Measuring quality of care in the treatment of acute coronary syndrome

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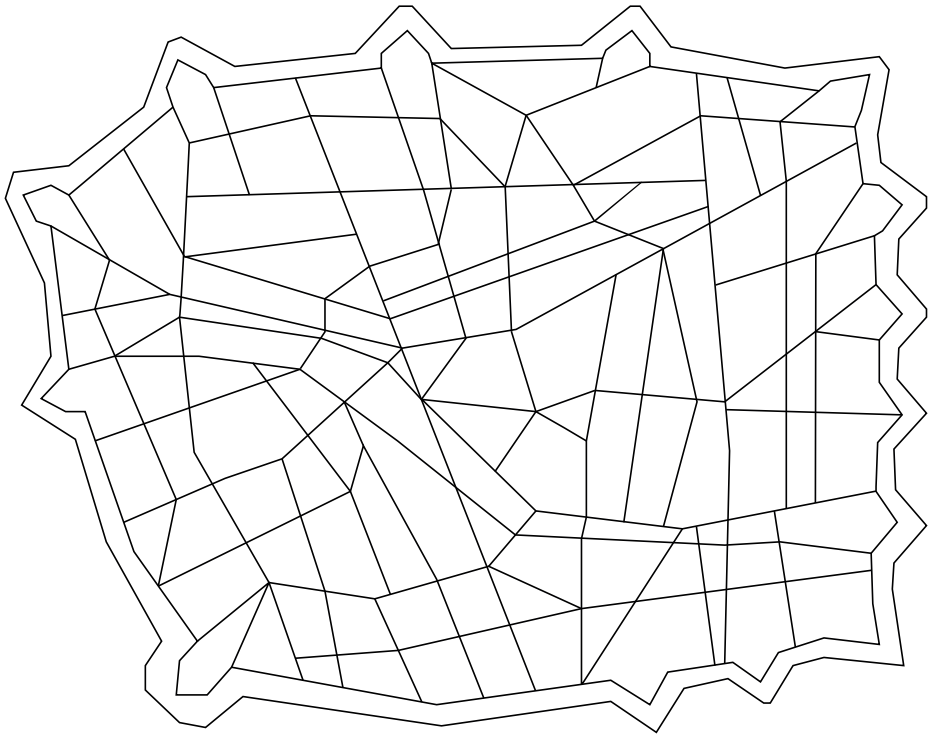
Part One

Quality of Care on a Local Level



Chapter 2

Design and reliability of a specific instrument to evaluate patient safety for acute myocardial infarction patients treated in a pre-defined care track: a retrospective patient record review study in a single tertiary hospital in the Netherlands.

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ABSTRACT

OBJECTIVE: Numerous studies have shown that a substantial number of patients suffer from adverse events (AE) as a result of hospital care. However, specific data on adverse events in acute cardiac care are scarce. The current manuscript describes the development and validation of a specific instrument to evaluate patient safety of a predefined care track for acute myocardial infarction (AMI) patients.

SETTING AND PARTICIPANTS: A total of 879 hospital admissions treated in a tertiary care center for an acute myocardial infarction (age 64 ± 12 years, 71% male).

MAIN OUTCOME MEASURE: In the first phase, the medical records of AMI patients warranting coronary angiography or coronary intervention were analysed for process deviations. In the second phase, the medical records of these patients were checked for any harm that had occurred which was caused by the health care provider or the health care organisation (adverse event) and whether the harm that occurred was preventable.

RESULTS: Of all 879 patients included in the analysis, 40% (n = 354) had one or more process deviation. Of these 354 patients, 116 patients (33%) had an adverse event. AE-patients experienced more process deviations compared to non-AE-patients (2 ± 1.7 versus 1.5 ± 0.9 process deviations per patient, p = 0.005). Inter-rater reliability in assessing a causal relation of health care with the origin of an adverse event showed a kappa of 0.67 (95% CI 0.51 – 0.83).

CONCLUSION: This study shows that it is possible to develop a reliable method, which can objectively assess process deviations and the occurrence of AEs in a specified population. This method could be a starting point for developing an electronic tracking system for continuous monitoring in strictly pre-defined care tracks.

INTRODUCTION

Patient safety, defined by the National Academy of Medicine, formerly called the American Institute of Medicine, as the prevention of harm to patients, is the minimum prerequisite for a good quality of care.[1] In 1999 they published a report called 'To Err is Human', which drew attention to the fact that a significant number of patients suffered from injuries or even had died as a result of care delivered in hospitals.[2] Subsequently, various studies in different countries reported that 2.9% to 16.6% of in-hospital patients experienced one or more adverse events and that in 5% to 13% of the adverse events the patients died.[3-13] In these studies, an adverse event (AE) was defined as an unintended injury that results in disability at the time of discharge, death, or prolonged hospital stay and is caused by health care management rather than by the patient's underlying disease process.

In various studies, a large variation in the incidence of adverse events among the different hospital departments was shown (0.5%-29.9%).[4 14-16] However, these studies had a general hospital-wide approach and provided hardly any insight in causal relations on a departmental level. To develop specific interventions at each department in order to improve patient safety appeared even more challenging. Particularly cardiology, which is a department with a high intervention rate and a large number of patients with a life threatening illnesses. A subset of studies contain results on the occurrence of AE among general cardiac patients, based on small numbers of patients and showing a substantial variety in the incidence of AE (13.3%-29.9%).[15 16] Therefore, sufficiently powered studies are needed for specific patient groups to gain more insight into the incidence of (preventable) AEs and to define *'How safe is our care'*.

Inspired by high-risk industries and best-practice hospitals, the aim of this study is to provide a system to review our work and to define if our work process is sufficiently safe. High-risk industries, such as the aviation and chemical industry, are required to perform structured assessments of all processes that contribute to a particular activity, which allows them to make a reasoned claim regarding safety. In the healthcare sector, best-practice hospitals such as the Intermountain Healthcare group, provide a framework like the Quality and Patient Safety Plan upon which an integrated and comprehensive program to monitor, assess and improve the quality and safety of patient care delivered.[17] This study attempts to analyse process deviations and potential correlation with AEs in hospitalised patients who are treated according to a protocolised care pathway, in this case patients who suffer from an acute myocardial infarction (AMI). The developed method to assess AEs in acute MI patients, is based on the Harvard Medical Practice Study (HMPS), which is a structured patient record review that has also been used in other AE-studies.[4 16 18 19] This current manuscript describes how this commonly used method is adapted for our specific patient

population. In addition, it was examined whether the linkage between process deviations and AEs will increase the uniformity of the assessments of AEs and creates the possibility to develop better improvement strategies.

METHODS

Patient population

Patients who were admitted in 2012 and 2013 to the Leiden University Medical Center with an acute myocardial infarction warranting coronary angiography (CAG) or percutaneous coronary intervention (PCI) and treated according the MISSION!-Protocol were included.[20] The Leiden University Medical Center functions as a tertiary referral center performing PCI procedures on a 24/7 basis and serves an area of approximately 750,000 inhabitants. The MISSION!-protocol contains a prehospital, in-hospital, and outpatient framework for clinical decision making and treatment for the different diagnosis in acute myocardial infarctions (unstable angina (UA)), ST-segment elevation myocardial infarction (STEMI) and non-ST-segment elevation myocardial infarction (NSTEMI)). This study focussed on the in-hospital program (early reperfusion, same diagnostic trajectory like 2D-echocardiography, structured medical therapy, and disease education). Generally, patients are planned for discharge 12 hours after a coronary angiography, or 48 hours after a percutaneous coronary intervention. The MISSION!-protocol is based on the evolving guidelines of the European Society of Cardiology.[20-22] The MISSION!-patient records were extracted from the electronic patient file system (EPD-Vision, LUMC, Leiden The Netherlands) by selecting the diagnose coding of a diagnosis-treatment-combination for UA (11.203), STEMI (11.204) and NSTEMI (11.205). Patients with any of these three diagnose-codings were linked with the clinical database to select the patients who received an intervention procedure (CAG or PCI) within 24hrs after admission. This was applied to all patients admitted to the LUMC between January 1, 2012 and December 31, 2013. Patients with an urgent coronary artery bypass grafting after CAG or urgent PCI were excluded because they underwent a different treatment path.

Review Process

The method used in this study was based on a protocol originally developed by the Harvard Medical Practice Study. A modified version of this protocol was used in studies in Australia, Canada, Denmark France, New Zealand, the United Kingdom and the United States.[3 5 10 11 13 14] A Dutch protocol, based on the Canadian Adverse Events study, was used in studies in 2004, 2008 and 2011/2012.[15 16 19] To identify high risk patient records, the Harvard Medical Practice Study developed 18 triggers (i.e. "Unplanned return to the operating room" or "Hospital-incurred patient injury"). The presence of one or more of

these 18 triggers was established in Phase 1. In case a trigger was found, the patient record entered a second phase, which focused on identifying whether harm was done to the patient, whether the harm was due to the care that the patient received, and whether the harm was preventable. To increase the uniformity of the assessment of AE and to gain more insight into patterns of adverse events, the triggers of the Harvard Medical Practise Study were specified for acute cardiac care, thereby creating the opportunity to identify specific process deviations. In the first phase of the review process we focused on identifying these process deviations in the patient records, and in the second phase AEs were identified. In case an AE was identified, it was also scored on preventability.[3]

Phase I: specification of process deviations for AEs

In the MISSION!-protocol, the patient can have different workflows according to their electrocardiographic-diagnosis at admission (ST-elevation myocardial infarct, non-ST-elevation myocardial infarction or unstable angina). In the search for adverse events all process deviations from the MISSION!-protocol were identified. During this review-phase, a process deviation was defined as every operation or treatment that differed from the MISSION!-protocol, such as additional procedures (a pacemaker implantation or second PCI), prescription of extra medication other than described in the protocol (use of anti-aritmica, anti-coagulation, inotropics or diuretics) or omission of a procedure (no diagnostics performed). If a patient had a transient heart rhythm disorder without treatment consequences, the process deviation was noted as an observation of the heart rhythm. **Figure 1** shows all the defined process deviations. The review process of all medical records (nursing and medical records) was performed by a physician with work-experience at the clinical department and who is familiar with reviewing electronic files. In contrast to the original triggers of the Harvard Medical Practice Study and other process deviation frameworks like the Process Deviations Analysis Framework, no judgements were made during Phase 1 on whether the process deviation were 'unexpected' or 'unplanned'.[23] After identifying all process deviations, the process deviations were categorised into main categories and translated back to one (or more) of the original 18 triggers of the Harvard Medical Practice Study. Because of the defined inclusion criteria stated in the MISSION!-protocol and restrictions concerning the availability of data from the patient records in the peripheral hospitals up to 30 days after discharge, it was decided beforehand that events experienced prior to (i.e. unplanned admission before index admission), or after the index admission (i.e. readmission) were excluded from the review process.

Phase II: Determination of an adverse event and preventability

During phase two the nursing and medical records of the admission were reviewed for adverse events by a clinical physician. If applicable, also the records of patients who were

transferred to another hospital during their admission were traced. In case the physician found more than one AE in a patient, they were separately registered.

Event classification

First it was assessed whether the event resulted in harm to the patient. The definitions are mentioned in **Supplementary file 1**. If the patient experienced harm that resulted in any disadvantage for the patient, such as prolonged admission, temporary or permanent (physical and/or mental) impairment or death, it was rated whether the harm was caused by health care (i.e. an adverse event) and if so, whether it was preventable (i.e. caused by an error). Both the causation and the preventability were scored on a 6-point-Likert scale. Preventability of the AE was assessed by indicating a score between 4 and 6 on the Likert scale. This is in accordance with other AE studies.**(Supplementary file 2 and 3)**

To support the reviewer in the rather implicit judgement of determining the causation in health care of the AE, the causation score was preceded by structuring questions to direct if the injury was indeed caused by medical care rather than the underlying acute coronary syndrome. **(Supplementary file 2 and 3)** For example: *"Does the timing of the (adverse) event suggest that the injury is related to the treatment?"* and *"Is the lack of treatment or delayed treatment a recognised cause of this injury?"* Analogously, preceding questions were used to judge if an adverse event was preventable. An adverse event was found to be preventable when the **performance of the practitioner** fell short of the expected **level** of competence based on the professional standard. Appropriate management of the myocardial infarction was outlined in the previously mentioned MISSION!-protocol. Also local hospital guidelines on precautionary measures to prevent common events, such as measures to prevent a delirium, were taken into account by the reviewer and the expert panel. The questions preceding the preventability score were also used to evaluate the complexity of the medical history and comorbidity of the patient. In addition, it was of importance to consider the potential benefit of the procedure, the calculated risk, and the degree of emergency in treating a patient with a myocardial infarction. Therefore, the original preceding questions were augmented by two extra questions on whether the management of the AMI was appropriate, and on the estimated risk of an adverse event associated with the management.**(Supplementary file 3)**

Expert panel

In case of doubt regarding the causality and/or the preventability of an event, an advisory opinion of an expert panel was requested. The expert panel consisted of two consultants, cardiologists with a wide range of experience in interventional cardiology or electrophysiology. Both cardiologists were either involved in managerial tasks or departmental incident analysis. In addition two cardiologists in their final year of training and involved in the daily

New process deviations	Category	
Observation	OBSERVATION	199
Observation - Physical or mental complaints.		120
Observation - Rhythm or conduction disorders.		79
Diagnostic	DIAGNOSTIC	79
Diagnostic - Consultation of other specialism.		27
Diagnostic - CT-scan		19
Diagnostic - Infectious.		1
Diagnostic - Ultrasound of the groin.		14
Diagnostic - Other, not specified before.		18
Therapy	THERAPY	280
Therapy - Anti-aritmica.		7
Therapy - Anticoagulation.		26
Therapy - Blood transfusion.		11
Therapy - Consultation of other specialism.		14
Therapy - Diuretics.		23
Therapy - ICD-implantation.		8
Therapy - Infectious.		15
Therapy - Inotropics.		12
Therapy - Medication error.		1
Therapy - Palliative care		4
Therapy - Pericardial drainage.		6
Therapy - Positioning of a temporary cardiac pacing wire.		14
Therapy - Positioning of an intra-aortic balloon pump.		14
Therapy - Return to catherization room for a new procedure (CAG or PCI)		42
Therapy - Resuscitation		17
Therapy - Thrombin injection.		17
Therapy - Rhythm or conduction disorders (incl. pacemaker implantation).		9
Therapy - Other, not specified before.		40
Logistic	TRANSFER	29
Logistic - IC-transfer.		17
Logistic - Other, not specified before .		12

Related Harvard Medical Practice Study Triggers
Any other undesirable outcome not covered above.
Unplanned return to the operating room.
Unplanned removal, injury, or repair of organ during surgery.
Hospital-acquired infection or sepsis (initiated > 72 hours after admission).
Other patient complication (no natural consequence of disease).
Development of neurological deficit not present on admission.
Hospital-incurred patient injury (Permanent or temporary injury obtained (acquired) during index admission).
Adverse drug reaction.
Cardiac or respiratory arrest.
Unexpected death.
Unplanned transfer from general care to intensive care (unit).

The colours of the process deviation category corresponds with the Harvard Medical Practice Study Triggers. CAG = coronary angiography; CT = computer tomography; PCI = percutaneous coronary intervention; IABP = intra-aortic balloon pump; ICD = implantable cardioverter-defibrillator; IC = intensive care.

Figure 1: Newly defined process deviations in relation to the original Harvard Medical Practice Study.

clinical practice formed part of the expert panel. In case there was a discrepancy about the causation or preventability between the reviewer and the expert panel, the structuring questions were used to guide the discussion and reach a final decision.**(Supplementary file 2 and 3)** The expert panel was also involved in reaching consensus on the causality and preventability of events, which frequently occurred such as a groin hematoma.

Privacy

Guarding privacy and anonymity were considered to be a high priority. To warrant the privacy and anonymity all people involved in the study signed a confidentiality agreement to maintain the confidentiality of the information. Study results were stored in a Microsoft Access 2010 Database® on a safety disk which can only be accessed by individuals who are involved in the study.

Ethical approval

The Leiden University Medical Center gave a declaration of "medical-ethical permittance not necessary" for this retrospective records study (reference number P15.133). The peripheral hospitals, had formally consented to obtain data from outpatient clinical records, in accordance with their local medical-ethical committee.

ANALYSIS & STATISTICS

Patient characteristics and process deviations

For all patients, baseline characteristics such as age, sex, medical history and admission characteristics like length of stay, comorbidities, cardiac diagnosis and procedural characteristics (stenting or not) were retrieved. Continuous variables are presented as mean with standard deviation or median with 25th and 75th percentile, where appropriate. Dichotomous variables are presented as numbers and percentages. The number of process deviations within each main category were calculated by summing the number of process deviations of each subcategory, after which they were plotted in a pie chart. Baseline comparability between patients with or without an process deviations were evaluated by descriptive statistics and Independent T-test or Chi-square test, when appropriate. A p-value smaller than 0.05 was considered to be statistically significant. Furthermore, the *process deviation : AE ratio* was determined to assess the effectivity of the new method based on identifying process deviations, and a Chi-square analysis was performed to assess differences between patients with and without process deviations.

Inter-rater reliability

To assess the reliability of the assessment of the presence and preventability of an AE of the first reviewer, 10% (n = 87) of the patient records were independently screened by an experienced cardiologist from another center. This second reviewer was blinded to the outcome of the first review. To maximize efficiency, stratified sampling was performed. AE positive patient records were oversampled in relation to AE negative patient records, with a ratio of 2:1 (*AE : non AE*). These patients were randomly selected from the whole MI study population. Consecutively, all patient records that contained an AE according to both reviewers were also reviewed on preventability. The percentage of agreement on causality and preventability is determined on a patient-level and expressed separately for positive and negative rating. In addition, Cohen's kappa-statistics was calculated.[24] To avoid any potential bias in the kappa's coefficient, caused by the stratified sampling, the kappa-statistics were also calculated separately for the patient records with and without an AE.

Data accuracy

Data accuracy (missing data, inconsistent data) was checked on a regular basis and analysed using Microsoft Access 2010 and IBM SPSS Statistics for Windows, Version 23.0. Armonk, NY: IBM Corp.

RESULTS

Process deviations and adverse events

In total 879 patients (age 64 ± 12 years, 71% male) were reviewed, including the follow-up records of 274 patients who were transferred to three affiliated hospitals after a cardiac procedure in the tertiary care center.**(Table 1)** In 347 patients (39%) one or more process deviations during admission (587 deviations in total) were found. The process deviations (n = 587) were categorised into four main categories: observation, diagnostic, therapy, or transfer.**(Figure 2)** Most process deviations were found during observations (especially observation of mental and physical complaints or rhythm disorders) and therapy (especially anticoagulation therapy or return to catheterisation room for a second CAG or PCI procedure).**(Figure 1)** Patients with one or more process deviations were significantly older than patients without a process deviation (67 ± 12 vs 61 ± 11, $p< 0.001$). In addition, female patients (66% vs 75% male patients, $p = 0.006$) and patients with a lower renal function had a significantly higher risk for process deviations.**(Table 1)**

Translation of triggers to process deviations

After categorising the process deviations, the categories were translated back to one (or more) of the 18 original triggers of the Harvard Medical Practice Study.**(Figure 1)**

Due to the inclusion criteria of the study population, original triggers like *"unplanned admission before index admission", "unplanned transfer to another acute care hospital", "injury related to abortion or delivery or neonatal complications*" were not applicable to this population. Moreover, *"inappropriate discharge to home"* and *"unplanned readmission after discharge"* were not included because the medical records were only reviewed while the patient was admitted to the hospital. Triggers like *"dissatisfaction with care documented in the medical record"* and *"documentation or correspondence indicating litigation"* were not used if they did not result in an alteration of the workflow. Eleven original triggers remained. Especially triggers used for diagnostic or therapy procedures became more specified by using process deviations ("Unplanned return to the operating room", "unplanned removal, injury, or repair of organ during surgery", and "Other patient complication (no natural consequence of disease)"). Likewise, the trigger "Unexpected death" was more specified in process deviations as "Resuscitation" or "Positioning of an intra-aortic balloon pump".

In 116 patients, 33% of all patients with a process deviation, an adverse event was found. The majority of patients with an adverse event had more than one process deviation (64 of 116 patients (55%), average of 2.0 ± 1.7 process deviations per patient). In the group of patients with no adverse event (150 of 231 patients (65%) had more than one process deviation, average of 1.5 ± 0.9 process deviations per patient) ($p = 0.005$). No significant differences were found in patients with and without an adverse event in the distribution of the type of process deviations.**(Table 2)** Likewise, no differences in mortality-rate (5 of 116 AE patients died (4.3%) vs. 13 of 763 non-AE-patients (1.7%), $p = 0.065$). All patients who died (n = 18, 2.0%) during their hospital stay, experienced a process deviation (n = 23 in 18 patients) and 5 patients an adverse event. The process deviations that were found in deceased patients were mainly related with Therapy (21) or Transfer (2) and no differences were seen between deceased patients with and without an adverse event in the type of process deviation (4 of 5 Therapy deviation in AE patients vs. 17 of 18 Therapy deviation in non-AE patients, $p = 0.395$). In patients without a process deviations, 2 patients (2 of 532, 0.4%) experienced a non-preventable adverse event.

Inter-rater reliability

The inter-rater reliability assessment was carried out for 87 patients (10% of n = 879) by a second, independent cardiologist with experience in the assessment the presence of preventable adverse events by means of medical record reviewing. On a patient level, there was an agreement in 73 patient record (agreement level of 84%). The positive agreement on the presence of an adverse event in the patient records was 87%, and the negative agreement on the absence of an adverse event in the patient records was agreement 80%. No differences were found when performing an independent analysis of the agreement

Table 1: Baseline characteristics

	All patients N = 879	With process deviation N = 347	No process deviation N = 532	p-value
Demographic characteristics				
Age (years)	64 ± 12	67 ± 12	61 ± 11	≤ 0.001
Male sex	626 (71%)	229 (66%)	397 (75%)	0.006
BMI (kg/m2)	27 ± 4	26 ± 4	27 ± 4	0.070
Length of stay (days) (median, IQR)	3 (2-4)	3 (2-5)	2 (2-3)	≤ 0.001
Comorbidities				
Hypertension	352 (40%)	155 (45%)	200 (38%)	0.066
Hyperlipidemia	198 (23%)	75 (22%)	123 (23%)	0.625
Diabetes mellitus	115 (13%)	52 (15%)	63 (12%)	0.177
Known coronary disease	145 (16%)	65 (19%)	80 (15%)	0.147
Known pulmonary disease	88 (10%)	43 (12%)	45 (8%)	0.055
Renal clearance (ml/min/1.73m2)	75 ± 23	72 ± 25	77 ± 22	0.002
Infarct characteristics				
Diagnosis				0.052
STEMI	594 (68%)	234 (67%)	360 (68%)	
NSTEMI	135 (15%)	63 (18%)	72 (14%)	
UAP	114 (13%)	34 (10%)	80 (15%)	
Other	36 (4%)	16 (5%)	20 (4%)	
Treated with PCI	747 (85%)	297 (86%)	450 (85%)	0.684

BMI = body-mass index; IQR = Interquartile range; STEMI = ST-elevated myocardial infarction; NSTEMI = non-ST-elevated myocardial infarction; UAP = unstable angina pectoris; PCI = percutaneous coronary intervention.

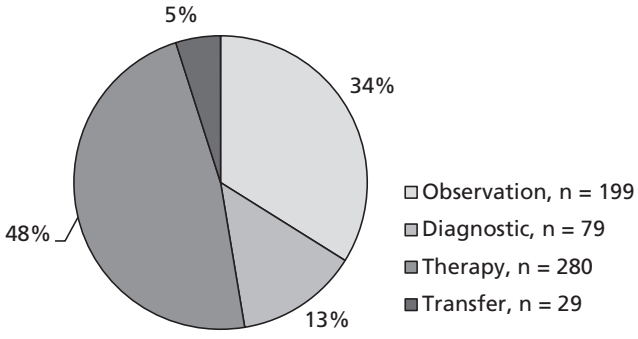

Figure 2: Five hundred and eighty-seven process deviations of all 879 patients.

in patient records with AE and without AE (independent analysis AE positive agreement 86%, independent analysis non-AE: negative agreement 98%). In 45 patients preventability was assessed on which there was an agreement of 84%. The kappa statistics of the preventability was substantial (κ 0.67 (95%CI 0.45 - 0.90)).**(Table 3)** Notable, a common type of adverse event was a groin complication (groin hematoma), on which consensus was established by the expert panel. In principle, a groin hematoma was judged to be preventable. The expert panel decided that despite adequate action, a groin hematoma is less preventable in high risk frailty groups like obese, restless, elderly and patients with known peripheral vascular disease when using dual antiplatelet therapy.

DISCUSSION

This study describes the development of a new valid screening tool for identifying process deviations and AEs in a specified patient population; patients with an acute myocardial infarction, treated according to a strict defined protocol.

First of all, process deviations were identified. We reviewed 879 patient records in which 587 process deviations in 347 patients were found. In 116 patients, 33% of all patients with a process deviation, an adverse event was found, leading to an *AE : process deviation* ratio of 1 : 3. This ratio seems higher in comparison to other studies where one adverse event was found in every sixth or seventh patient record with a trigger.[3 4 18] However, it is important to take into account that previous studies were focused on a wider range of specialties, which can explain a lower prevalence of AE's. Interestingly, the type of process deviation is not associated with experiencing an AE; no differences in the type of process deviations were found between patients with an adverse event compared to patients without an adverse event. This finding could be explained by the fact that, despite process

Table 2: Comparison of process deviations.

	Process deviations in all patients	Process deviations in all patients without an adverse event	Process deviations in all patients with an adverse event	p-value
Process deviations	N = 587	N = 354	N = 233	
Number of patients	879	231	116	
Observation	199 (34%)	124 (35%)	75 (32%)	0.477
Diagnostic	79 (13%)	46 (13%)	33 (14%)	0.685
Therapy	280 (48%)	163 (46%)	117 (50%)	0.322
Transfer	29 (5%)	21 (6%)	8 (3%)	0.172
None	532	n/a	n/a	n/a

deviations are present in a patient record, they may not be the root cause of the AE. Various preventive actions may have taken place after the occurrence of the process deviation which could have averted patient harm. In addition, AEs are more likely to be caused by a combination of multiple factors.[25] This makes it difficult to develop a targeted approach to improve patient safety. More research, for instance based on incident analysis methods using more sources of information than the patient record only, may help to identify other variables (i.e. patient characteristics) that predict an AE. The majority of process deviations were found during clinical observation and therapy, which is in line with prior studies using the related original HMPS triggers.[17 18]

Based on the inter-rater reliability that was found in this study (causality and preventability agreement are both 84%), this adapted method appears to be a reliable and suitable instrument to use in this well-defined patient population. In previous studies, the reliability of the occurrence of an AEs in general hospitals was moderate to substantial (kappa ranged from 0.42 – 0.83, agreement ranged from 76% to 92%), and if measured, it was moderate for determining the preventability of AEs (kappa ranged from 0.33 – 0.69, agreement ranged from 68% to 91%).**(Supplementary file 4)** [3 4 8 11 13 18 26-29] Recently a study focussed on hip fractures in elderly patients showed an agreement of 85% in the presence of an AE, with a k-value of 0.52.[30] The substantial reliability in the current study suggests that an assessment procedure shows reduced inter-rater variation when being performed in a specified population with a strictly pre-defined protocol. Nevertheless, a 100% agreement score was

Table 3: Assessment of the inter-rater reliability between two physicians.

Causality	**87 patients**
Agreement	84%
Positive agreement	87%
Negative agreement	80%
Kappa statistic (95% CI)	0.67 (0.51 – 0.83)
Preventability	**45 patients**
Agreement	84%
Positive agreement	87%
Negative agreement	80%
Kappa statistic (95% CI)	0.67 (0.45 – 0.90)

To assess the reliability of the preventability, the sample size population contained an overrepresentation of adverse events compared with the whole MI study population (AE:non AE ratio is 2:1).

not reached. This is probably due to the different perspectives of physicians and limitations in our medical knowledge in causal relations, therefore the assessment of preventability remains under debate until new scientific evidence is discovered. Previous studies on AEs

were performed in general hospital populations and encountered a large variation among specialities with regard to the risk of the procedures employed and the severity of illness of the patients. As a result, heterogeneous numbers and causes of (preventable)AEs were reported among the different specialities.[4 8 18 26] Focussing on one specific illness leads to a decrease in the workload for the hospital staff, makes it easier to plan the collection of data, and limits the interruption of the work flow. In the end, this specific instrument is likely to provide more valuable insights into the specific cause of an AE in myocardial patients and consequently, possibilities to improve patient safety. Similar, adverse events can show recurrent wrong patterns in the management within a clinic department.

Some limitations of the proposed method have to be considered. First, the validation method of the new process deviations tool can be considered incomplete because there was no direct comparison with an alternative screening tool, such as the original HMPS trigger tool. Therefore, we cannot exclude the possibility that other numbers of process deviations or triggers were found if a comparison using another tool was performed. In addition, tools for identifying process deviations, such as the Process Deviations Analysis Framework or the (Lean) Six Sigma Model, were not used for the design of the current method because they are not (yet) suitable for assessing whether process deviations are associated with undesirable (health care) outcomes.[23 31] Besides, there are still considerable challenges when it comes to implementing process deviations frameworks in a healthcare setting. Current process deviation frameworks are highly measurement- and data driven while a health care setting is mostly depended on human behaviour, which is difficult to quantify. Another limitation is that this study depended exclusively on documentation in medical and nursing records. However, the likelihood that this has affected the quality of our study is low since previous studies showed that a record review method is sensitive for identifying AEs.[32] Also, direct comparison of these results with different hospitals is difficult, as record reviewing highly depends on the level of record completeness and the use of a (electronic) patient record. To lower the possibility of hindsight bias, a prospective design with a weekly review process of a researcher can be considered.[8 33]

Future implications

In the future it could be of interest to explore whether application of this new method makes it possible to assign AEs to uniform groups after which action can be taken. Furthermore, the eventual goal is to monitor patient safety with real-time process deviations and adverse events measurements, or even better, to predict which patients are at risk for AEs to prevent harm. For this next step, existing approaches for measuring process deviations used in other fields can be helpful. An integration of HMPS and Lean Six Sigma, for example, may be beneficial for healthcare. HMPS's strength is to structure implicit relations and to define harm, on the other hand Lean Six Sigma is a data-driven approach, which

may facilitate detection of process deviations as indicators of adverse event. It should be explored whether it is possible to develop an electronic tracking system, as part of an electronic patient records system, which enables the continuous monitoring of care. This will shift the emphasis away from focusing solely on medical errors, and more on real-time performance and measures that relate to future risks and resilience of organisations. This could be the starting point for the development of a hospital benchmark Quality Instrument to objectify patient safety as part of quality of care in a specific patient population.[34] Bottom-up, this could serve as an incentive to improve safety and top down it will give insight to redesign patient work-flows which can improve efficacy and quality of care. Structural process deviations seem more useful for educational purposes compared to individual preventable incidents. Although this method is focussed on one illness, this approach may also be applied to other patient populations, or to evaluate other care tracks like the MISSION!-protocol, for example the total hip arthroplasty procedures.[17]

CONCLUSION

In conclusion, this paper describes the development of a reliable method to objectively assess the process deviations and the occurrence of AEs in a specified population.

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An **adverse event** is (1) an unintended injury (physical and/or mental) which results in (2) temporary or permanent disability, death of prolonged hospital stay and (3) that is caused by health care management rather than by the patient's underlying cardiac disease.

Unintended injury refers to any disadvantage for the patient that leads to prolonged or strengthened treatment, temporary or permanent (physical and/or mental) impairment or death.

Disability refers to temporary or permanent impairment of physical or mental function attributable to the adverse event (including prolonged or strengthened treatment, prolonged hospital stay, readmission, subsequent hospitalisation, extra outpatient department consultations or death).

Causation refers to injury caused by health care management including acts of omission (inactions) i.e. failure to diagnose or treat, and acts of commission (affirmative actions) i.e. incorrect diagnosis or treatment, or poor performance.

Health care management includes the action of individual hospital staff as well as the broader systems and care processes. Health care management is any care related activity that involves the delivery of care or monitoring of health which is provided by individuals or a team of professionals.

Preventable adverse event is an adverse event resulting from an error in management due to failure to follow accepted practice at an individual or system level. Accepted practice was taken to be 'the current level of expected performance for the average practitioner or system that manages the condition in question'.

Process deviation was defined as every operation or treatment that differentiated from the MISSION! Protocol.

Supplementary file 1: Definitions

Preceding questions:

1. Does the timing of events suggest that the injury is related to the treatment or to the lack of treatment? (Likely/Possibly/Unlikely/Not applicable)
2. Is there a note in the medical record indicating that a health care professional or health care management caused the injury? (No/Yes/Not applicable)
3. Is there a note in the medical record suggesting the possibility of an unintended injury from the patient's disease? (No/Yes/Not applicable)
4. Are there other reasonable explanations for the cause of the unintended injury? (No/Yes/Possibly/Not applicable)
5. Is the lack of treatment or delayed treatment a recognized cause of this injury? (Widely recognized/Recognized by other specialists/No/Not applicable)
6. Is the lack of diagnosis or delayed diagnosis a recognised cause of this injury? (Widely recognized/Recognized by other specialists/No/Not applicable)
7. Is this injury a recognized complication of the patient's underlying index disease? (Widely recognized/Recognized by other specialists/No/Not applicable)

A score on ***causation*** was given on a 6 point Likert scale:

1. (Virtually) no evidence for health care management causation.
2. Slight to modest evidence of health care management causation.
3. Health care management causation not likely (less than 50/50, but 'close call').
4. Health care management causation more likely (more than 50/50, but 'close call').
5. Moderate to strong evidence of health care management causation.
6. (Virtually) certain evidence of health care management causation.
   Counted as caused by healthcare if the score was 4 to 6.

Supplementary file 2: Causation score

Preceding questions:

1. How complex was this case? (Very complex/Moderately complex/Somewhat complex/Not complex/Unable to determine)
2. What was the co-morbidity of the patient? (Significant co-morbidity/Moderate co-morbidity/Mild co-morbidity/No co-morbidity)
3. What was the degree of deviation of management of the primary illness (not the adverse event) from the accepted norm? (Severe/Moderate/Little/None)
4. What potential benefit was associated with the management of the illness which led to the Adverse Event? (Life saving/Curing/Life prolonging/Symptom relief/Palliation//No potential benefit)
5. What was the degree of emergency in management of the primary illness (not the adverse event) prior to the occurrence of adverse event? (Very urgent/Moderately urgent/Not urgent)
6. Did the patient have any follow-up as a result of this Adverse Event? (No/Counselling/Psychiatric/Rehabilitation/Routine clinical/Other/UTD)

Preparatory questions, added to the protocol:

7. Was the management of the primary illness (not the adverse event) appropriate? (Definitely appropriate/Possibly appropriate/Probably appropriate/Definitely not appropriate)
8. What was the risk of an adverse event related to the management ? (High/Moderate/Low/Not applicable)

A score on ***preventability*** was given on a 6 point-Likert scale:

1. (Virtually) no evidence for preventability.
2. Slight to modest evidence of preventability.
3. Preventability not quite likely (less than 50/50, but 'close call').
4. Preventability more than likely (more than 50/50, but 'close call').
5. Strong evidence of preventability.
6. (Virtually) certain evidence of preventability.
   Counted as preventable if the score was 4 to 6.

Supplementary file 3: Preventability score

Supplementary file 4: Comparison of inter-rater variability in other adverse events studies.

Author	Year	Country	Causality		Preventability	
			Kappa statistics (95%CI)	Agreement	Kappa statistics (95% CI)	Agreement
Brennan	1991	United States of America	0.61	89%		
Wilson	1995	Australia	0.42		0.33	
Thomas	2000	United States of America	0.40 (0.3 – 0.5)	76%		
Baker	2004	Canada	0.45 (0.33 – 0.57)		0.69 (0.55 – 0.83)	
Michel	2007	France	0.83 (0.67 – 0.99)	92%	0.31 (0.05 – 0.57)	68%
Sari	2007	United Kingdom	0.64	86%	0.33	83%
Soop	2009	Sweden	0.80	91%	0.76	91%
Zegers	2009	The Netherlands	0.25 (0.05 – 0.45)	76%	0.40 (0.7 – 0.73)	70%
Hogan	2012	United Kingdom	0.54 (0.37 – 0.71)			
Baines	2013	The Netherlands	0.47 (0.33 – 0.61)	83%	0.49	74%
Merten	2015	The Netherlands (focus hip fractures)	0.52	85%	too small (4 cases)