of relevance and realism. The VR-experience took approximately 20 minutes, depending on the time a patient spend in each module.

Measures

Presence

Participants' degree of presence and immersion in the virtual environment was assessed with the Presence Questionnaire (PQ) (29). The PQ quantifies the amount of focus a person experiences on objects or tasks generated by a digital application, in this case the VR-application. The PQ is the most prevalent used questionnaire to measure presence (32). It was developed based on factors widely believed to underlie presence, and was found to be highly reliable and internally consistent with the ITQ (see next paragraph) (29). It consists of 22 questions covering different elements relating to the level of presence, such as the degree of realism and immersion, the degree of involvement, how compelling the sense of moving around was inside the virtual environment, and the degree of control over the virtual environment. All questions are answered on 7-point Likert scales, with answers ranging from 'not at all' till 'completely'. Total scores can vary between 22 and 154.

Immersive Tendencies

Immersion refers to a state in which an individual experiences an environment as an integral part of it, thus being enveloped in it and interacting with it naturally. Immersive tendencies relate to the tendencies to get immersed or involved easily in virtual or 'make-believe' situations, quantifying a person's tendency to become immersed and focused in digital environments.

In the current study, the Immersive Tendencies Questionnaire (ITQ) was used to quantify participants' immersive tendencies (29). The ITQ consists of 18 questions, mostly assessing the degree of involvement and focus in common activities ('Do you ever become so involved in a movie that you are not aware of things happening around you?', or 'When playing sports, do you become so involved in the game that you lose track of time?'). Answers were rated on a 7-point Likert scale ranging from 'never/not very well' to 'always/very well'. Higher cumulative scores (range total score 18 and 126) represented a higher immersive tendency to get immersed or involved easily in the virtual situation.

Table 1. Overview of the virtual reality (VR) experience.

Virtual locations	Means[a]	Description
Part 1: Hospital admission		
- Hospital entrance	P, I, A	The hospital's main entrance is shown and the main menu and gaze-function of the VR-experience are explained.
- Route to elevators	P, I, A	The hospital's main hall is shown with the route to the hospital elevators being explained.
- Elevator entrance & ride	P, I, A	The elevator entrance is shown and the choice of floor leading to the nursing ward is explained.
- Entrance cardiology ward	P, I, A	The entrance of the cardiology ward is shown.
Part 2: Admission to cardiology ward, pre-catheterization		
- Cardiology ward counter	V	The user virtually walks towards the counter of the cardiology ward, where the desk clerk welcomes him/her. The desk clerk asks for a hospital card and personal identification. Hereafter, the user walks towards the entrance of the patient room.
- Patient-room: photo	P, A, I	An interactive photo of the patient room is shown. Users need to collect items they will need to bring to the hospital (e.g., clothing, phone-charger). After all items are found, the user is placed in a hospital bed.
- Patient-room: videos	V	Two short videos are shown of a nurse and physician respectively, explaining the upcoming procedures.
- Transfer to operating room	V	The user is virtually being transferred in a hospital bed with wheels from the cardiology nursing ward to the operating room.
Part 3: Operating room		
- Operating room	P, V, I	A photo is shown of the interior of the operating room containing explanations of specific devices (e.g., radiology equipment). After this exploration the patient can start a video of the scrub-nurse and attending interventional cardiologist. They explain the upcoming procedure in general, including what they will do during the procedure and what is to be expected of the procedure (e.g., duration).
Part 4: Post-catheterization at the cardiology nursing ward		
- Patient-room: inside hospital bed	V, P	A video is shown where the nurse and physician explain important aftercare issues and procedures. When the video is finished, the user can freely look around in the room and choose to be discharged when finished.
Discharge		
- Exit cardiology ward	V, P	A short exit-video shows all personnel and wishes the patient the best of luck and a healthy recovery. Hereafter, the VR-experience is finished and the user is placed outside in front of the hospital.

VR = Virtual reality

[a] P = Photo, I = Interactive feature, A = Audio, V = Video

Satisfaction

Patient satisfaction was assessed by the Client Satisfaction Questionnaire (CSQ-8) (33). The CSQ-8 is a short 8-item standardized global satisfaction measure, and each of items can be scored on a scale from 1 to 4, with total scores ranging from 8 to 32. Mean satisfaction levels were computed for each individual. The CSQ-8 is widely used across healthcare studies with good reliability and validity (34, 35).

Several questions were asked to further assess satisfaction levels. First, participants were asked to rate their satisfaction with Pre-View on a scale of 1 (extremely dissatisfied) to 10 (extremely satisfied), and to shortly summarize and clarify their score subsequently. Second, participants were asked to what extent Pre-View met their need in terms of received information on a 5-point Likert scale (1 'definitely not' to 5 'definitely'), and to shortly summarize and clarify their score subsequently. Third, participants were asked whether they experienced any discomfort or side-effects when undergoing the VR experience (yes/no), and if yes, to shortly elaborate on these.

Usability

In order to assess the usability of Pre-View, participants were asked to complete the System Usability Scale (SUS) (36). The SUS provides a quick and reliable tool for measuring the usability of a wide variety of products and services. It comprises a 10-item questionnaire with 5-point Likert scales ranging from 'strongly agree' to 'strongly disagree'. Total SUS scores can range from 0 to 100. The SUS is reliable and robust tool in assessing usability (37).

Perceived Effectiveness

Participants were asked to what extent they agreed with several statements assessing their perceived effectiveness of Pre-View in terms of 1) feeling better informed about the care process of cardiac catheterization, 2) feeling better prepared for the care process of cardiac catheterization, and 3) reduction or prevention of potential negative psychological consequences (e.g., nightmares, anxiety, symptoms of depression) after cardiac catheterization. Answer scales ranged from 1 'totally do not agree' to 5 'totally agree'.

Statistical Analysis

All data was processed by means of SPSS™ version 25. Descriptive analyses (i.e., means, standard deviations, frequencies, percentages) were used to describe the socio-demographic characteristics of participants of the study population, as well as to summarize the questionnaire data in terms of the measures described in the section 'measures'.

Results

Study Population

A total of 27 patients were approached to participate in this study, of whom twelve patients were interested to participate. One patient dropped out of the study before undergoing the Pre-View due to a fear of motion sickness symptoms. Furthermore, three patients were not included in the study because of cancellation of the VR-appointment due to the start of the Covid-19 pandemic and preventative measures which forced an early termination of study enrollment. This resulted in a total of eight patients participating in the current pilot study. Socio-demographic characters of the study population can be found in Table 2. The average age of the study population was 67 years, including six males and two females. Half of the participants chose to undergo the VR experience in the hospital, the other half at home.

Presence and Immersive Tendencies

Patients reported high levels of presence in the virtual environment with an average PQ-score of approximately 129 (Table 2). At an individual item level, items that were scored lowest related to how much one was able to control events (*M* = 4.3), the extent to which the visual display quality interfered or distracted one from performing assigned tasks or required activities (*M* = 4.6), and how much delay one experienced between their actions and expected outcomes (*M* = 4.9). Items that were scored highest related to how well one could concentrate on the assigned tasks or required activities rather than on the mechanisms used to perform those tasks or activities (*M* 6.8), how involved one was in the virtual environment experience (*M* = 6.5), how well one could actively survey or search the virtual environment (*M* = 6.5).

Regarding immersive tendencies, participants showed a mean score of approximately 76, indicative of above-average tendency to get immersed or involved in virtual or 'make-believe' situations. Higher levels of immersive tendencies and presence were found for those who underwent the VR experience at home (PQ *M* = 139.8, ITQ *M* = 80.8) in comparison to those who underwent it at the hospital (PQ *M* = 118.5, and ITQ *M* = 53.8), although patients in the hospital-group were on average roughly ten years older in comparison the home-group; 73 versus 61 respectively.

Satisfaction and Usability

As shown in Table 2, the usability of the Pre-View application was well evaluated by all participants with a SUS mean score of approximately 89 on a scale of 0 to 100. Patient satisfaction as assessed by the CSQ-8 was high, with an average score of approximately 27 on a scale of 8 to 32. The results of the additional assessment of participants' satisfaction are shown in Table 3.

Table 2. Socio-demographic characteristics of the study population, as well as outcome descriptives.

Gender	Age	Location	PQ	ITQ	CSQ-8	SUS
Individual participants						
Male	73	Hospital	115.0	42.0	21.0	70.0
Male	77	Hospital	114.0	52.0	27.0	72.5
Female	73	Hospital	129.0	70.0	29.0	87.5
Male	68	Hospital	137.0	67.0	24.0	90.0
Male	60	Home	116.0	51.0	28.0	92.5
Male	69	Home	130.0	105.0	28.0	100.0
Female	59	Home	142.0	69.0	31.0	100.0
Male	57	Home	150.0	82.0	29.0	100.0
Total study population[a]						
Male 6 (75)	67.0 (7.5)	Hospital: 4 (50)	129.1 (13.4)	76.3 (20.0)	27.1 (3.2)	89.1 (12.0)
Female 2 (25)		Home: 4 (50)				

PQ = Presence Questionnaire; ITQ = Immersive Tendencies Questionnaire; CSQ-8 = Client Satisfaction Questionnaire – 8; SUS = System Usability Score

[a] As provided in means (*SD*) and *N* (%) where appropriate.

These results demonstrated acceptable to good satisfaction with Pre-View. Positive remarks were mostly about the clear explanation and visualization of the procedure day. One patient elaborated on his score of 6 on the item 'Overall, how satisfied are you with Pre-View?' (Table 3); he was not able to see all of the videos during the experience because of a technical error resulting in a black screen.

Also, there were two remarks identifying targets for improvements. One patient indicated having missed seeing the actual catheterization. Another patient indicated that the cardiologist in the VR-experience could perhaps be a little more elaborate about the diversity of complaints that one could experience, as now only chest pain was stated as the reason for visiting the cardiologist. Finally, none of the participants reported side-effects during or after the VR-experience.

Table 3. Result in terms of satisfaction and perceived effectiveness of the VR-application.

	Answer scale	*N* (%)	Mean (*SD*)
Satisfaction items			
Overall, how satisfied are you with Pre-View?	1 = extremely dissatisfied	0 (0.0)	8.6 (1.3)
	2	0 (0.0)	
	3	0 (0.0)	
	4	0 (0.0)	
	5	0 (0.0)	
	6	1 (12.5)	
	7	0 (0.0)	
	8	2 (25.0)	
	9	3 (37.5)	
	10 = extremely satisfied	2 (25.0)	
To what extent did Pre-View fulfill your need in terms of information received prior to the cardiac catheterization?	1 = Not at all	0 (0.0)	4.5 (0.5)
	2 = Not really	0 (0.0)	
	3 = Neutral / Do not know	0 (0.0)	
	4 = Fairly well	4 (50.0)	
	5 = Really well	4 (50.0)	
Have any side effects occurred while undergoing Pre-View (e.g., nausea, dizziness, headache, etc.)?	1 = Yes	0 (0.0)	2 (0.0)
	2 = No	8 (100.0)	
Perceived effectiveness items			
Pre-View was effective in terms of feeling better informed about the cardiac catheterization care process	1 = Totally disagree	0 (0.0)	4.5 (0.5)
	2 = Disagree	0 (0.0)	
	3 = Neutral / Do not know	0 (0.0)	
	4 = Agree	4 (50.0)	
	5 = Totally agree	4 (50.0)	
Pre-View was effective in terms of feeling better prepared for the care process of cardiac catheterization	1 = Totally disagree	0 (0.0)	4.3 (0.7)
	2 = Disagree	0 (0.0)	
	3 = Neutral / Do not know	1 (12.5)	
	4 = Agree	4 (50.0)	
	5 = Totally agree	3 (37.5)	
Pre-View was effective, or could potentially be effective, in terms of reducing or preventing negative psychological consequences (e.g., anxiety, nightmares, symptoms of depression) after cardiac catheterization	1 = Totally disagree	0 (0.0)	4.0 (0.9)
	2 = Disagree	0 (0.0)	
	3 = Neutral / Do not know	1 (12.5)	
	4 = Agree	5 (62.5)	
	5 = Totally agree	2 (25.0)	

When looking at usability and satisfaction scores separately for the patients who underwent Pre-View at home versus those who underwent Pre-View in the hospital, both scores were higher for the former group: 98 versus 80 regarding usability scores, and 29 versus 25 regarding acceptability scores. These subgroups differed however not only in terms of where they underwent the VR-experience, but also in terms of age; those who underwent Pre-View in the hospital showed a higher mean age (M = 72.8, SD = 3.7) in comparison to those who underwent it at home (M = 61.3, SD = 5.3).

Perceived Effectiveness

As presented in Table 3, all patients agreed that Pre-View was effective in terms of feeling better informed about the care process of cardiac catheterization; half of the participants 'totally agreed' with this statement, and the other half 'agreed'. Furthermore, seven out of eight patients agreed or totally agreed with the statement that Pre-View was effective in terms of feeling better prepared for the care process of cardiac catheterization. Two patients who agreed elaborated: '*If you know what is going to happen, you experience less stress'*, and *'The more you know, the better'*. Finally, when asked whether Pre-View has been effective, or could potentially be effective, in terms of reducing or preventing negative psychological consequences after cardiac catheterization, two participants 'totally agreed', five participants 'agreed', and one participants 'disagreed'. The patient who disagreed elaborated '*Even though you are better prepared for what is going to happen, you still don't know exactly what they are doing during the procedure. Nor does it completely take away the anxiety about what they will find, which so there is always some uncertainty'*. Another patient who agreed also specifically remarked that even though he felt better informed and prepared, he still indicated to feel somewhat anxious and stressed before the hospital admission for his cardiac catheterization.

Discussion

The current pilot study investigated the feasibility, usability, and acceptability of a pre-operative VR-application ('Pre-View') in the context of better informing and preparing patients for cardiac catheterization. Its feasibility was demonstrated by participants reporting high levels of presence in the virtual environment, and the VR-experience being well tolerated without experiencing any side effects. Results furthermore indicated good user satisfaction and system usability. Finally, the majority of participants self-reported Pre-View to have been effective in terms of feeling better informed, feeling better prepared for the cardiac catheterization care process, and in terms of its potential to reduce or prevent negative psychological consequences after cardiac catheterization.

The current study results are promising in terms of feeling better informed about the hospital stay and corresponding elective cardiac catheterization. This is in line with previous literature suggesting that the incorporation of multimedia tools is beneficial in terms of perceived benefits and understanding of upcoming treatment(s) (16-18). Our results also adds to the body of literature underscoring the usefulness of VR as an engaging tool for patient education. For example the results of a study by Pandrangi et al. (38), showing that a VR-experience modeling an abdominal aortic aneurysm (AAA) for patients diagnosed with AAA, was perceived as beneficial in better understanding their health status and feeling more engaged in their healthcare. Another study demonstrated that patient education using a VR-training on radiotherapy increased knowledge and positive experiences of undergoing radiation therapy for breast cancer patients (39). Hence, the results of this pilot study underscore not only the acceptability and usability of using VR as a patient educational tool, but furthermore highlight the potential of using VR as a means to better inform patients on upcoming, stressful treatment processes.

The preliminary results of the current study suggests Pre-View to be potentially effective in preventing or reducing of potential negative psychological consequences after surgery, which is compatible with the existing theory and body of literature indicating the potency of using VR-technology as a means to desensitize individuals for stressful future events such as combat situations, thereby supporting resilience and prevention of negative psychological symptoms (25-28). Related to hospital settings and surgery specially, there is scarce research investigating the effects of pre-operative VR applications on patient outcomes. A single-blinded randomized controlled trial by Eijlers et al. (40) investigated the effects of a child friendly VR-exposure to the operating theatre on the day of children's' surgery, aiming to get them familiarized with the upcoming medical procedures (e.g., anesthesia procedures, transfer to operating room) and corresponding environment. The VR-exposure was not found to beneficially impact on anxiety levels during anesthesia and post-surgery, nor on levels of post-operative pain and emergence deliriums. Nevertheless, a subgroup of children who underwent the more painful surgeries (i.e., adenoidectomy and tonsillectomy) were significantly less often in need of rescue analgesia when having received the VR-exposure in comparison to those who had not. Another randomized controlled trial investigated the effects of a pre-operative VR experience in patients undergoing cranial and spinal operations (41). In comparison to usual pre-operative procedures, the VR experience was found to lead to higher patient satisfaction, as well better preparedness and lower levels of stress on the day of the surgery. Thus, based on the results of our pilot study and the limited available research as discussed above, VR seems to be an acceptable and feasible pre-operative preparation tool to use in hospital settings before medical procedures. However, further research is needed to establish its effects in terms of both physical and psychological outcomes.

Future studies could furthermore explore the effects of using pre-operative VR experiences across different contexts (e.g., type of medical procedures in different types of illnesses), and different patient demographics (e.g., age, immersive tendencies, psychological wellbeing status). Additionally, the role of presence on patients' satisfaction and outcomes may be an interesting direction for future research; is presence a necessary pre-condition or moderator of patient satisfaction and outcomes in the context of pre-operative VR interventions? Not feeling 'present' in the virtual environment has found to be associated with higher levels of drop-out in VR treatment for anxiety disorders, however the same review did not find an effect of the degree of presence on patient outcomes (30). A final interesting direction for future research is to investigate whether pre-operative VR interventions can be effectively delivered via smartphones. In the literature the feasibility of smartphone-based delivery of VR has already been demonstrated for various goals. Google's 'Cardboard' platform has for example been successfully used to deliver VR experiences for educational purposes (42) as well as in the context of a smoking cessation program (43). The Google Cardboard is a fold-out cardboard viewer that provides the structure for Head Mounted Display while the display is provided by a smartphone that can be placed inside the cardboard viewer. Such smartphone-based delivery of VR-experiences is of interest and relevance in light of its possibility for less costly and timely VR-experiences, thereby enabling more easy and broad-scale implementation as individuals would be enabled to start and walk through the experience whenever and wherever they chose or prefer to.

Limitations

The results of this pilot study should be interpreted in light of several limitations. The study sample was rather small. Due to the Covid-19 pandemic, appointments with included patients were cancelled, and elective surgeries including cardiac catheterization, were at the time of study recruitment postponed until further notice by the hospital. This led to a premature ending of patient inclusion. The study was designed to assess the feasibility, usability and acceptability of the pre-operative VR-experience. Hence, no definitive statements can be made about the effectiveness of the VR-experience in better informing and preparing patients for their upcoming hospital admission and corresponding procedures, or in reducing negative psychological consequences afterwards.

Conclusion

The current results provide initial support for the feasibility and acceptability of a pre-operative Virtual Reality application, creating a virtual experience that can support patient education and preparation for upcoming coronary catheterization. Further studies are needed to investigate the effects of VR as a tool to better prepare patients for medical procedures, its effectiveness in terms of reducing negative patient outcomes after such procedures, and its effects across different settings and patient populations.

Acknowledgements

The authors would like to acknowledge Andy Jansen, founder of Pre-View, for the provision of equipment (i.e., VR-devices and experience) and for developing the VR-experience in collaboration with the company Dutch VR. We would also like to thank all hospital and medical staff for their cooperation in developing the VR-experience, and all involved patients for participating in this study. Finally, we would like to thank Marjolein Elderhorst for her support regarding the design and content of the VR-experience.

Conflicts of Interest

None.

References

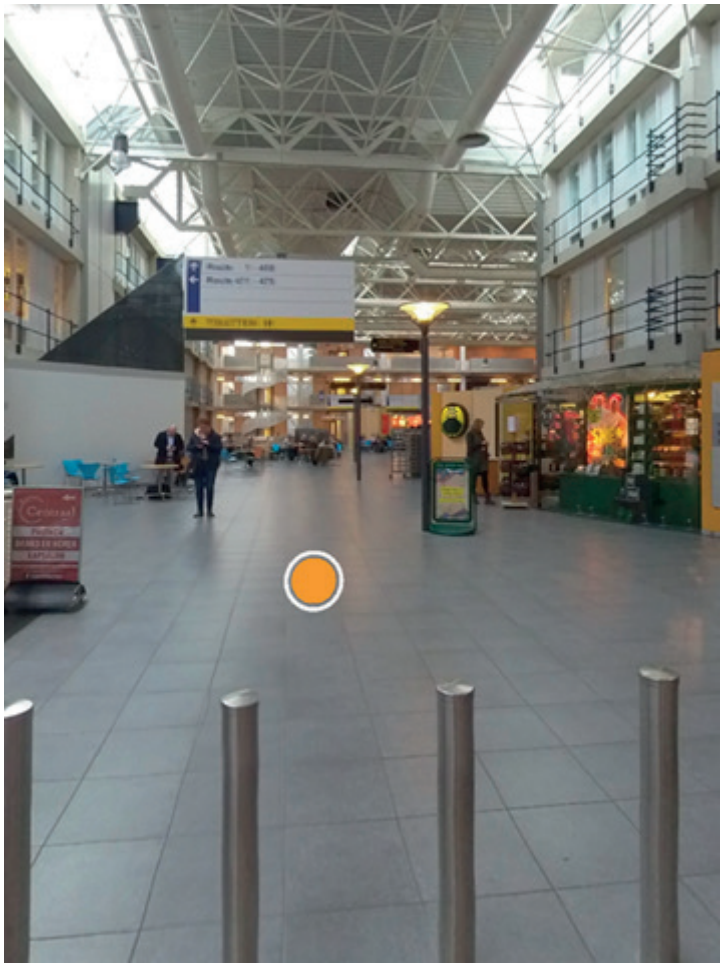
1. World Health Organization. 2017; Available from: https://www.who.int/news-room/fact-sheets/detail/cardiovascular-diseases-(cvds).
2. Nabel EG, Braunwald E. A Tale of Coronary Artery Disease and Myocardial Infarction. New England Journal of Medicine. 2012 2012/01/05;366(1):54-63. doi: 10.1056/NEJMra1112570.
3. Tully PJ, Baker RA. Depression, anxiety, and cardiac morbidity outcomes after coronary artery bypass surgery: A contemporary and practical review. Journal of geriatric cardiology : JGC. 2012 Jun;9(2):197-208. PMID: 22916068. doi: 10.3724/sp.j.1263.2011.12221.
4. Connolly D, McClowry S, Hayman L, Mahony L, Artman M. Posttraumatic stress disorder in children after cardiac surgery. The Journal of Pediatrics. 2004 2004/04/01/;144(4):480-4. doi: /10.1016/j.jpeds.2003.12.048.
5. Stoll C, Schelling G, Goetz AE, Kilger E, Bayer A, Kapfhammer H-P, et al. Health-related quality of life and post-traumatic stress disorder in patients after cardiac surgery and intensive care treatment. The Journal of thoracic and cardiovascular surgery. 2000 2000/09/01/;120(3):505-12. doi: /10.1067/mtc.2000.108162.
6. Gallo LC, Malek MJ, Gilbertson AD, Moore JL. Perceived cognitive function and emotional distress following coronary artery bypass surgery. Journal of behavioral medicine. 2005 Oct;28(5):433-42. PMID: 16179981. doi: 10.1007/s10865-005-9010-y.
7. Rosenberger PH, Jokl P, Ickovics J. Psychosocial factors and surgical outcomes: An evidence-based literature review. The Journal of the American Academy of Orthopaedic Surgeons. 2006 Jul;14(7):397-405. PMID: 16822887.
8. Schelling G, Richter M, Roozendaal B, Rothenhausler HB, Krauseneck T, Stoll C, et al. Exposure to high stress in the intensive care unit may have negative effects on health-related quality-of-life outcomes after cardiac surgery. Critical care medicine. 2003 Jul;31(7):1971-80. PMID: 12847391. doi: 10.1097/01.ccm.0000069512.10544.40.
9. Connerney I, Sloan RP, Shapiro PA, Bagiella E, Seckman C. Depression is associated with increased mortality 10 years after coronary artery bypass surgery. Psychosomatic medicine. 2010 Nov;72(9):874-81. PMID: 20841558. doi: 10.1097/PSY.0b013e3181f65fc1.
10. Peterson JC, Charlson ME, Williams-Russo P, Krieger KH, Pirraglia PA, Meyers BS, et al. New postoperative depressive symptoms and long-term cardiac outcomes after coronary artery bypass surgery. Am J Geriatr Psychiatry. 2002 Mar-Apr;10(2):192-8. PMID: 11925280.
11. Asilioglu K, Celik S. The effect of preoperative education on anxiety of open cardiac surgery patients. Patient education and counseling. 2004 Apr;53(1):65-70. PMID: 15062906. doi: 10.1016/s0738-3991(03)00117-4.
12. Ramesh C, Nayak BS, Pai VB, Patil NT, George A, George LS, et al. Effect of Preoperative Education on Postoperative Outcomes Among Patients Undergoing Cardiac Surgery: A Systematic Review and Meta-Analysis. Journal of PeriAnesthesia Nursing. 2017 2017/12/01/;32(6):518-29.e2. doi: /10.1016/j.jopan.2016.11.011.

13. Guo P, East L, Arthur A. A preoperative education intervention to reduce anxiety and improve recovery among Chinese cardiac patients: a randomized controlled trial. International journal of nursing studies. 2012 Feb;49(2):129-37. PMID: 21943828. doi: 10.1016/j.ijnurstu.2011.08.008.
14. Johansson K, Nuutila L, Virtanen H, Katajisto J, Salantera S. Preoperative education for orthopaedic patients: systematic review. J Adv Nurs. 2005 Apr;50(2):212-23. PMID: 15788086. doi: 10.1111/j.1365-2648.2005.03381.x.
15. Ronco M, Iona L, Fabbro C, Bulfone G, Palese A. Patient education outcomes in surgery: a systematic review from 2004 to 2010. International journal of evidence-based healthcare. 2012 Dec;10(4):309-23. PMID: 23173656. doi: 10.1111/j.1744-1609.2012.00286.x.
16. Huber J, Ihrig A, Yass M, Bruckner T, Peters T, Huber CG, et al. Multimedia Support for Improving Preoperative Patient Education: A Randomized Controlled Trial Using the Example of Radical Prostatectomy. Annals of Surgical Oncology. 2013 2013/01/01;20(1):15-23. doi: 10.1245/s10434-012-2536-7.
17. Gautschi OP, Stienen MN, Hermann C, Cadosch D, Fournier JY, Hildebrandt G. Web-based audiovisual patient information system--a study of preoperative patient information in a neurosurgical department. Acta Neurochir (Wien). 2010 Aug;152(8):1337-41. PMID: 20419459. doi: 10.1007/s00701-010-0663-0.
18. Sørlie T, Busund R, Sexton J, Sexton H, Sørlie D. Video information combined with individualized information sessions: Effects upon emotional well-being following coronary artery bypass surgery—A randomized trial. Patient education and counseling. 2007 2007/02/01/;65(2):180-8. doi: /10.1016/j.pec.2006.07.006.
19. Ibanez B, James S, Agewall S, Antunes MJ, Bucciarelli-Ducci C, Bueno H, et al. 2017 ESC Guidelines for the management of acute myocardial infarction in patients presenting with ST-segment elevation: The Task Force for the management of acute myocardial infarction in patients presenting with ST-segment elevation of the European Society of Cardiology (ESC). European heart journal. 2018 Jan 7;39(2):119-77. PMID: 28886621. doi: 10.1093/eurheartj/ehx393.
20. Botella C, Fernández-Álvarez J, Guillén V, García-Palacios A, Baños R. Recent Progress in Virtual Reality Exposure Therapy for Phobias: A Systematic Review. Current psychiatry reports. 2017 2017/05/24;19(7):42. doi: 10.1007/s11920-017-0788-4.
21. Gerardi M, Cukor J, Difede J, Rizzo A, Rothbaum BO. Virtual reality exposure therapy for post-traumatic stress disorder and other anxiety disorders. Current psychiatry reports. 2010 Aug;12(4):298-305. PMID: 20535592. doi: 10.1007/s11920-010-0128-4.
22. Goncalves R, Pedrozo AL, Coutinho ES, Figueira I, Ventura P. Efficacy of virtual reality exposure therapy in the treatment of PTSD: A systematic review. PLoS One. 2012;7(12):e48469. PMID: 23300515. doi: 10.1371/journal.pone.0048469.
23. Meyerbroker K, Emmelkamp PM. Virtual reality exposure therapy in anxiety disorders: A systematic review of process-and-outcome studies. Depression and anxiety. 2010 Oct;27(10):933-44. PMID: 20734361. doi: 10.1002/da.20734.

24. Parsons TD, Rizzo AA. Affective outcomes of virtual reality exposure therapy for anxiety and specific phobias: A meta-analysis. Journal of behavior therapy and experimental psychiatry. 2008 Sep;39(3):250-61. PMID: 17720136. doi: 10.1016/j.jbtep.2007.07.007.
25. Hourani L, Kizakevich P, Hubal R, Spira J, Strange L, Holiday D, et al. Predeployment stress inoculation training for primary prevention of combat-related stress disorders. Journal of Cyber Therapy and Rehabilitation. 2011;4(1):101-17.
26. Rizzo A, Shilling R. Clinical Virtual Reality tools to advance the prevention, assessment, and treatment of PTSD. European journal of psychotraumatology. 2017;8(sup5):1414560. PMID: 29372007. doi: 10.1080/20008198.2017.1414560.
27. Stetz MC, Thomas ML, Russo MB, Stetz TA, Wildzunas RM, McDonald JJ, et al. Stress, mental health, and cognition: A brief review of relationships and countermeasures. Aviation, space, and environmental medicine. 2007 May;78(5 Suppl):B252-60. PMID: 17547326.
28. Wiederhold BK, Wiederhold MD. Virtual reality for posttraumatic stress disorder and stress inoculation training. Journal of Cybertherapy and Rehabilitation. 2008;1(1):23-35.
29. Witmer BG, Singer MJ. Measuring Presence in Virtual Environments: A Presence Questionnaire. Presence: Teleoperators and Virtual Environments. 1998 1998/06/01;7(3):225-40. doi: 10.1162/105474698565686.
30. Krijn M, Emmelkamp PMG, Olafsson RP, Biemond R. Virtual reality exposure therapy of anxiety disorders: A review. Clinical psychology review. 2004 2004/07/01/;24(3):259-81. doi: /10.1016/j.cpr.2004.04.001.
31. Wiederhold BK, Wiederhold MD. The Effect of Presence on Virtual Reality Treatment. Virtual reality therapy for anxiety disorders: Advances in evaluation and treatment. Washington, DC, US: American Psychological Association; 2005. p. 77-86.
32. Grassini S, Lauman K. Questionnaire Measures and Physiological Correlates of Presence: A Systematic Review. Frontiers in Psychology. 2020;11:349. Doi: 10.3389/fpsyg.2020.00349.
33. Larsen DL, Attkisson CC, Hargreaves WA, Nguyen TD. Assessment of client/patient satisfaction: Development of a general scale. Evaluation and Program Planning. 1979 1979/01/01/;2(3):197-207. doi: /10.1016/0149-7189(79)90094-6.
34. Attkisson CC, Zwick R. The client satisfaction questionnaire. Psychometric properties and correlations with service utilization and psychotherapy outcome. Eval Program Plann. 1982;5(3):233-7. PMID: 10259963.
35. De Wilde EF, Hendriks VM. The Client Satisfaction Questionnaire: Psychometric properties in a Dutch addict population. European addiction research. 2005;11(4):157-62. PMID: 16110221. doi: 10.1159/000086396.
36. Brooke J. SUS: A “quick and dirty” usability scale. In: in P. W. Jordan BT, B. A. Weerdmeester, & A. L. McClelland, editor. Usability Evaluation in Industry. London: Taylor and Francis; 1986. p. 189–94.
37. Bangor A, Kortum PT, Miller JT. An Empirical Evaluation of the System Usability Scale. International Journal of Human–Computer Interaction. 2008 2008/07/29;24(6):574-94. doi: 10.1080/10447310802205776.

38. Pandrangi VC, Gaston B, Appelbaum NP, Albuquerque FC, Levy MM, Larson RA. The Application of Virtual Reality in Patient Education. Annals of Vascular Surgery. 2019 2019/08/01/;59:184-9. doi: /10.1016/j.avsg.2019.01.015.
39. Jimenez YA, Cumming S, Wang W, Stuart K, Thwaites DI, Lewis SJ. Patient education using virtual reality increases knowledge and positive experience for breast cancer patients undergoing radiation therapy. Supportive Care in Cancer. 2018 2018/08/01;26(8):2879-88. doi: 10.1007/s00520-018-4114-4.
40. Eijlers R, Dierckx B, Staals LM, Berghmans JM, van der Schroeff MP, Strabbing EM, et al. Virtual reality exposure before elective day care surgery to reduce anxiety and pain in children: A randomised controlled trial. Eur J Anaesthesiol. 2019;36(10):728-37. PMID: 31356373. doi: 10.1097/EJA.0000000000001059.
41. Bekelis K, Calnan D, Simmons N, MacKenzie TA, Kakoulides G. Effect of an Immersive Preoperative Virtual Reality Experience on Patient Reported Outcomes: A Randomized Controlled Trial. Annals of surgery. 2017;265(6).
42. Ray AB, Deb S, editors. Smartphone Based Virtual Reality Systems in Classroom Teaching — A Study on the Effects of Learning Outcome. 2016 IEEE Eighth International Conference on Technology for Education (T4E); 2016 2-4 Dec. 2016.
43. Goldenhersch E, Thrul J, Ungaretti J, Rosencovich N, Waitman C, Ceberio MR. Virtual Reality Smartphone-Based Intervention for Smoking Cessation: Pilot Randomized Controlled Trial on Initial Clinical Efficacy and Adherence. J Med Internet Res. 2020 2020/7/29;22(7):e17571. doi: 10.2196/17571.

Multimedia Appendix 1



CHAPTER IX

SUMMARY, CONCLUDING REMARKS AND FUTURE PERSPECTIVES

In this thesis, two research methods are used to systematically evaluate patterns of national and local cardiovascular care to improve it further. The introduction (**chapter I**) describes the general outline of the thesis. A definition of evidence based cardiovascular medicine and its value as seen by the professional, is discussed. Value Based Healthcare research, which prioritizes the *patient* perspective of value and outcome, is offered as a valuable addition to improve clinical care. In line with this, a systematic approach to evaluate and modify cardiovascular healthcare on a national level for the professional is stressed in **Part I**. For both the professional and patient, **Part II** describes research to improve local (i.e. hospital) cardiovascular care. Both parts combined, provide a holistic framework to improve clinical work on multiple levels.

The first part of the introduction describes how value in cardiovascular care is defined by the modern-day professional via evidence based medicine and clinical guidelines. **Chapters II and III** illustrate the disparities between 'guideline recommendation' and 'real world patterns' regarding treatment of myocardial infarction patients in the Netherlands.

Results are discussed of two studies using national-, and regional claims data to find modifiable factors in the treatment of myocardial infarction patients. The second part of the introduction describes the multilayered concepts of 'health' and 'value' for the professional and patient, within the framework of Value Based Healthcare as described by Porter and Teisberg. The principles of Human Factors (HF) science are described, which provides a fruitful addition in Value Based Healthcare research of cardiovascular patients. **Chapters IV to VIII** describe various studies concerning HF science, its methodology and the utilization of this type of research in clinical cardiovascular care. Below, all individual chapters of parts I and II are described in detail.

Part One – Claims Data Analysis

Chapter II describes the use of claims data to assess treatment of non ST elevation myocardial infarction (NSTEMI) patients in the Netherlands. The aim of the study was to search for modifiable factors to improve Dutch NSTEMI care.

For that reason, real world data was compared to guideline recommendations regarding revascularization via percutaneous intervention (PCI) and secondary preventive medication. Claims data of almost 18,000 unique (i.e. ever first) NSTEMI patients treated in Dutch hospitals in 2015 was analyzed. PCI use within 72hours during hospitalization and total secondary preventive medication use (combined use of aspirin-specie, P2Y12-inhibitor, betablocker, ACE/AT-II inhibitor, and statin) during 30 days follow-up were assessed.

Via propensity score matching, the effect of PCI, and optimal medical treatment on one year mortality were calculated. Less than half of all NSTEMI patients (43%) received a PCI during hospitalization within 72hrs. Identically, less than half (47%) of all NSTEMI patients had optimal medical therapy after 30 days of the initial NSTEMI. Having had a PCI within 72hrs of hospitalization and having had optimal medical therapy at 30days, were both associated with lower 1-year mortality (respectively OR 0.42; 95%CI 0.37-0.48 and OR 0.59; 95%CI 0.51-67). The presented study highlights the usefulness of claims data in regard to the evaluation of real-world care in a large cohort of NSTEMI patients with data of past years with minimal registrational burden.

The results aid cardiologists by stressing awareness for thorough evaluation of revascularization options and strive for complete medical adherence in NSTEMI patients.

Chapter III investigates the use of claims data combined with open-access governmental socioeconomic status statistics on a zip-code level to assess myocardial infarction care on a regional level of three Dutch hospitals. Almost 3,200 patients were included.

Total revascularization- (PCI and CABG), optimal medical therapy- and mortality patterns were assessed among ST elevation myocardial infarction (STEMI)- and NSTEMI patients. The study showed that low SES STEMI and NSTEMI patients more often receive a CABG and more often use complete optimal medical therapy after myocardial infarction. No mortality differences were observed. This proof-of-concept study shows that claims data can be effectively coupled to zip-code socioeconomic statistics to asses regional myocardial infarction care and provide specific recommendations to improve care on a zip-code level.

This enables care givers to focus for instance on primary prevention strategies in low-income areas or on secondary prevention awareness campaigns in wealthier neighborhoods.

Part Two – Human Factors Science in Cardiovascular Care

Chapter IV describes an editorial which introduces the concept of Human Factors (HF) science into the domain of cardiovascular healthcare to support research in line with Value Based Healthcare principles and optimize care processes for both the professional and patient.

Chapter V discusses the results of a study implementing a common aviation HF questionnaire (Safety Attitudes Questionnaire -SAQ) to measure and understand the safety climate of two teams performing open- and endovascular repair of complex aortic aneurysms.

This qualitative study shows that the SAQ is an effective screening tool to assess local safety culture of surgical teams and hint at suggestions to improve interprofessional collaboration between physicians and support-personnel to optimize patient safety during procedures.

Chapter VI outlines HF research to assess outpatient education of myocardial infarction patients to eventually develop a Mixed Reality Hololens application to support this process. Twelve patients and six healthcare professionals were randomly included in this qualitative interview study. Patients and professionals were asked on the importance of educational topics (anatomy, medication, rehabilitation, personal life). Provided information to all patients was perceived as being too extensive, incoherent and difficult to comprehend, especially regarding the importance of secondary preventive medication. Although rated by the professional as being of importance, patients indicated that little attention was given by the healthcare provider to address the impact of medication use on personal life. On the contrary, professionals noted that there should be more education on anatomical aspects of myocardial infarction and secondary prevention. The findings of this study strikingly highlight the disparities between patient-, and professional perspectives on the subject of education, which should be an eye-opener to clinicians.

The Microsoft™ HoloLens was proposed as an educational tool, capable of uniting patient and professional perspectives on for instance secondary preventive medication.

Chapter VII extends the findings of chapter VI into a controlled clinical study, by designing a working MR model to educate the importance of statins to myocardial infarction patients.

A human centered design approach was used, novel in the field of clinical cardiology. Effects of conventional education (verbal education, booklets) on statin knowledge were assessed in 10 STEMI and NSTEMI patients. This was compared to the effect of an MR-statin model on statin knowledge in 12 STEMI and NSTEMI patients. The study shows that conventional education only has little impact on statin understanding, while the HoloLens statin model is effective in teaching patients the importance of statins and may promote learning over time.

Both **chapters VI and VII** showcase the usefulness of combining HF design-thinking and scientific evaluation into a fluid process. **Chapter VIII** focusses on the patient perspective of a pre-cardiac catheterization Virtual Reality application for outpatient care.

The study primarily assess the acceptability and feasibility of an alpha version of a VR application called ‘Pre-View’ in patients receiving elective cardiac catheterization. Identical to chapter VII, a design-thinking approach was used to evaluate the VR application to improve it further.

The application shows patients the hospital admission via interactive 360- degrees photos and videos. A small patient population (N=8) tested the application in the outpatient setting before cardiac catheterization, which showed that patients felt overall informed with a high sense of participation in the care-process and being highly involved in the application with only minimal side-effects (i.e. cybersickness). Despite the small study population, the study shows that VR is an acceptable medium in the outpatient setting of cardiovascular care, enabling new possibilities for patient education.

Concluding Remarks and Future Perspectives

This thesis discussed a systematic approach to evaluate value in clinical cardiovascular care on multiple levels and how to improve it further. Common treatment patterns of nationwide myocardial infarction care were assessed as well as the evaluation and re-design of clinical collaboration between professionals during aortic surgery and outpatient care of myocardial infarction patients. Although evidence based choices are present in clinical work, the presented studies stress the reality of Dutch clinical cardiovascular care in the 21st century. They demonstrate the tension between, on the one hand, professionals who try to follow guideline-treatment in order to optimize clinical outcome and, on the other hand, patients who also experience healthcare on a more qualitative and less quantifiable level. Overall, claims data analysis and HF research are both methodologies that provide a unique framework to investigate and improve care processes for both the patient and professional in cardiovascular care.

Data Driven Healthcare

In the Netherlands, hospitals are committed to collect and register encrypted quality-of-care patient data to monitor and assess care provided to patients(1-3). This provides transparency of delivered care and the possibility to evaluate outcomes of various patient categories(4).

For cardiovascular care, The Dutch cardiovascular quality of care registry (Nederlandse Hart Registratie, NHR) is an important example(5). The collection, storage and maintenance is predominantly driven by professionals (i.e. thoracic surgeons, cardiologists) to evaluate treatment patterns on a national level, as well as patient survival or the occurrence of adverse events. In more recent years, claims data is seen as a valuable source of data for quality assessment in various disciplines such as cardiology(6-10), pulmonology(11-13), nephrology(14, 15), and oncology(16-19).

Apart from quality assessment, claims data analysis offers a prolific addition to clinical research to assess healthcare and provide insight in patient numbers, treatment patterns over various years and demographic entities.

Compared to common, observational registry studies, claims data analysis is predominantly retrospective, with a low registrational burden as this data is automatically coupled to governmental data and logged/stored after patients' hospital discharge.

It reflects 'real world' patterns and evidence rather than data from randomized studies which is highly dependable on in- or exclusion criteria(13, 20, 21). Nonetheless, important shortcomings are the lack of clinical details such as journal entries, laboratory findings or imaging data and the fact that all claims data are stored at insurance company data centers, not rapidly available to physicians.

For future purposes, a coupling of claims data and clinical data may further support the clinical use of it. A hybrid system of claims data coupled to clinical data, generated and stored *at hospitals,* might be a solution to improve availability for research, and thus eventually support the creation of clinical guidelines.

With an expanding global population of patients and the endless possibilities to generate and store data in modern medicine, healthcare becomes more 'data-driven'(22-24).

Identically, as the quality of the data stored becomes better and more complete, the possibilities in clinical medicine expand such as the development of Artificial Intelligence (AI) (25-27). To improve the use of clinical data overall, the generation and storage of it as well as the availability of the data to professional and patient, should be a focus of development in the future with the electronic medical record (EMR) as the backbone(28). The EMR as the daily digital work environment of modern healthcare, provides a useful foundation of data formation, storage, access and analysis.

To improve the usefulness of this clinical data, a strong position by professional societies, even in governance, is crucial in my opinion. Firstly to determine for what purpose/meaning data should be collected and secondly, to create more unity in the generation, storage and usability of clinical data in modern medicine.

Human Factors in Cardiovascular Care – Meta Value

Although novel in cardiovascular research, HF science is a discipline which increasingly finds its way into medical care(29-34).
Cardiovascular care being heavily reliant on human physical- and cognitive performance in a complex environment, can benefit from HF science on multiple levels. Not only in sole diagnostic- or curative domains but also on the organizational level. Especially in the development and usability of novel technologies in clinical care as proposed in part two of this thesis, HF science offers a novel approach to change and hopefully improve cardiovascular healthcare in a meaningful way for both the patient and professional.

In recent years, implementation of electronic- or mobile health (eHealth, mHealth) into cardiovascular healthcare has gained increased attention. Electronic devices become more and more present in daily life and clinical care, which expand the possibilities in modern healthcare for both the patient and professional(35-38).

Traditional physical check-ups are exchanged for video conferences with physicians(39, 40) and the use of wearable Bluetooth™ devices such as blood pressure monitors or ECG-devices enable the professional to closely monitor the patient at home, and interfere when necessary(41, 42). Moreover, these devices enable certain patient 'empowerment' with a positive impact on overall health(43). However, although the interaction between humans (patients) and technology is perceived as something that just 'is', it is worth investigating *how* this interaction is perceived and where the true value lies for the individual.

In cardiovascular medicine, professionals and patients are overall positive about the potential of eHealth(44-46), however little is known what effect of this technological transition has on an ever growing, elderly, patient population in terms of psychological stress or anxiety, as evidence is limited(47). Technological advancements in cardiovascular science show an exponential growth yearly(48), however as humans, our biology and psychology are not altered in a similar way. A good example among the young is an increased level of anxiety and depression among frequent users of novel social media applications and modern mobile technology(49-51). Studies examining the impact of eHealth on psychological wellbeing in cardiovascular patients are scarce today.

HF science can be a valuable addition to systematically understand the (psychological) impact of technological advancements such as eHealth, and simultaneously offer a method to develop and implement new devices and technology in line with patient and professional preferences.

Especially the use of a patient-experience journey as proposed in this thesis, is essential in understanding the many elements of clinical care of which daily work consists, such as the interaction with the professional and the impact on the patient. From a VBHC perspective, outcomes on a personal level become thus more transparent and quantifiable(33, 34, 52).

Furthermore, this process of mapping the healthcare experience by placing the human at the center of it, has become refined not only to support the utilization of novel devices in clinical care, but identically in the development of care tracks across multiple domains of healthcare(33, 53, 54).

The strength of this process lies not only in the fact that it helps understand how stakeholders perceive and value the implementation of new elements of care, but also how the whole care-track can be redesigned by using this input. Regarding VBHC, this methodology enables a focus on value on a *meta-level*. Many dimensions of human health, disease and outcomes create an interaction with healthcare, not a single encounter.

Using HF science and predominantly patient experience mapping supports the view that designing care is not merely for one aspect of disease. HF science in a sense, paves the way to healthcare design becoming more focused around the care continuum of chronic ailments, of which cardiovascular disease is a large part. A close collaboration between patients and medical professionals is eminent in this process.
Despite some studies in this thesis having a small study population, meaningful information can still be gathered using a structured systematic analysis such as the patient journey/ experience mapping offers.

An interesting next step in human centered design and patient experience mapping, can be a focus on the permanency of the disease and care processes when re-designing healthcare. Cardiovascular disease is foremost a chronic ailment, which leads to suffering longitudinally on a physical and emotional level(55). 'Empowering' the patient by actively pursuing self-management and autonomy, can improve the perceptions regarding treatment and outcome, which in turn, lead to improved life expectancy(56). To empower, it is crucial to understand how patients perceive their illness in terms of coping and what they expect from treatment(57), but identically how they perceive their health in general(58). As a foundation, these illness and health perceptions can steer research and eventually let outcomes become more patient and value driven. In my opinion, to achieve this and to embed principles of human centered design and HF science further in modern cardiovascular research, a partnership with professionals from other disciplines such as humanities, design and technology will be crucial for the evolution of cardiovascular healthcare in the 21st century, to ensure a broad scientific basis.

To improve quality of clinical care and research, thorough evaluation of the scientific processes on usability, meaning and value should be done on regular basis, not only by professionals, but equally patients. Thus creating a loop of continued improvement (figure 1). Incorporating HF scientists in the foundation of this process within modern hospitals and clinical research creates hybrid care-centers with diverse specialists, which opens new possibilities in the future development of cardiovascular care. Designed by humans, for humans.

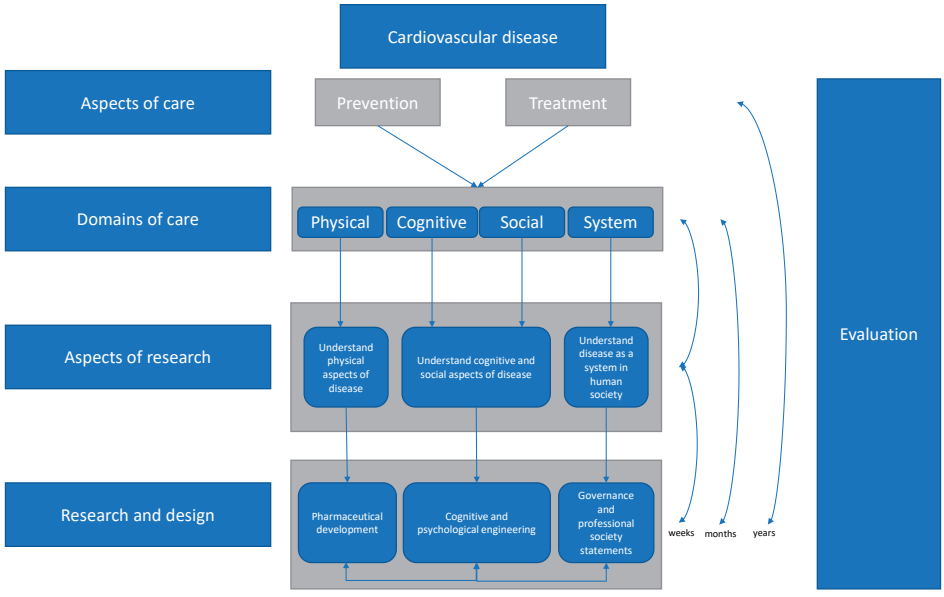


Figure 1. The future of cardiovascular care and scientific research.

Legend: To ensure a continuous system of improvement of daily clinical care and scientific research, Human Factors science provides a holistic approach to develop complex systems such as cardiovascular healthcare. At the basis should be thorough evaluation of research,- and design elements on personal and system levels, creating a continued loop of improvement.

References

1. CardioPulse Articles - SWEDEHEART: Sweden's new online cardiac registry, the first of its kind. European Heart Journal. 2009;30(18):2165-73.
2. Dutch Government. Law Quality, Complaints and Disputes in Healthcare. [Article 9]. 2015 [Available from: https://www.overheid.nl/.
3. Bridgewater B, Grant S, Hickey G, Fazel N. National Institute for Cardiovascular Outcomes Research & The Society of Cardiothoracic Surgery in Great Britain and Ireland. (2012). National Adult Cardiac Surgery Audit Report: 2010-112012.
4. Wierda E, Eindhoven DC, Schalij MJ, Borleffs CJW, Amoroso G, van Veghel D, et al. Privacy of patient data in quality-of-care registries in cardiology and cardiothoracic surgery: the impact of the new general data protection regulation EU-law. European heart journal Quality of care & clinical outcomes. 2018;4(4):239-45.
5. Nederlandse Hart Registratie 2021 [Available from: https://nederlandsehartregistratie.nl/.
6. Dhruva SS, Parzynski CS, Gamble GM, Curtis JP, Desai NR, Yeh RW, et al. Attribution of Adverse Events Following Coronary Stent Placement Identified Using Administrative Claims Data. Journal of the American Heart Association. 2020;9(4):e013606.
7. Eindhoven DC, Wu HW, Kremer SWF, van Erkelens JA, Cannegieter SC, Schalij MJ, et al. Mortality differences in acute myocardial infarction patients in the Netherlands: The weekend-effect. American heart journal. 2018;205:70-6.
8. Hemingway H, Asselbergs FW, Danesh J, Dobson R, Maniadakis N, Maggioni A, et al. Big data from electronic health records for early and late translational cardiovascular research: challenges and potential. Eur Heart J. 2018;39(16):1481-95.
9. Kohsaka S, Katada J, Saito K, Jenkins A, Li B, Mardekian J, et al. Safety and effectiveness of non-vitamin K oral anticoagulants versus warfarin in real-world patients with non-valvular atrial fibrillation: a retrospective analysis of contemporary Japanese administrative claims data. Open heart. 2020;7(1):e001232.
10. Ten Have P, Hilt AD, Paalvast H, Eindhoven DC, Schalij MJ, Beeres S. Non-ST-elevation myocardial infarction in the Netherlands: room for improvement! Netherlands heart journal : monthly journal of the Netherlands Society of Cardiology and the Netherlands Heart Foundation. 2020;28(10):537-45.
11. Jarow JP, LaVange L, Woodcock J. Multidimensional Evidence Generation and FDA Regulatory Decision Making: Defining and Using "Real-World" Data. Jama. 2017;318(8):703-4.
12. Mueller S, Gottschalk F, Groth A, Meeraus W, Driessen M, Kohlmann T, et al. Primary data, claims data, and linked data in observational research: the case of COPD in Germany. Respiratory research. 2018;19(1):161.
13. Saturni S, Bellini F, Braido F, Paggiaro P, Sanduzzi A, Scichilone N, et al. Randomized Controlled Trials and real life studies. Approaches and methodologies: a clinical point of view. Pulmonary pharmacology & therapeutics. 2014;27(2):129-38.

14. Sohlberg EM, Brubaker WD, Zhang CA, Anderegg LDL, Dallas KB, Song S, et al. Urinary Stone Disease in Pregnancy: A Claims Based Analysis of 1.4 Million Patients. The Journal of urology. 2020;203(5):957-61.
15. Woodside KJ, Bell S, Mukhopadhyay P, Repeck KJ, Robinson IT, Eckard AR, et al. Arteriovenous Fistula Maturation in Prevalent Hemodialysis Patients in the United States: A National Study. American journal of kidney diseases : the official journal of the National Kidney Foundation. 2018;71(6):793-801.
16. Boggon R, van Staa TP, Chapman M, Gallagher AM, Hammad TA, Richards MA. Cancer recording and mortality in the General Practice Research Database and linked cancer registries. Pharmacoepidemiology and drug safety. 2013;22(2):168-75.
17. Cogle CR, Levin G, Lee DJ, Peace S, Herna MC, MacKinnon J, et al. Finding incident cancer cases through outpatient oncology clinic claims data and integration into a state cancer registry. Cancer causes & control : CCC. 2021;32(2):199-202.
18. Ennis RD, Parikh AB, Sanderson M, Liu M, Isola L. Interpreting Oncology Care Model Data to Drive Value-Based Care: A Prostate Cancer Analysis. Journal of oncology practice. 2019;15(3):e238-e46.
19. Kuliszewski MG, Lee FF, Schymura MJ. Can Oncology Practice Claims Data Replace Physician Reporting to State Cancer Registries? Journal of registry management. 2020;47(3):113-7.
20. Berger ML, Mamdani M, Atkins D, Johnson ML. Good research practices for comparative effectiveness research: defining, reporting and interpreting nonrandomized studies of treatment effects using secondary data sources: the ISPOR Good Research Practices for Retrospective Database Analysis Task Force Report--Part I. Value in health : the journal of the International Society for Pharmacoeconomics and Outcomes Research. 2009;12(8):1044-52.
21. Strom JB, Tamez H, Zhao Y, Valsdottir LR, Curtis J, Brennan JM, et al. Validating the use of registries and claims data to support randomized trials: Rationale and design of the Extending Trial-Based Evaluations of Medical Therapies Using Novel Sources of Data (EXTEND) Study. American heart journal. 2019;212:64-71.
22. Hasselgren A, Kralevska K, Gligoroski D, Pedersen SA, Faxvaag A. Blockchain in healthcare and health sciences-A scoping review. International journal of medical informatics. 2020;134:104040.
23. Issa NT, Byers SW, Dakshanamurthy S. Big data: the next frontier for innovation in therapeutics and healthcare. Expert review of clinical pharmacology. 2014;7(3):293-8.
24. Ohno-Machado L. Advancing healthcare and biomedical research via new data-driven approaches. Journal of the American Medical Informatics Association : JAMIA. 2017;24(3):471.
25. Johnson KW, Torres Soto J, Glicksberg BS, Shameer K, Miotto R, Ali M, et al. Artificial Intelligence in Cardiology. Journal of the American College of Cardiology. 2018;71(23):2668-79.
26. Lopez-Jimenez F, Attia Z, Arruda-Olson AM, Carter R, Chareonthaitawee P, Jouni H, et al. Artificial Intelligence in Cardiology: Present and Future. Mayo Clinic proceedings. 2020;95(5):1015-39.

27. Westcott RJ, Tcheng JE. Artificial Intelligence and Machine Learning in Cardiology. JACC Cardiovascular interventions. 2019;12(14):1312-4.
28. Gillum RF. From papyrus to the electronic tablet: a brief history of the clinical medical record with lessons for the digital age. The American journal of medicine. 2013;126(10):853-7.
29. Haerkens MH, Jenkins DH, van der Hoeven JG. Crew resource management in the ICU: the need for culture change. Annals of intensive care. 2012;2(1):39.
30. Mearns K, Whitaker S, Flin R. Safety Climate, Safety Management Practice and Safety Performance in Offshore Environments. Safety Science2003. 641-80 p.
31. Russ AL, Fairbanks RJ, Karsh BT, Militello LG, Saleem JJ, Wears RL. The science of human factors: separating fact from fiction. BMJ quality & safety. 2013;22(10):802-8.
32. Sexton JB, Thomas EJ, Helmreich RL. Error, stress, and teamwork in medicine and aviation: cross sectional surveys. BMJ (Clinical research ed). 2000;320(7237):745-9.
33. Carayon P, Wooldridge A, Hoonakker P, Hundt AS, Kelly MM. SEIPS 3.0: Human-centered design of the patient journey for patient safety. Appl Ergon. 2020;84:103033.
34. Holden RJ, Carayon P. SEIPS 101 and seven simple SEIPS tools. BMJ quality & safety. 2021;30(11):901-10.
35. Cheung CC, Deyell MW. Remote Monitoring of Cardiac Implantable Electronic Devices. The Canadian journal of cardiology. 2018;34(7):941-4.
36. DeVore AD, Wosik J, Hernandez AF. The Future of Wearables in Heart Failure Patients. JACC Heart failure. 2019;7(11):922-32.
37. Howard IM, Kaufman MS. Telehealth applications for outpatients with neuromuscular or musculoskeletal disorders. Muscle & nerve. 2018;58(4):475-85.
38. Jeong IC, Bychkov D, Searson PC. Wearable Devices for Precision Medicine and Health State Monitoring. IEEE transactions on bio-medical engineering. 2019;66(5):1242-58.
39. Dulai R, Shunmugam SR, Veasey RA, Patel NR, Sugihara C, Furniss S. An economic evaluation of an advanced video conferencing system for cardiac multidisciplinary team meetings. International journal of clinical practice. 2020;74(9):e13562.
40. Fatehi F, Martin-Khan M, Smith AC, Russell AW, Gray LC. Patient satisfaction with video teleconsultation in a virtual diabetes outreach clinic. Diabetes technology & therapeutics. 2015;17(1):43-8.
41. Dagher L, Shi H, Zhao Y, Marrouche NF. Wearables in cardiology: Here to stay. Heart rhythm. 2020;17(5 Pt B):889-95.
42. Pevnick JM, Birkeland K, Zimmer R, Elad Y, Kedan I. Wearable technology for cardiology: An update and framework for the future. Trends in cardiovascular medicine. 2018;28(2):144-50.
43. Brickwood KJ, Watson G, O'Brien J, Williams AD. Consumer-Based Wearable Activity Trackers Increase Physical Activity Participation: Systematic Review and Meta-Analysis. JMIR mHealth and uHealth. 2019;7(4):e11819.
44. Birkhoff SD, Smeltzer SC. Perceptions of Smartphone User-Centered Mobile Health Tracking Apps Across Various Chronic Illness Populations: An Integrative Review. Journal of nursing

scholarship : an official publication of Sigma Theta Tau International Honor Society of Nursing. 2017;49(4):371-8.
45. Treskes RW, Koole M, Kauw D, Winter MM, Monteiro M, Dohmen D, et al. Adults with congenital heart disease: ready for mobile health? Netherlands heart journal : monthly journal of the Netherlands Society of Cardiology and the Netherlands Heart Foundation. 2019;27(3):152-60.
46. Treskes RW, Wildbergh TX, Schalij MJ, Scherptong RWC. Expectations and perceived barriers to widespread implementation of e-Health in cardiology practice: Results from a national survey in the Netherlands. Netherlands heart journal : monthly journal of the Netherlands Society of Cardiology and the Netherlands Heart Foundation. 2019;27(1):18-23.
47. Narasimha S, Madathil KC, Agnisarman S, Rogers H, Welch B, Ashok A, et al. Designing Telemedicine Systems for Geriatric Patients: A Review of the Usability Studies. Telemedicine journal and e-health : the official journal of the American Telemedicine Association. 2017;23(6):459-72.
48. Bhavnani SP, Narula J, Sengupta PP. Mobile technology and the digitization of healthcare. Eur Heart J. 2016;37(18):1428-38.
49. Lissak G. Adverse physiological and psychological effects of screen time on children and adolescents: Literature review and case study. Environmental research. 2018;164:149-57.
50. Vidal C, Lhaksampa T, Miller L, Platt R. Social media use and depression in adolescents: a scoping review. International review of psychiatry (Abingdon, England). 2020;32(3):235-53.
51. Woods HC, Scott H. #Sleepyteens: Social media use in adolescence is associated with poor sleep quality, anxiety, depression and low self-esteem. Journal of adolescence. 2016;51:41-9.
52. Carayon P, Wood KE. Patient safety. Information Knowledge Systems Management. 2009;8:23-46.
53. Kianfar S, Carayon P, Hundt AS, Hoonakker P. Care coordination for chronically ill patients: Identifying coordination activities and interdependencies. Applied Ergonomics. 2019;80:9-16.
54. Holden RJ, Valdez RS, Schubert CC, Thompson MJ, Hundt AS. Macroergonomic factors in the patient work system: examining the context of patients with chronic illness. Ergonomics. 2017;60(1):26-43.
55. Leventhal H, Phillips LA, Burns E. The Common-Sense Model of Self-Regulation (CSM): a dynamic framework for understanding illness self-management. Journal of behavioral medicine. 2016;39(6):935-46.
56. Petrie KJ, Cameron LD, Ellis CJ, Buick D, Weinman J. Changing illness perceptions after myocardial infarction: an early intervention randomized controlled trial. Psychosomatic medicine. 2002;64(4):580-6.
57. Broadbent E, Wilkes C, Koschwanez H, Weinman J, Norton S, Petrie KJ. A systematic review and meta-analysis of the Brief Illness Perception Questionnaire. Psychology & health. 2015;30(11):1361-85.
58. Huber M, van Vliet M, Giezenberg M, Winkens B, Heerkens Y, Dagnelie PC, et al. Towards a 'patient-centred' operationalisation of the new dynamic concept of health: a mixed methods study. BMJ open. 2016;6(1):e010091.

CHAPTER X

NEDERLANDSE SAMENVATTING

In dit proefschrift zijn twee onderzoeksmethonden gebruikt om systematisch nationale-, en lokale cardiovasculaire zorg in kaart te brengen en inzicht te verkrijgen waar te verbeteren voor zowel patient en professional. De introductie (**hoofdstuk I**) beschrijft globaal de inhoud van dit proefschrift. Een definitie van 'waarde gedreven cardiovasculaire zorg' en de meerwaarde hiervan voor de professional wordt uiteengezet. Wetenschappelijk onderzoek binnen het thema 'waarde gedreven zorg' plaatst vooral de patient en diens visie op waarde en uitkomsten binnen medische zorg voorop bij het uitvoeren van onderzoek, wat een unieke toevoeging kan zijn in de kliniek. **Deel I** van dit proefschrift omvat studies die pogen *nationale* cardiovasculaire zorg in kaart te brengen en suggesties te doen waar te verbeteren voor de professional. **Deel II** omvat onderzoeken die vooral op *lokaal niveau* (d.w.z. op ziekenhuis niveau) pogen klinische zorg voor zowel professional als ook de patient te verbeteren. Beide delen tezamen vormen een overkoepelend wetenschappelijk kader waarmee klinische zorg op diverse niveaus verbeterd kan worden.

Het eerste deel van de introductie geeft een definitie van het begrip 'waarde' binnen cardiovasculaire zorg, zoals gezien door de professional, gevormd door richtlijnen en uitkomsten van 'Evidence Based Medicine'-onderzoek (Geneeskunde op basis van bewijs).

Hoofdstuk II en III illustreren het verschil tussen wat richtlijnen aanbevelen, en wat van deze aanbevelingen terug te zien is in de dagelijkse zorg van hartinfarctpatiënten in Nederland. De resultaten van twee studies worden besproken waarbij gebruik gemaakt is van nationale-, en regionale declaratiedata om de zorg rondom het hartinfarct te verbeteren.

Het tweede deel van de introductie beschrijft het meerlaagse concept van 'gezondheid' en 'waarde' voor zowel professional en patient binnen de wetenschappelijke discipline van 'Waarde Gedreven Zorg' (Value Based Healthcare) zoals beschreven door Porter en Teisberg. Daarnaast worden de beginselen van de Human Factors (HF) wetenschap beschreven, wat een bruikbare toevoeging kan zijn aan onderzoek binnen 'Waarde Gedreven Zorg' van cardiovasculaire patiënten.

Hoofdstukken IV tot en met VIII beschrijven verscheidene studies waarbij de HF wetenschap en methodologie zijn gebruikt om onderzoek binnen klinische cardiovasculaire zorg vorm te geven in lijn met 'Waarde Gedreven Zorg' principes. Hieronder worden alle hoofdstukken van deel I en II in detail beschreven.

Deel Een – Financieel Klinische Data Analyse

Hoofdstuk II beschrijft het gebruik van financieel klinische data om de behandeling van non ST elevatie myocard infarct (NSTEMI) patiënten in Nederland in kaart te brengen. Het doel van de studie was te zoeken naar modificeerbare factoren om de Nederlandse NSTEMI zorg te verbeteren. Financieel klinische data werd vergeleken met adviezen uit geldende internationale richtlijnen aangaande revascularisatie middels percutane coronaire interventie (PCI, of 'dotter') en gebruik van secundair preventieve medicatie. Data van ongeveer 18,000 unieke (d.w.z. voor het eerst doorgemaakt) NSTEMI patiënten behandeld in Nederlandse ziekenhuizen in 2015, werden geanalyseerd.

Het toepassen van een PCI binnen 72 uur tijdens opname in het ziekenhuis en optimaal gebruik van secundair preventieve medicatie (d.w.z. het gecombineerd gebruik van een aspirine-preparaat, P2Y12-remmer, betablokker, ACE-AT-II remmer en een statine) gedurende 30 dagen follow-up werden geanalyseerd. Statistisch werd 'Propensity score matching' gebruikt om het effect van een PCI en gebruik van optimale secundair preventieve medicatie op de één jaar-sterfte te berekenen. Minder dan de helft (43%) van de NSTEMI patiënten kreeg een PCI binnen 72 uur tijdens ziekenhuis opname. Tevens gebruikte minder dan de helft (47%) van alle NSTEMI patiënten optimale secundaire preventieve medicatie 30 dagen na het doormaken van het hartinfarct. Het krijgen van een PCI binnen 72 uur tijdens ziekenhuis opname en het gebruiken van optimale secundaire preventieve medicatie na 30 dagen, droegen beide bij aan een lagere sterfte na één jaar (respectievelijk OR 0.42; 95%CI 0.37-0.48 en OR 0.59; 95%CI 0.51-67). De studie toont de bruikbaarheid aan van financieel klinische data in de evaluatie van dagelijkse hartziekten zorg in een groot cohort NSTEMI patiënten, zonder een al te grote registratielast.
De resultaten helpen cardiologen bewust te worden van het belang van een weloverwogen revascularisatie strategie en het nastreven van compleet gebruik van medicatie in NSTEMI patiënten.

Hoofdstuk III onderzocht het gebruik van financieel klinische data gecombineerd met socio-economische status data op postcode niveau, om zo een beeld te krijgen van regionale hartziekten zorg rondom drie Nederlandse ziekenhuizen. Bijna 3,200 patiënten werden geïncludeerd uit jaren 2015 tot en met 2017. Totaal aantal revascularisaties (PCI of bypass/ CABG operatie), optimaal secundair preventief medicatie gebruik en sterftecijfers werden geanalyseerd in ST elevatie myocard infarct (STEMI)- en NSTEMI patiënten. De studie liet zien dat lage socio-economische klasse STEMI en NSTEMI patiënten vaker een Bypass/CABG kregen dan hoge socio-economische klasse patiënten, maar wel vaker het compleet pakket secundaire preventieve medicatie na het hartinfarct gebruiken in vergelijk tot de hoge socio-economische klasse patiënten. Er waren geen sterfteverschillen tussen socio-economische klassen.

Deze 'proof-of-concept study' laat zien dat financieel klinische data effectief gekoppeld kan worden aan socio-economische data op postcode niveau om zo regionale hartinfarcten zorg in kaart te brengen en verbeteringen op wijk/postcode niveau te formuleren.

Dit geeft zorgprofessionals (huisartsen, cardiologen e.a.) de mogelijkheid om gerichter te werk te gaan zoals primaire preventie strategieën toe te spitsen op lagen inkomsten wijken of het correct gebruik van medicatie te promoten in hogere inkomsten wijken.

Deel Twee – Human Factors Wetenschap in Cardiovasculaire Zorg

Hoofdstuk IV beschrijft een opinie stuk welke het wetenschappelijk domein van Human Factors (HF) introduceert in de cardiovasculaire gezondheidszorg om 'Waarde Gedreven Zorg' op onderzoekvlak meer vorm te geven. Met als einddoel zorgprocessen voor zowel professional en patient tezamen te verbeteren.

Hoofdstuk V toont de resultaten van een studie waarbij een veelgebruikte luchtvaart HF vragenlijst (Safety Attitudes Questionnaire – SAQ) werd gebruikt om het veiligheidsklimaat van twee teams tijdens open- en endovasculaire complexe aorta chirurgie te meten. Deze kwalitatieve studie laat zien dat de SAQ een effectieve vragenlijst kan zijn om de veiligheidscultuur in chirurgische teams tastbaar te maken en aanpassingen in het dagelijks samenwerken kan suggereren om de patiëntveiligheid tijdens operaties te verbeteren.

Hoofdstuk VI toont de resultaten van een HF studie waarbij de focus lag op wat hartinfarct patiënten onthouden en leren van educatie die gegeven wordt na het doormaken van een hartinfarct, en hoe dit proces ondersteund zou kunnen worden door een Mixed Reality (MR) Hololens applicatie. Twaalf patiënten en zes zorgprofessionals werden door middel van het toeval geïncludeerd in deze kwalitatieve interview studie. Patiënten en professionals werd gevraagd welke onderdelen van onderwijs (anatomische kennis, medicatie gebruik, revalidatie, invloed op persoonlijk leven) zij het meest belangrijk vonden.

Patiënten gaven aan dat gegeven informatie te uitgebreid en inconsistent was als ook moeilijk te bevatten, voornamelijk het gebruik van secundair preventieve medicatie. Alhoewel professionals aangaven het belangrijk te vinden om patiënten goed te onderwijzen in het belang van medicatie in hun leven, vonden patiënten dat te weinig aandacht werd besteedt aan de impact van medicatie op het dagelijks leven. In tegenstelling tot patiënten, vonden professionals dat er meer onderwijs over anatomie en medicatie in het algemeen onderwezen moest worden.

De bevindingen van deze studie laten zien dat er behoorlijke verschillen zijn in wat professionals en patiënten belangrijk vinden als het gaat om informatievoorziening na het hartinfarct. De Microsoft™ HoloLens werd aangehaald als een bruikbaar gereedschap om de perspectieven van zowel professional als patient te harmoniseren, bijvoorbeeld om het belang van medicatie gebruik na het hartinfarct te verduidelijken.

Hoofdstuk VII bouwt voort op de bevindingen van hoofdstuk VI in de vorm van een gecontroleerde klinische studie waarbij een werkend Mixed Reality (MR) model werd ontworpen om de functie en het belang van statines uit te leggen aan hartinfarct patiënten.

Een Human Factors ontwerp strategie werd toegepast waarin de mens centraal staat, een nieuw concept binnen de klinische cardiologie. Het effect van conventionele educatie (verbale en geschreven educatie) op statine kennis werd gemeten in 10 STEMI en NSTEMI patiënten. Deze uitkomst werd vergeleken met het effect van het MR model op statine kennis in 12 STEMI en NSTEMI patiënten. Deze studie laat zien dat conventionele geschreven of gesproken statine educatie maar minimaal effect heeft op het begrip van statines. Het MR statine model lijkt daarentegen effectief in het overbrengen van kennis met de mogelijkheid om patiënten het geleerde te laten behouden over langere tijd. **Hoofdstukken VI en VII** laten de bruikbaarheid zien van Human Factors denken in het proces van zowel het ontwerpen van nieuwe technologie als ook de wetenschappelijke evaluatie in de kliniek als één vloeiend proces.

Hoofdstuk VIII richt zich op de evaluatie van een poliklinische Virtual Reality (VR) hartkatheterisatie applicatie vanuit het patient perspectief. Deze studie onderzoekt met name de bruikbaarheid en haalbaarheid van de toepassing in de kliniek door een alfa versie van de VR applicatie genaamd ‘Pre-View’ te testen in patiënten die electief een hartkatheterisatie ondergaan.

Vergelijkbaar met hoofdstuk VII, wordt een ontwerp-strategie gebruikt waarbij de mens centraal staat. De VR applicatie laat patiënten de gehele opname beleven via interactieve 360- graden foto’s en video’s. Een kleine patient populatie (N=8) testte de applicatie in de poliklinische setting voorafgaand aan de hartkatheterisatie. Hieruit kwam naar voren dat patiënten zich goed geïnformeerd voelden, het idee hadden actief deel te nemen in het zorgproces en maar weinig bijwerkingen (cyberziekte) te ervaren van de applicatie. Ondanks de kleine studiepopulatie laat de studie zien dat VR een acceptabel medium is in de poliklinische setting van cardiovasculaire zorg, wat nieuwe mogelijkheden biedt voor patient educatie.

Conclusie en Toekomst Perspectieven

In dit proefschrift werd een uiteenzetting gemaakt van een systematische beoordeling van klinische cardiovasculaire zorg en hoe deze te verbeteren valt. Patronen in de alledaagse behandeling van Nederlandse myocardinfarct patiënten werden onderzocht als ook de evaluatie en het nieuw vormgeven van klinisch werk tussen professionals tijdens aortale chirurgie en poliklinische zorg van myocardinfarct patiënten.

Ondanks dat veel keuzes in deze zorg gebaseerd zijn op 'bewijs' (evidence), laten de gepresenteerde studies de realiteit van Nederlandse cardiovasculaire zorg in de 21ste eeuw zien. De studies tonen het spanningsveld tussen de professional die klinische behandelrichtlijnen volgt om de uitkomsten voor de patient te verbeteren, en aan de andere kant, de patient die de zorg beleefd op een meer kwalitatief en minder kwantificeerbaar niveau. In het algemeen kan gesteld worden dat financiële klinische data analyse en human factors wetenschap methodologieën zijn die tezamen een uniek kader vormen om cardiovasculaire zorgprocessen te onderzoeken en verder te verbeteren voor zowel patient en professional.

Data Gedreven Gezondheidszorg

In Nederland zijn ziekenhuizen gedreven in het verzamelen en registreren van versleutelde patient data om zo de kwaliteit van geleverde zorg te raadplegen en te vervolgen(1-3).

Dit geeft transparantie van geleverde zorg en de mogelijkheid om de uitkomsten van verschillende patient categorieën te evalueren(4). Betreffende cardiovasculaire zorg data is de Nederlandse Hart Registratie (NHR) een belangrijk voorbeeld (5). De verzameling en opslag als ook het onderhoud hiervan is voornamelijk door professionals gedreven (zoals thoraxchirurgen, cardiologen) om zo behandelpatronen op een landelijk niveau te evalueren als ook de overleving en eventuele complicaties te monitoren van patiënten. De afgelopen jaren is financiële klinische data hierbij een waardevolle aanvullende bron gebleken voor kwaliteitsdoeleinden in verscheidene disciplines zoals cardiologie (6-10), longgeneeskunde (11-13), nefrologie (14-15) en oncologie (16-19).

Los van kwaliteitsanalyses, kan financiële klinische data analyse een vruchtbare toevoeging zijn in klinisch onderzoek binnen de gezondheidszorg om inzicht in patient aantallen te geven, behandelpatronen over meerdere jaren weer te geven als ook demografische entiteiten te belichten. In vergelijk tot alledaagse, observationele studies, is financiële klinische data analyse voornamelijk retrospectief met een lage registratielast, temeer omdat deze data automatisch wordt gekoppeld aan overheidsdata en opgeslagen wordt na ontslag uit het ziekenhuis. Op die manier geeft het patronen weer die getrouw zijn aan de werkelijkheid, in tegentelling tot de data die gegenereerd wordt uit gerandomiseerde studies, die in het algemeen afhankelijk zijn van in- en exclusie criteria (13, 20, 21).

Desalniettemin zijn belangrijke tekortkomingen van financiële klinische data het ontbreken van klinische details zoals opname verslagen, laboratorium,- of röntgen uitslagen, en het gegeven dat alle financiële data opgeslagen wordt bij verzekeraars. Dit maakt de toegang tot deze data beperkt voor professionals. Voor toekomstige toepassingen is een adequate koppeling tussen financiële- en klinische data onontbeerlijk voor de klinische toepassing hiervan.

Een hybride system van financiële data gekoppeld aan klinische data, opgeslagen in *ziekenhuizen,* kan een oplossing zijn om de toegankelijkheid voor onderzoek en dus de ontwikkeling van klinische richtlijnen te vergemakkelijken.

Met een immer groeiende mondiale patient populatie en daarnaast een toename in mogelijkheden om patient data te genereren en op te slaan in de hedendaagse gezondheidszorg, maakt dit dat de zorg meer en meer 'data gedreven' wordt (22-24). Tevens neemt de kwaliteit en volledigheid van opgeslagen data toe wat leidt tot meer toepassingsmogelijkheden in klinisch werk, zoals de ontwikkeling van 'Artificial Intelligence'(AI) systemen (25-27). Om het gebruik van klinische data in toto te verbeteren zou de datageneratie, de opslag ervan als ook de toegankelijkheid voor professional en patient meer aandacht moeten krijgen in toekomstige ontwikkelingen. Het elektronisch patient dossier (EPD) kan hierbij als hoeksteen fungeren(28). Het EPD als dagelijkse digitale werkomgeving binnen de moderne geneeskunde is een sterke basis voor zowel klinische datageneratie, de opslag ervan als ook de toegang ertoe en de analyse ervan.

Om de bruikbaarheid van deze klinische data te vergroten moet naar mijn mening een resoluut standpunt door vakverenigingen worden ingenomen om sturing hierin te bewerkstelligen. Allereerst om vast te stellen wat het doel van de te verzamelen data is, en ten tweede aan te sturen naar meer homogeniteit in de generatie en opslag van klinische data, om zo de bruikbaarheid ervan in moderne geneeskunde te bevorderen.

Human Factors in Cardiovasculaire Zorg – Waarde op Meta Niveau

Ondanks dat het een nieuwe entiteit binnen cardiovasculair onderzoek is, vindt de HF wetenschap als discipline meer en meer zijn weg in de medische zorg (29-34). De cardiovasculaire zorg kan hiervan profiteren, daar het afhankelijk is van menselijk functioneren in een complexe werkomgeving, op zowel fysiek als ook cognitief vlak. En niet alleen op het diagnostische-, of curatieve domein, maar ook op een organisatorisch niveau.

Vooral bij de ontwikkeling en het gebruik van nieuwe technologieën in de zorg, zoals voorgesteld in deel twee van dit proefschrift, kan de HF wetenschap een unieke bijdrage leveren om de cardiovasculaire zorg op een betekenisvolle manier voor zowel patient en professional te verbeteren.

Recent heeft de implementatie van elektronische-, of mobiele applicaties (eHealth, mHealth) in de cardiovasculaire gezondheidszorg een vlucht genomen. Elektronische apparaten vinden steeds meer hun weg in het alledaagse leven en zo ook in de klinische zorg, wat voor een toename in mogelijkheden zorgt in het ziekenhuis voor zowel patient als professional (35-38). Klassieke contactmomenten bij de arts worden ingeruild voor consulten via beeldbellen (39,40) en het gebruik van draagbare Bluetooth™ apparaten zoals bloeddrukmeters en hartritmemonitoren maken het de professional mogelijk om patiënten op afstand te vervolgen en in te grijpen wanneer noodzakelijk (41, 42). Verondersteld wordt dat deze apparaten een positief effect hebben op de patient en algemene gezondheid (43). Alhoewel de interactie tussen mens (patient) en technologie wordt gezien als een gegeven, is het de moeite waard om te onderzoeken *hoe* deze interactie precies tot stand komt en waar de werkelijke waarde voor de gebruiker ligt.

Binnen de cardiovasculaire gezondheidszorg zijn patiënten en professionals in het algemeen positief over het potentieel van eHealth(44-46), echter is maar weinig bekend over welke impact deze technologische transitie heeft op vlak van stress en angst in een steeds maar groeiende, ouder wordende, patiënt populatie. Bewijs hiervoor blijft beperkt (47). De technologische ontwikkelingen in de cardiovasculaire gezondheidszorg nemen jaarlijks exponentieel toe (48), echter is de ontwikkeling van ons als mens op biologisch en psychologisch vlak niet vergelijkbaar.

Een goed voorbeeld hiervan is de toename van depressies en angststoornissen onder jongeren als gevolg van frequent 'social media' gebruik en moderne mobiele technologie (49-51). Studies die de invloed van eHealth op het psychologisch welbevinden van cardiovasculaire patiënten onderzoeken zijn schaars. HF wetenschap kan een waardevolle aanvulling hierin zijn om systematisch de (psychologische) impact van nieuwe technologie, zoals eHealth, op de gebruiker te begrijpen. Tegelijkertijd biedt het methoden om nieuwe apparaten *te ontwikkelen en te implementeren* in lijn met de voorkeur van patient en professional.

Vooral het gebruik van de 'patient-belevenis' (patient journey) zoals voorgesteld in dit proefschrift, maakt het mogelijk om het dagelijks klinisch werk en al zijn aspecten te belichten, zoals de interactie met de professional en de impact hiervan op de patient. Vanuit een waarde gedreven perspectief worden uitkomsten op een persoonlijk niveau zo meer transparant en kwantificeerbaar (33, 34, 52).

Dit proces van de 'zorg-beleving' in kaart brengen door de mens centraal te stellen wordt niet alleen ingezet om het gebruik van nieuwe technologie te ondersteunen, maar ook om complete zorgpaden in andere domeinen van de gezondheidszorg te ontwikkelen (33, 53, 54).

De meerwaarde van dit proces ligt niet alleen bij het feit dat duidelijk wordt hoe deelnemers nieuwe elementen van zorg waarderen of beleven, maar ook dat de gehele 'zorg-beleving' tegelijkertijd kan worden aangepast met deze input op een zinnige manier. Vanuit een 'Waarde Gedreven Zorg' perspectief zorgt deze methodologie ervoor dat de nadruk komt te liggen bij *waarde op meta-niveau*.

Verscheidene dimensies van menselijke gezondheid, ziekte en de uitkomsten ervan op de mens zorgen voor een interactie met het gezondheidszorg *systeem*, en niet zozeer een enkel los contactmoment. Het gebruik van HF wetenschap en voornamelijk het in kaart brengen van de patient beleving in de zorg, ondersteund de gedachte dat het ontwikkelen van zorg niet bedoeld is voor een enkel aspect van ziekte. De HF wetenschap maakt het in zekere zin mogelijk dat bij de ontwikkeling en vormgeving van de zorg de focus komt te liggen op het gehele zorgcontinuüm van chronische ziekten, waar cardiovasculaire ziekte een groot deel van uit maakt. Hierbij is een nauwe samenwerking tussen patiënten en professionals onontbeerlijk. Ondanks dat enkele studies in dit proefschrift uit kleine studiepopulaties bestaan, kan betekenisvolle informatie ingewonnen worden door gestructureerde systematische analyses te gebruiken, zoals het in kaart brengen van de 'patient beleving'.

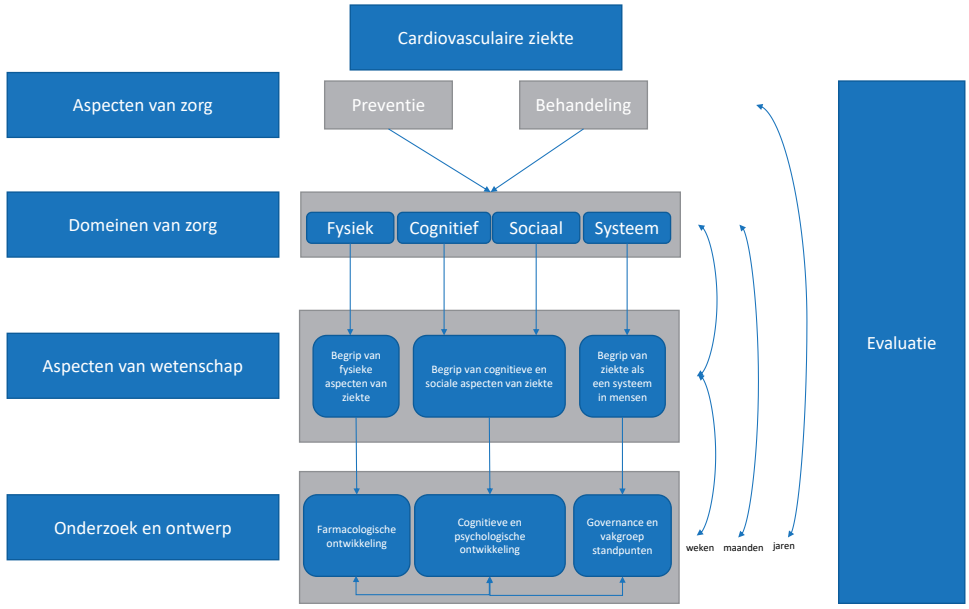
Om de zorg verder te ontwikkelen kan aandacht voor de langdurigheid van ziekte en de zorgprocessen die het met zich meebrengt een volgende interessante stap zijn in 'mens gecentreerd ontwerpen' en het in kaart brengen van de patient beleving.

Cardiovasculaire ziekte is voornamelijk een chronische aandoening wat tot langdurig lijden op lichamelijk en emotioneel vlak leidt (55). Het ondersteunen van de patiënt door zelfzorg en autonomie te bevorderen, kan de perceptie van behandeling en de uitkomst hiervan positief beïnvloeden met uiteindelijk toegenomen levensverwachting (56). Om de patient hiertoe in staat te stellen is het vooral van belang om te begrijpen hoe patiënten hun ziekte beleven, hoe zij er mee omgaan en wat zij verwachten van de behandeling (57), maar ook hoe zij hun algemene gezondheid zien (58). Deze 'ziekte- en gezondheidspercepties' kunnen als fundament dienen voor verder onderzoek om uiteindelijk uitkomsten meer patient,- en waarde gedreven te maken.

Om dit te bereiken is het naar mijn mening noodzakelijk om professionals uit andere disciplines zoals de geesteswetenschappen en ingenieurswetenschap te betrekken bij de implementatie van 'mens gecentreerd ontwerpen' en de HF wetenschap in modern

cardiovasculaire onderzoek. Dit zal leiden tot een brede wetenschappelijke basis, essentieel voor verdere ontwikkeling van cardiovasculaire zorg in de 21ste eeuw.

Om de kwaliteit van klinische zorg en onderzoek te bevorderen is daarnaast frequente gedegen evaluatie van de wetenschappelijke processen noodzakelijk op vlak van bruikbaarheid, betekenis en waarde. Niet alleen door de professional, maar ook de patient. Zo wordt het verbeteren van zorg continue gewaarborgd (figuur 1). Het betrekken van HF specialisten in het fundament van dit proces in moderne ziekenhuizen en bij klinisch onderzoek, zorgt voor hybride zorgcentra met een diversiteit aan specialisten wat voor nieuwe mogelijkheden zorgt in de verdere ontwikkeling van cardiovasculaire zorg. Ontworpen door mensen, voor mensen.



Figuur 1. De toekomst van cardiovasculaire zorg en wetenschappelijk onderzoek.

Legenda: Human Factors wetenschap maakt het mogelijk om met een holistische methode, complexe systemen zoals cardiovasculaire zorg verder te ontwikkelen aangaande dagelijkse zorg en wetenschappelijk onderzoek. De basis hiervan bestaat uit gedegen evaluatie van wetenschap,- en ontwerp elementen op het persoonlijke,- en systeem niveau, waardoor een continue lus van verbeteren ontstaat.

Referenties

1. CardioPulse Articles - SWEDEHEART: Sweden's new online cardiac registry, the first of its kind. European Heart Journal. 2009;30(18):2165-73.
2. Dutch Government. Law Quality, Complaints and Disputes in Healthcare. [Article 9]. 2015 [Available from: https://www.overheid.nl/.
3. Bridgewater B, Grant S, Hickey G, Fazel N. National Institute for Cardiovascular Outcomes Research & The Society of Cardiothoracic Surgery in Great Britain and Ireland. (2012). National Adult Cardiac Surgery Audit Report: 2010-112012.
4. Wierda E, Eindhoven DC, Schalij MJ, Borleffs CJW, Amoroso G, van Veghel D, et al. Privacy of patient data in quality-of-care registries in cardiology and cardiothoracic surgery: the impact of the new general data protection regulation EU-law. European heart journal Quality of care & clinical outcomes. 2018;4(4):239-45.
5. Nederlandse Hart Registratie 2021 [Available from: https://nederlandsehartregistratie.nl/.
6. Dhruva SS, Parzynski CS, Gamble GM, Curtis JP, Desai NR, Yeh RW, et al. Attribution of Adverse Events Following Coronary Stent Placement Identified Using Administrative Claims Data. Journal of the American Heart Association. 2020;9(4):e013606.
7. Eindhoven DC, Wu HW, Kremer SWF, van Erkelens JA, Cannegieter SC, Schalij MJ, et al. Mortality differences in acute myocardial infarction patients in the Netherlands: The weekend-effect. American heart journal. 2018;205:70-6.
8. Hemingway H, Asselbergs FW, Danesh J, Dobson R, Maniadakis N, Maggioni A, et al. Big data from electronic health records for early and late translational cardiovascular research: challenges and potential. Eur Heart J. 2018;39(16):1481-95.
9. Kohsaka S, Katada J, Saito K, Jenkins A, Li B, Mardekian J, et al. Safety and effectiveness of non-vitamin K oral anticoagulants versus warfarin in real-world patients with non-valvular atrial fibrillation: a retrospective analysis of contemporary Japanese administrative claims data. Open heart. 2020;7(1):e001232.
10. Ten Have P, Hilt AD, Paalvast H, Eindhoven DC, Schalij MJ, Beeres S. Non-ST-elevation myocardial infarction in the Netherlands: room for improvement! Netherlands heart journal : monthly journal of the Netherlands Society of Cardiology and the Netherlands Heart Foundation. 2020;28(10):537-45.
11. Jarow JP, LaVange L, Woodcock J. Multidimensional Evidence Generation and FDA Regulatory Decision Making: Defining and Using "Real-World" Data. Jama. 2017;318(8):703-4.
12. Mueller S, Gottschalk F, Groth A, Meeraus W, Driessen M, Kohlmann T, et al. Primary data, claims data, and linked data in observational research: the case of COPD in Germany. Respiratory research. 2018;19(1):161.
13. Saturni S, Bellini F, Braido F, Paggiaro P, Sanduzzi A, Scichilone N, et al. Randomized Controlled Trials and real life studies. Approaches and methodologies: a clinical point of view. Pulmonary pharmacology & therapeutics. 2014;27(2):129-38.

14. Sohlberg EM, Brubaker WD, Zhang CA, Anderegg LDL, Dallas KB, Song S, et al. Urinary Stone Disease in Pregnancy: A Claims Based Analysis of 1.4 Million Patients. The Journal of urology. 2020;203(5):957-61.
15. Woodside KJ, Bell S, Mukhopadhyay P, Repeck KJ, Robinson IT, Eckard AR, et al. Arteriovenous Fistula Maturation in Prevalent Hemodialysis Patients in the United States: A National Study. American journal of kidney diseases : the official journal of the National Kidney Foundation. 2018;71(6):793-801.
16. Boggon R, van Staa TP, Chapman M, Gallagher AM, Hammad TA, Richards MA. Cancer recording and mortality in the General Practice Research Database and linked cancer registries. Pharmacoepidemiology and drug safety. 2013;22(2):168-75.
17. Cogle CR, Levin G, Lee DJ, Peace S, Herna MC, MacKinnon J, et al. Finding incident cancer cases through outpatient oncology clinic claims data and integration into a state cancer registry. Cancer causes & control : CCC. 2021;32(2):199-202.
18. Ennis RD, Parikh AB, Sanderson M, Liu M, Isola L. Interpreting Oncology Care Model Data to Drive Value-Based Care: A Prostate Cancer Analysis. Journal of oncology practice. 2019;15(3):e238-e46.
19. Kuliszewski MG, Lee FF, Schymura MJ. Can Oncology Practice Claims Data Replace Physician Reporting to State Cancer Registries? Journal of registry management. 2020;47(3):113-7.
20. Berger ML, Mamdani M, Atkins D, Johnson ML. Good research practices for comparative effectiveness research: defining, reporting and interpreting nonrandomized studies of treatment effects using secondary data sources: the ISPOR Good Research Practices for Retrospective Database Analysis Task Force Report--Part I. Value in health : the journal of the International Society for Pharmacoeconomics and Outcomes Research. 2009;12(8):1044-52.
21. Strom JB, Tamez H, Zhao Y, Valsdottir LR, Curtis J, Brennan JM, et al. Validating the use of registries and claims data to support randomized trials: Rationale and design of the Extending Trial-Based Evaluations of Medical Therapies Using Novel Sources of Data (EXTEND) Study. American heart journal. 2019;212:64-71.
22. Hasselgren A, Kralevska K, Gligoroski D, Pedersen SA, Faxvaag A. Blockchain in healthcare and health sciences-A scoping review. International journal of medical informatics. 2020;134:104040.
23. Issa NT, Byers SW, Dakshanamurthy S. Big data: the next frontier for innovation in therapeutics and healthcare. Expert review of clinical pharmacology. 2014;7(3):293-8.
24. Ohno-Machado L. Advancing healthcare and biomedical research via new data-driven approaches. Journal of the American Medical Informatics Association : JAMIA. 2017;24(3):471.
25. Johnson KW, Torres Soto J, Glicksberg BS, Shameer K, Miotto R, Ali M, et al. Artificial Intelligence in Cardiology. Journal of the American College of Cardiology. 2018;71(23):2668-79.
26. Lopez-Jimenez F, Attia Z, Arruda-Olson AM, Carter R, Chareonthaitawee P, Jouni H, et al. Artificial Intelligence in Cardiology: Present and Future. Mayo Clinic proceedings. 2020;95(5):1015-39.

27. Westcott RJ, Tcheng JE. Artificial Intelligence and Machine Learning in Cardiology. JACC Cardiovascular interventions. 2019;12(14):1312-4.
28. Gillum RF. From papyrus to the electronic tablet: a brief history of the clinical medical record with lessons for the digital age. The American journal of medicine. 2013;126(10):853-7.
29. Haerkens MH, Jenkins DH, van der Hoeven JG. Crew resource management in the ICU: the need for culture change. Annals of intensive care. 2012;2(1):39.
30. Mearns K, Whitaker S, Flin R. Safety Climate, Safety Management Practice and Safety Performance in Offshore Environments. Safety Science2003. 641-80 p.
31. Russ AL, Fairbanks RJ, Karsh BT, Militello LG, Saleem JJ, Wears RL. The science of human factors: separating fact from fiction. BMJ quality & safety. 2013;22(10):802-8.
32. Sexton JB, Thomas EJ, Helmreich RL. Error, stress, and teamwork in medicine and aviation: cross sectional surveys. BMJ (Clinical research ed). 2000;320(7237):745-9.
33. Carayon P, Wooldridge A, Hoonakker P, Hundt AS, Kelly MM. SEIPS 3.0: Human-centered design of the patient journey for patient safety. Appl Ergon. 2020;84:103033.
34. Holden RJ, Carayon P. SEIPS 101 and seven simple SEIPS tools. BMJ quality & safety. 2021;30(11):901-10.
35. Cheung CC, Deyell MW. Remote Monitoring of Cardiac Implantable Electronic Devices. The Canadian journal of cardiology. 2018;34(7):941-4.
36. DeVore AD, Wosik J, Hernandez AF. The Future of Wearables in Heart Failure Patients. JACC Heart failure. 2019;7(11):922-32.
37. Howard IM, Kaufman MS. Telehealth applications for outpatients with neuromuscular or musculoskeletal disorders. Muscle & nerve. 2018;58(4):475-85.
38. Jeong IC, Bychkov D, Searson PC. Wearable Devices for Precision Medicine and Health State Monitoring. IEEE transactions on bio-medical engineering. 2019;66(5):1242-58.
39. Dulai R, Shunmugam SR, Veasey RA, Patel NR, Sugihara C, Furniss S. An economic evaluation of an advanced video conferencing system for cardiac multidisciplinary team meetings. International journal of clinical practice. 2020;74(9):e13562.
40. Fatehi F, Martin-Khan M, Smith AC, Russell AW, Gray LC. Patient satisfaction with video teleconsultation in a virtual diabetes outreach clinic. Diabetes technology & therapeutics. 2015;17(1):43-8.
41. Dagher L, Shi H, Zhao Y, Marrouche NF. Wearables in cardiology: Here to stay. Heart rhythm. 2020;17(5 Pt B):889-95.
42. Pevnick JM, Birkeland K, Zimmer R, Elad Y, Kedan I. Wearable technology for cardiology: An update and framework for the future. Trends in cardiovascular medicine. 2018;28(2):144-50.
43. Brickwood KJ, Watson G, O'Brien J, Williams AD. Consumer-Based Wearable Activity Trackers Increase Physical Activity Participation: Systematic Review and Meta-Analysis. JMIR mHealth and uHealth. 2019;7(4):e11819.
44. Birkhoff SD, Smeltzer SC. Perceptions of Smartphone User-Centered Mobile Health Tracking Apps Across Various Chronic Illness Populations: An Integrative Review. Journal of nursing

scholarship : an official publication of Sigma Theta Tau International Honor Society of Nursing. 2017;49(4):371-8.
45. Treskes RW, Koole M, Kauw D, Winter MM, Monteiro M, Dohmen D, et al. Adults with congenital heart disease: ready for mobile health? Netherlands heart journal : monthly journal of the Netherlands Society of Cardiology and the Netherlands Heart Foundation. 2019;27(3):152-60.
46. Treskes RW, Wildbergh TX, Schalij MJ, Scherptong RWC. Expectations and perceived barriers to widespread implementation of e-Health in cardiology practice: Results from a national survey in the Netherlands. Netherlands heart journal : monthly journal of the Netherlands Society of Cardiology and the Netherlands Heart Foundation. 2019;27(1):18-23.
47. Narasimha S, Madathil KC, Agnisarman S, Rogers H, Welch B, Ashok A, et al. Designing Telemedicine Systems for Geriatric Patients: A Review of the Usability Studies. Telemedicine journal and e-health : the official journal of the American Telemedicine Association. 2017;23(6):459-72.
48. Bhavnani SP, Narula J, Sengupta PP. Mobile technology and the digitization of healthcare. Eur Heart J. 2016;37(18):1428-38.
49. Lissak G. Adverse physiological and psychological effects of screen time on children and adolescents: Literature review and case study. Environmental research. 2018;164:149-57.
50. Vidal C, Lhaksampa T, Miller L, Platt R. Social media use and depression in adolescents: a scoping review. International review of psychiatry (Abingdon, England). 2020;32(3):235-53.
51. Woods HC, Scott H. #Sleepyteens: Social media use in adolescence is associated with poor sleep quality, anxiety, depression and low self-esteem. Journal of adolescence. 2016;51:41-9.
52. Carayon P, Wood KE. Patient safety. Information Knowledge Systems Management. 2009;8:23-46.
53. Kianfar S, Carayon P, Hundt AS, Hoonakker P. Care coordination for chronically ill patients: Identifying coordination activities and interdependencies. Applied Ergonomics. 2019;80:9-16.
54. Holden RJ, Valdez RS, Schubert CC, Thompson MJ, Hundt AS. Macroergonomic factors in the patient work system: examining the context of patients with chronic illness. Ergonomics. 2017;60(1):26-43.
55. Leventhal H, Phillips LA, Burns E. The Common-Sense Model of Self-Regulation (CSM): a dynamic framework for understanding illness self-management. Journal of behavioral medicine. 2016;39(6):935-46.
56. Petrie KJ, Cameron LD, Ellis CJ, Buick D, Weinman J. Changing illness perceptions after myocardial infarction: an early intervention randomized controlled trial. Psychosomatic medicine. 2002;64(4):580-6.
57. Broadbent E, Wilkes C, Koschwanez H, Weinman J, Norton S, Petrie KJ. A systematic review and meta-analysis of the Brief Illness Perception Questionnaire. Psychology & health. 2015;30(11):1361-85.

58. Huber M, van Vliet M, Giezenberg M, Winkens B, Heerkens Y, Dagnelie PC, et al. Towards a 'patient-centred' operationalisation of the new dynamic concept of health: a mixed methods study. BMJ open. 2016;6(1):e010091.

Appendices

Dankwoord

De studies die in dit proefschrift staan beschreven zijn uitgevoerd in het Hart Long Vaatcentrum van het LUMC te Leiden, waarvan enkele in nauwe samenwerking met de TU Delft. Deze studies zouden niet bestaan zonder de patiënten die eraan mee wilden werken als ook de waardevolle en vruchtbare samenwerking met verscheidene collega's van diverse disciplines. Mijn dank is dan ook uitermate groot aan eenieder die mij tijdens deze reis heeft begeleid, van feedback heeft voorzien of er op een of andere manier voor me was danwel mij heeft ondersteund tijdens de afgelopen jaren om mijn proefschrift te schrijven. Enkele van jullie wil ik in het bijzonder bedanken.

Mijn promotor, Prof. Dr. Martin Jan Schalij. Beste Martin, met bijzonder veel plezier en blijdschap kijk ik terug op onze samenwerking. Je zei het meteen; 'ik ga je niet aan de hand nemen, van een promotietraject leer jij het meeste als je het zelf doet'. Ik heb het geweten. Ik heb alles kunnen doen zoals ik dat voor me zag en jij faciliteerde het. De mate waarin je leidt, visie tot uiting brengt, een voorbeeld bent als clinicus en dat combineert met de academie, is een groot voorbeeld. Ik hoop nog veel met je samen te mogen werken.

Mijn copromotores, Dr Scherptong en Dr Beeres: Roderick, onze samenwerking waardeer ik tot op de dag; ik wil je bedanken voor alle nuttige en scherpe overleg momenten die we samen hadden en onze talloze schaterlach momenten; je hebt heerlijke humor. Jouw gevatheid en compacte manier van wetenschap bedrijven heeft me veel geleerd en pas ik nog dagelijks toe. Saskia: wat een assertieve en recht-door-zee clinica ben je! Onze wetenschappelijk samenwerking en het schrijven van manuscripten was ontzettend fijn. Je hebt me rust en structuur gegeven, overleg was altijd to the point en effectief. Je schrijfstijl en aanvullingen scherp en concreet. Ik hoop nog vele jaren met jullie beide te mogen samenwerken tijdens mijn verdere opleiding.

Mijn directe en indirecte collega's binnen en buiten het LUMC en de 'tuin'; het zijn er teveel om op te noemen, maar ook jullie bedankt voor de fijne samenwerking. In het bijzonder Danielle; jouw enthousiasme voor het onderwerp 'kwaliteit van zorg' was aanstekelijk, super hoe je me daarnaast bij de eerste stappen van dit proefschrift en het PhD-leven hebt begeleid.

Lieve Wilco, Felix, Nasiem, Thomas, Leonieke, Ineke, Ahmed, Gido en Karen; ook na onze gezamenlijke studententijd geniet ik enorm van ons samenzijn. Tijdens mijn promotietijd hebben jullie me ook enorm gesteund; dank voor de luisterende oren en momenten van ontspanning.

Lieve groep Alfa's en aanhang – Tom & Claire, Nicky & Lisa, Kevin, Chris & Daniela, Guido, Maurice & Shirley en Swen; het is zo bijzonder dat wij, acht mannen (en inmiddels wat aanhang) die elkaar als sinds 2001 kennen, nog steeds zulke hechte en goede vrienden zijn. We hebben door alle jaren heen heel wat meegemaakt, van leuke tot minder leuke periodes. Ook tijdens mijn promotietijd zijn jullie er altijd voor me geweest; ik kon alles kwijt bij jullie, jullie zijn altijd een veilige haven geweest. Onze vriendschap koester ik voor altijd, op naar nog meer mooie jaren.

Lieve Doctor Daniel, jij bent er altijd voor me en nu ben je ook nog eens mijn paranimf. Ik ken je al sinds 1993 en we zien mekaar nog steeds geregeld. Onze liefde voor alles wat het woord 'nerd' draagt verbindt ons gigantisch. Je bent een van m'n meest dierbare vrienden; ik hoop nog etmalen meer tijd met je door te brengen.

Aan alle vrienden en familie die ik niet apart heb benoemd; jullie zijn niet vergeten, ik ben dankbaar voor de momenten die we samen hebben en hoop nog veel met jullie door te brengen in de nabije toekomst.

Lieve Pap en Mam, Jan en Angelika. Jullie hebben mij een liefdevol thuis gegeven, een rijke opvoeding laten genieten die van onschatbare waarde is, dag in, dag uit. Jullie hebben mij de mogelijkheid gegeven te studeren en mij te ontplooien tot een zelfstandig, breed ontwikkeld persoon in een roerige wereld. Een *Uomo Universale* in hart en nieren. Ik hoop nog vele jaren veel lol met jullie te mogen hebben, op reis maar ook thuis. Ik houd van jullie.

Tot slot m'n lieve Roos. De korte tijd dat we samenzijn zegt niets over de manier waarop we samen zijn; het voelt alsof het altijd al zo was. De manier waarop je mij, m'n werk en alles wat ik doe begrijpt en me liefde geeft; het maakt het makkelijk om van je te houden.

Contributing authors

Albayrak A, Technical University Delft, Faculty of Industrial Design Engineering, Delft, the Netherlands.

Atsma DE, Department of Cardiology, Leiden University Medical Center, Leiden, The Netherlands.

Aardoom JJ, Department of Public Health and Primary Care, LUMC, Leiden, The Netherlands, National E-health Living Lab, NELL, Leiden, The Netherlands.

Beeres SLMA, Department of Cardiology, Leiden University Medical Center, Leiden, The Netherlands.

Chavannes NH, Department of Public Health and Primary Care, LUMC, Leiden, The Netherlands, National E-health Living Lab, NELL, Leiden, The Netherlands.

Eijkenduijn J, Faculty of Technical Medicine, Delft University of Technology, Delft, The Netherlands.

Eindhoven DC, Department of Cardiology, Leiden University Medical Center, Leiden, The Netherlands.

Kaptein AA, Department of Clinical Psychology, Leiden University Medical Center, Leiden, The Netherlands.

Kemp AC, Technical University Delft, Faculty of Industrial Design Engineering, Delft, the Netherlands.

Mamaqi Kapplani K, Technical University Delft, Faculty of Industrial Design Engineering, Delft, the Netherlands.

Melles M, Technical University Delft, Faculty of Industrial Design Engineering, Delft, the Netherlands. Amsterdam University Medical Centre, Vrije Universiteit Amsterdam, Department of Public and Occupational Health, Amsterdam, The Netherlands.

Paalvast H, Zorginstituut Nederland (ZINL), Diemen, The Netherlands.

ten Have P, Zorginstituut Nederland (ZINL), Diemen, The Netherlands.

Schalij MJ, Department of Cardiology, Leiden University Medical Center, Leiden, The Netherlands.

Scherptong RWC, Department of Cardiology, Leiden University Medical Center, Leiden, The Netherlands.

van Schaik J, Department of Vascular Surgery, Leiden University Medical Center, Leiden, The Netherlands.

Umans VAWM, Department of Cardiology, Noordwest Ziekenhuisgroep, locatie Alkmaar, Alkmaar, The Netherlands.

Vossenberg TNE, Department of Cardiology, Medisch Centrum Leeuwarden, Leeuwarden, The Netherlands.

Wessilius FJ, Faculty of Technical Medicine, Delft University of Technology, Delft, The Netherlands.

Woudenberg T, Faculty of Medicine, Leiden University Medical Center, Leiden, The Netherlands.

List of Abbreviations

ACE-/AT2-inhibitors	Angiotensin Converting Enzyme/ Angiotensin II receptor inhibitors
CAD:	Coronary Artery Disease
CI	Confidence Interval
CMAQ	Cockpit Management Attitudes Questionnaire
CRM	Crew Resource Management
DBC	Diagnose Behandel Combinatie
DIS	DBC Informatie Systeem
EMR:	Electronic Medical Record
ET(T)	Endovascular Treatment (Team)
FMAQ	Flight Management Attitudes Questionnaire
GIP	Geneesmiddelen Informatie Project
GS-PEQ:	Generic Short Patient Experiences Questionnaire
HF	Human Factors
HMD:	Head Mounted Device
ICU	Intensive Care Unit
ICUMAQ	Intensive Care Unit Management Attitudes Questionnaire
ITQ	Immersive Tendencies Questionnaire
IQR	Inter Quartile Range
JS	Job Satisfaction
LUMC	Leiden University Medical Centre
LVF%	Left Ventricular Function in percentages
METC:	Medical Ethical Committee
MI:	Myocardial Infarction
MR:	Mixed Reality
NSTEMI	Non ST-elevation Myocardial Infarction
OR	Odds Ratio
OR*	Operating Room
OT(T)	Open Treatment (Team)
PIE:	Patient Information and Education
PROM:	Patient Reported Outcome Measure
PQ	Presence Questionnaire
PCI	Percutaneous Coronary Intervention
P2Y12	Thienopyridine receptor blockers
PoM	Perceptions of Management
SAQ	Safety Attitudes Questionnaire
SAQ-NL	Safety Attitudes Questionnaire Dutch Edition
SC	Safety Climate

SMD	Standardized Mean Difference
STEMI	ST-elevation Myocardial Infarction
SR	Stress Recognition
STEMI	ST-elevation myocardial infarction
Tmax	Maximum Troponin release
TC	Teamwork Climate
TeamSTEPPS	Team Strategies and Tools to Enhance Performance and Patient Safety
VBHC	Value Based Healthcare
VR	Virtual Reality
WC	Working Conditions
WHO	World Health Organization
ZINL	Zorginstituut Nederland

List of publications

This thesis

- Ten Have P*, **Hilt AD***, Paalvast H, Eindhoven DC, Schalij MJ, Beeres SLMA.
  Non-ST-elevation myocardial infarction in the Netherlands: room for improvement! Neth Heart J. 2020 Oct;28(10):537-545. doi: 10.1007/s12471-020-01433-x. PMID: 32495295.

- **Hilt AD,** Umans VAWM, Vossenberg TNE, Schalij MJ, Beeres SMLA.
  Myocardial infarction treatment among socioeconomic environments – claims data analysis. (submitted)

- **Hilt AD,** Scherptong RWC.
  Value Based Healthcare in cardiovascular care – the added value of human factors science. Human Factors NL September 2020 (Human Factors NL issue 45(4), November 2020)

- **Hilt AD**, Kaptein AA, Schalij MJ, van Schaik J.
  Teamwork and Safety Attitudes in Complex Aortic Surgery at a Dutch Hospital: Cross-Sectional Survey Study. JMIR Hum Factors. 2020 Apr 8;7(2):e17131. doi: 10.2196/17131. PMID: 32267238; PMCID: PMC7177441.

- **Hilt AD***, Mamaqi Kapllani K*, Hierck BP, Kemp AC, Albayrak A, Melles M, Schalij MJ, Scherptong RWC.
  Perspectives of Patients and Professionals on Information and Education After Myocardial Infarction With Insight for Mixed Reality Implementation: Cross-Sectional Interview Study. JMIR Hum Factors. 2020 Jun 23;7(2):e17147. doi: 10.2196/17147. PMID: 32573464; PMCID: PMC7381062.

- **Hilt AD,** Hierck BP, Eijkenduijn J, Wessilius F, Schalij MJ, Scherptong RWC.
  Development of a Patient-Oriented Hololens Application to Illustrate the Function of Medication after Myocardial Infarction *European Heart Journal - Digital Health*, Volume 2, Issue 3, September 2021; 511-520, https://doi.org/10.1093/ehjdh/ztab053

- Aardoom JJ*, **Hilt AD***, Woudenberg T, Chavannes NH, Atsma DE.
  A Preoperative Virtual Reality App for Patients Scheduled for Cardiac Catheterization: Pre-Post Questionnaire Study Examining Feasibility, Usability, and Acceptability. JMIR Cardio. 2022 Feb 22;6(1):e29473. doi: 10.2196/29473. PMID: 35191839; PMCID: PMC8905473.

Not this thesis:

- **CAPACITY-COVID collaborative consortium and LEOSS Study Group***
  Clinical presentation, disease course and outcome of COVID-19 in hospitalized patients with and without pre-existing cardiac disease – a cohort study across eighteen countries. Eur Heart J. 2021 Nov 4:ehab656. doi: 10.1093/eurheartj/ehab656. Epub ahead of print. PMID: 34734634.

- Biersteker TE, MD; **Hilt AD, MD;** Schalij MJ MD, PhD; Treskes RW, MD, PhD.
  The Box: methods and results of a real world experience of mHealth implementation in clinical practice. JMIR Cardio. 2021 Dec 16;5(2):e26072. doi: 10.2196/26072. PMID: 34642159.

- **Hilt AD,** Rasing I, Schalij MJ, Wermer MJH.
  To treat or not to treat: left ventricular thrombus in a patient with cerebral amyloid angiopathy: a case report. Eur Heart J Case Rep. 2020 Dec 7;4(6):1-5. doi: 10.1093/ehjcr/ytaa492. PMID: 33629014; PMCID: PMC7891271.

- Kaptein AA, van der Meer PB, Florijn BW, **Hilt AD**, Murray M, Schalij MJ.
  Heart in art: cardiovascular diseases in novels, films, and paintings. Philos Ethics Humanit Med. 2020 Feb 13;15(1):2. doi: 10.1186/s13010-020-0086-3. PMID: 32050992; PMCID: PMC7017445.

- Eindhoven DC, **Hilt AD**, Zwaan TC, Schalij MJ, Borleffs CJW.
  Age and gender differences in medical adherence after myocardial infarction: Women do not receive optimal treatment - The Netherlands claims database. Eur J Prev Cardiol. 2018 Jan;25(2):181-189. doi: 10.1177/2047487317744363. Epub 2017 Nov 22. PMID: 29164916.

- van Vliet P, **Hilt AD**, Thijs RD, van Dijk JG.
  Effect of orthostatic hypotension on sustained attention in patients with autonomic failure. J Neurol Neurosurg Psychiatry. 2016 Feb;87(2):144-8. doi: 10.1136/jnnp-2014-309824. Epub 2015 Mar 6. PMID: 25749693.

Portfolio (Overview of PhD training)

Education and Courses

- *Basiscursus Regelgeving en Organisastie voor Klinisch onderzoekers (eBROK)* *2020*
- *Gevorderde Epidemiologie cursus* *2018*
- *Basis Epidemiologie cursus* *2018*
- *Basic Methods and Reasoning in Biostatistics* *2018*
- *PhD Introductory Meeting* *2017*

Conferences, Symposia and Meetings

Oral Presentations

- *"Human Factors research in cardiovascular diseases – overview"*
  Human Factors NL conference, Contact der Kontinenten, Soesterberg,
  The Netherlands. *2019*
- *"Mixed Reality in cardiovascular disease – experimental approach"*
  Leiden University Medical Center quality of care symposium
  Leiden University Medical Center, Leiden, The Netherlands. *2018*
- *"Developing a Mixed Reality educational tool for myocardial infarction patients"*
  Behavioural Sciences Applied to Surgery and acute care settings (BSAS) meeting,
  Klinikum der Universitat Munchen, Munich, Germany. *2018*
- *"Added value of Claims data research in clinical cardiovascular research"*
  Nederlandse Vereniging Voor Cardiologie(NVVC)-connect ACS workgroup,
  Holland Heart House, Utrecht, The Netherlands. *2017*

Poster Presentations

- *Myocardial infarction care among socioeconomic classes*
  ACC '21, the digital experience. *2021*
- *Safety Culture analysis in cardiology – Human Factors approach*
  Behavioural Sciences Applied to Surgery and acute care settings (BSAS) meeting,
  Klinikum der Universitat Munchen, Munich, Germany. *2018*

Teaching Activities

- Monthly Supervision of Master's scientific internship (3 months) 2021
- Daily Supervision of Master's scientific internship (6 months) 2020
- Daily Supervision of Master's thesis (3 months) 2020
- Daily Supervision of Master's thesis (3 months) 2019
- Daily Supervision of Master's scientific internship (6 months) 2018
- Daily Supervision of Bachelor's thesis (5 months) 2017-2020
- Bachelor Workgroup teaching (1 month) 2018-2019

Societal Outreach

- Bi-monthly out-patient care of myocardial infarction patients 2017-2020

Curriculum Vitae

Alexander Daniel Hilt werd op 3 oktober 1988 geboren te Rotterdam. Hij groeide op in Berkel en Rodenrijs. Zijn middelbare schooltijd aan het Sint Laurens college te Hillegersberg, Rotterdam begon in 2001 en voltooide hij in 2007 toen hij zijn VWO diploma in ontvangst nam. In september 2007 begon hij met aan de studie geneeskunde in Leiden.

Zijn eerste aanraking met medisch wetenschappelijk onderzoek was in het jaar 2012 toen hij zijn wetenschapsstage begon bij Prof. Dr. Gert van Dijk en Dr. Roland Thijs alwaar hij klinisch experimenteel onderzoek deed naar syncope en invloed op cognitie, waarvan tevens een publicatie zou volgen. Na zijn afstuderen in 2015 heeft hij 2 jaar als arts-assistent bij de afdelingen Neurologie, Spoed Eisende Hulp en Interne Geneeskunde van het Albert Schweitzer Ziekenhuis te Dordrecht gewerkt om klinische ervaring op te doen. Het was in dit ziekenhuis dat hij werd gefascineerd door het vakgebied cardiologie.

In maart 2017 kwam hij terecht bij zijn alma mater (LUMC) om zich daar te storten op de academische cardiologie binnen het Hartlong centrum; allereerst door zes maanden klinische ervaring op te doen, gevolgd door de start van zijn promotie onderzoek in september van dat jaar. Begeleid door hoogleraar Prof. Dr. Martin Jan Schalij, Dr. Roderick Scherptong en Dr. Saskia Beeres, heeft hij in ruim drie-en-een-half jaar tijd gekeken hoe waarde gedreven zorg (‘Value Based Healthcare’) vorm gegeven kon worden binnen de moderne cardiologie op zowel landelijk- als lokaal (ziekenhuis) niveau. Per 1 januari 2021 is Alex cardioloog in opleiding.