Innovations in prehospital emergency cardiac care: alleviating the strain on overcrowded hospitals

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7.
CONCLUSIES
AI
TRIAGE HUB
UITSLAG

Chapter 7

Summary, conclusions and future perspective

Chapter 1 of this thesis provided an extensive examination of the demographic changes, healthcare obstacles, and the imperative for inventive solutions. It stressed the urgency of tackling these issues in light of the predicted surge in the elderly population and the resultant strain on healthcare resources.

The introduction discussed the rising demand for healthcare services amidst a shrinking workforce, leading to considerable challenges in healthcare organization and escalating healthcare costs. The unsustainable burden on the Dutch gross national product due to healthcare expenditure necessitates urgent measures to ensure the long-term financial stability and effectiveness of the healthcare system.

Moreover, it highlighted the complications arising from an aging population, such as higher rates of comorbidity and complex patient problems, contributing to longer waiting times, growing waiting lists, and hospital overcrowding. The adverse effects of overcrowding on patient outcomes and healthcare professionals' well-being were emphasized, especially in the context of the COVID-19 pandemic, which further strained healthcare resources.

To address these challenges, the Dutch government formulated the Integral Healthcare Agreement (IZA) to prioritize fitting care and regional collaboration between healthcare providers, financiers, and the government. The focus on streamlining data exchange, reinforcing primary care or care at home, and tailoring healthcare to patients' specific needs were highlighted as key strategies to ensure sustainable healthcare delivery now and in the future.

The introduction further emphasized the importance of triage and risk scores in optimizing healthcare resource utilization, particularly in the prehospital setting. It discussed various risk scores, such as the HEART score, commonly used in the assessment of patients with chest pain, and highlighted the potential of prehospital risk scores, such as the preHEART and modified HEART scores, in identifying low-risk patients before they are presented to the hospital. Furthermore, it delved into prehospital clinical studies using these (prehospital) risk scores, such as the ACCESS study, URGENT 1.5 trial, FamouS Triage study, and ARTICA trial, which demonstrated the effectiveness of risk scores in identifying low-risk patients in the prehospital setting.

The importance of data sharing among healthcare providers and the potential of AI and machine learning technologies in optimizing prehospital triage protocols were discussed. Data sharing among healthcare providers is critical for effective decision-making, particularly in prehospital cardiac triage. Current practices often resulted in fragmented data, hindering comprehensive patient care. By establishing seamless communication channels between paramedics, general practitioners, and hospitals, crucial information like frailty and patient preferences could be integrated into the decision-making processes, enhancing the accuracy of care plans beyond traditional scoring systems.

As a last point, Artificial Intelligence (AI) holds significant promise in addressing challenges posed by textual data and in optimizing healthcare processes. While numerical data analysis has improved medical care and is current practice for research, textual data remains complex, unstructured and difficult to study. AI-powered natural language processing (NLP) can offer a solution by enabling systematic analysis and interpretation of textual medical information. Integrating AI and machine learning technologies can help form a transformative shift towards a more data-driven and patient-centered healthcare approach, promising to improve prehospital care delivery and patient outcomes in the digital age.

Chapter 2 outlined the study protocol of the HART-c study, a multicenter prospective study evaluating the efficacy and feasibility of a novel comprehensive prehospital triage method. In this triage method patients visited by paramedics for all cardiac complaints were included. Paramedic consultation consisted of a full medical history, physical examination, noting of vital signs, and ECG measurements. All this data was noted on a handheld device and was transferred to a newly developed digital triage platform. An on-shift triage cardiologist was able to log in remotely on the triage platform and view all (live-streamed) data. This prehospital data was combined with in-hospital medical records and real-time admission capacity of all regional hospitals. The consulting paramedic contacted the triage cardiologist and together a shared decision was made whether admission was necessary and, if so, which hospital was most appropriate.

In **Chapter 3**, the recent COVID-19 pandemic and its effect on the healthcare system in the West-Netherlands region were examined. A Regional Capacity and Patient Transfer Service (RCPS) was set up. The RCPS combined information on capacity and triage capabilities to effectively transfer patients throughout the region and the country. Hospitals with high influx of COVID-19 patients were able to transfer patients to other hospitals in the region who had a higher reserve capacity or a lower influx of patients. The RCPS ensured that regional ICU occupation never exceeded maximal capacity and thus allowed patients in need of acute direct care to be admitted to the ICU. The presented method could be useful in reducing waiting lists caused by delayed care and for coordinating and transferring patients with new variants or other infectious diseases in the future.

Chapter 4 aimed to assess the indirect health effects of the COVID-19 lockdown in 2020, focusing on people's reluctance to seek medical care. Evaluation of paramedic consultations for chest pain or out-of-hospital cardiac arrest (OHCA) compared to the same period in 2019 revealed a significant reduction in the number of evaluated chest pain patients and ST-elevation myocardial infarction (STEMI) patients, while the incidence of OHCA remained similar. Possible factors contributing to the decrease in chest pain and STEMI incidence were discussed, including a decrease in physical exertion, a dramatic decrease in air pollution, and reluctance to contact medical authorities during the COVID-19 lockdown. Alerting the public to the importance of contacting EMS in case of suspected cardiac complaints was proposed to reduce secondary health damage in possible future lockdowns.

Chapter 5 showcased the potential of data and AI in healthcare, presenting a retrospective study as a proof-of-concept of an AI model developed to identify patients with ACS in the prehospital setting based on textual data. Prehospital data collected by emergency medical services' nurse paramedics between September 2018 and September 2020 were retrospectively analyzed. A supervised text classification algorithm was employed to develop the AI model, which underwent iterative evaluation, feature selection, and hyperparameter tuning. The AI model demonstrated a specificity of 11% and a sensitivity of 99.5%, with a positive predictive value (PPV) of 15% and a negative predictive value (NPV) of 99%. In comparison, usual care exhibited a specificity of 1%, a sensitivity of 99.5%, a PPV of 13%, and an NPV of 94%. The AI model significantly improved specificity and NPV compared to usual care, while maintaining similar sensitivity levels. The potential for AI to support decision-making in the future was discussed, with the caveat that final decisions on patient management should always rest with a physician or nurse paramedic.

Finally, **Chapter 6** presented the results of the HART-c study of which the protocol was extensively discussed in chapter 2. The intervention group consisted of 1536 patients (69± 15 years, 51.3% male), while the historical cohort control group comprised 1376 patients (68± 15 years, 49.9% male), with comparable baseline characteristics. In the intervention group, 181 (11.8%) patients were able to stay at home after EMS consultation, compared to 77 (5.9%) patients in the control group. Logistic regression demonstrated increased odds of staying at home in the intervention group compared to the control group (adjusted odds ratio: 2.31, 95% CI 1.74–3.05, p< 0.0001), even after adjusting for age, sex, and month of presentation. The most prevalent presenting symptom for patients who could stay at home was chest pain. Only one patient in the intervention group developed ACS within 30 days after EMS evaluation, with no reported deaths and a low rate of loss to follow-up (2.8%). In terms of secondary endpoints, there was no significant difference in the incidence of EMS consultations between the two groups, but the intervention group experienced a lower incidence of interhospital transfers. The time from EMS consultation to hospital arrival increased slightly in the intervention group. Additionally, there were no significant differences in ACS diagnoses or final diagnoses between the control and intervention groups. Patients who could stay at home reported high satisfaction scores, as did their GPs and cardiologists involved in their care. The HART-c study demonstrated an increase in patients who could safely stay at home after EMS consultation and a reduction in interhospital transfers, potentially relieving substantial pressure on the currently overloaded healthcare system. Furthermore, the presented triage method was noted to be adjustable and easily implementable for other medical specialties, further aiding in reducing overcrowding.

Conclusions

This thesis addressed current and forthcoming challenges in (cardiac) healthcare, offering innovative strategies to alleviate overcrowding through enhanced prehospital triage. The newly developed triage method, integrating prehospital and in-hospital data with expert

cardiologist consultation, efficiently identified patients suitable to stay at home post-paramedic assessment, reduced interhospital transfers, and thereby optimized resource allocation. Consequently, this method significantly contributed to decreasing overcrowding by streamlining prehospital patient management.

Additionally, the thesis examined the impact of the recent COVID-19 pandemic on cardiac healthcare, revealing declines in chest pain referrals and STEMI diagnoses. Additionally, the pandemic underscored the importance of effective triage mechanisms and collaborative (regional) approaches to increase healthcare resilience, exemplified by the RCPS.

Lastly, this research provided a glimpse into the future, demonstrating the proof-of-concept of artificial intelligence in prehospital decision-making, promising further advancements in cardiac care delivery.

Future perspectives

In contemplating the future landscape of cardiac prehospital triage, significant improvements emerge, most notably in the management of patients experiencing chest pain. The integration of point-of-care (POC) high-sensitivity cardiac troponin (hs-cTn) assessments into existing triage protocols such as those discussed in this thesis holds promise for further improving prehospital risk assessment. By enhancing prehospital risk scores prehospital patient selection can be elevated to unprecedented levels of precision. However, this integration should also represent a paradigm shift, aiming to redefine prehospital triage as a selective process focused on excluding patients from hospitalization rather than admitting them. When scientifically proven to be safe, implementing POC hs-cTn assessment within the HART-c triage method (or other similar triage methods) can mean low-risk patients are allowed to be managed at home without cardiologist consultation. Expert consultation can then be reserved to ensure patient tailored care for medium- to high-risk categories or in cases where there's uncertainty regarding low-risk patients. Recent studies, including the TRIAGE-ACS study, have demonstrated the efficacy of identifying high-risk patients without ST-elevation on prehospital ECGs for direct transport to hospitals with interventional capabilities . In these instances, prehospital consultation with a cardiologist can further refine patient selection, ensuring that those who would benefit most from rapid intervention are appropriately identified.

Additionally, when point-of-care high-sensitivity cardiac troponin (POC hs-cTn) is measured before hospital arrival, obtaining a subsequent POC hs-cTn measurement upon hospital admission facilitates the calculation of a 'delta' troponin. This enables much faster classification of patients by the 1-hour or 2-hour rule-out algorithms as recommended in the European Society of Cardiology (ESC) guidelines for the management of acute coronary syndromes.

Implementing the combination of prehospital POC hs-cTn with expert consultation would parallel prehospital care to in-hospital assessment in the emergency department (ED),

complete with real-time ECG, monitoring vital signs, high-sensitivity troponin tests, and facilitating consultations with cardiologists. Carrying out this process before patients arrive at the ED would further alleviate hospital- and ED overcrowding. It will also significantly reduce the time patients spend in diagnostic uncertainty by minimizing unnecessary hospital referrals and by enabling faster use of the rule-out algorithm. Once in place, the level and accuracy of prehospital cardiac triage will be unparalleled.

The logical progression from regional improvement and implementation would be towards national dissemination. The Netherlands, because of it's geography and healthcare system, is positioned to lead this transformative endeavor. Collaboration among the many currently ongoing clinical studies in prehospital cardiac triage will lay the groundwork for nationwide adoption, with attention to the nuanced needs of individual regions. The triage method discussed in this thesis can be used as a template adaptable to the unique needs of every region within the Netherlands. Different healthcare providers can freely share relevant patient data and look in to data which is shared by others. These regionale platforms could provide a comprehensive and complete view of a patient's medical history, enabling healthcare professionals to make more accurate assessments and prioritize treatment accordingly. Moreover, the development of a triage platform adaptable to various symptoms or medical specialties, such as neurologic symptoms, or pediatric care, holds promise for optimizing triage processes across diverse healthcare contexts.

A central point to this endeavor is the meticulous stewardship of data, crucial for scientifically demonstrating the safety and efficacy of these methods. Combining the eventual outcomes from patients classified as low-, medium- or high risk in a single (prehospital) registry could be of great benefit to assess quality of care and to increase the power for (clinical trial) safety assessments. Furthermore, this would make the development of observational – and randomized clinical trials easier for whoever has ideas to improve prehospital patient care further. Of note, some agreements should be made by healthcare providers and healthcare financiers, such as the (local) government and healthcare insurers, on how to structurally finance these triage platforms and – registries.

Proper data management enables the integration of AI-powered predictive models, promising a future where risk prediction and decision support reach unparalleled levels of sophistication. Accurate storage and annotation of data for AI or ML models are important, as it ensures precise model training, generalization, and bias mitigation, while also enabling model interpretability and compliance with regulations. Such meticulous data management bolsters the reliability, fairness, and security of AI systems, for their successful implementation and public trust. In this thesis an AI algorithm was demonstrated as a proof-of-concept in prehospital triage, however such models should undergo thorough validation before eventual implementation. Furthermore, developers should be forced, by professional associations or national governments, to publicly share the underlying algorithm and data before publication. In this way other researchers have the possibility

for further improvements to the algorithm, and thus further improvements to patient care. If deemed safe, this approach holds promise for enhancing risk prediction, akin to existing risk score models for conditions like chest pain, providing healthcare professionals with a supportive tool to aid in the decision-making processes. This approach can reduce the reliance on human-based healthcare, thereby alleviating some strain on the system. Consequently, only patients who genuinely require hospital care will be admitted or seen in the emergency department, leading to a higher acuity of patients on average. This shift necessitates corresponding adjustments in healthcare financing.

Improving prehospital cardiac triage in the entirety of the Netherlands will benefit patients experiencing symptoms of cardiac origin. The triage method can further alleviate the strain on healthcare because of its flexibility and therefore adaptability across diverse medical specialties such as neurologic symptoms or pediatric care. One can imagine that for these specialties adaptations might be necessary, such as the ability to examine patients through video calling inside the ambulance to assess neurologic symptoms. However, it will not solve the demographic shifts, rising demand for healthcare, workforce shortages and the resulting strain on healthcare resources. The COVID-19 pandemic underscored the importance of collaboration among healthcare providers, transcending the confines of competition-driven healthcare models. Through working together, healthcare providers have demonstrated their capacity to address significant crises. Embracing transparency in capacity and by sharing resources, they must transcend the prevailing profit-driven model, striving towards a future characterized by equity and sustainability for all. Herein lies a role for government and policymakers as well, to enact policies that support and incentivize collaboration, transparency, and equitable resource allocation in healthcare.

This thesis has demonstrated that collaboration among healthcare providers and subsequent shared decision-making can improve patient outcomes. Although hopeful and definitely useful, even necessary, these endeavors they may serve as temporary solutions to larger systemic challenges. The aging population and subsequent smaller working population will lead to persistent overcrowding in most countries, and efficient resource use will not alleviate escalating healthcare costs. Sustainable healthcare delivery hinges not only on technological advancements but also on the willingness to make difficult decisions in resource allocation. Whether through increased funding or judicious admission criteria, addressing these challenges demands bold action. The thesis offers a preliminary glimpse into the future and highlights the importance of innovation, collaboration, transparency, adaptability and equitable resource distribution. Drawing lessons from the past and implementing scientifically proven advancements, policymakers and healthcare professionals are urged to develop a healthcare system that can stand the test of time.