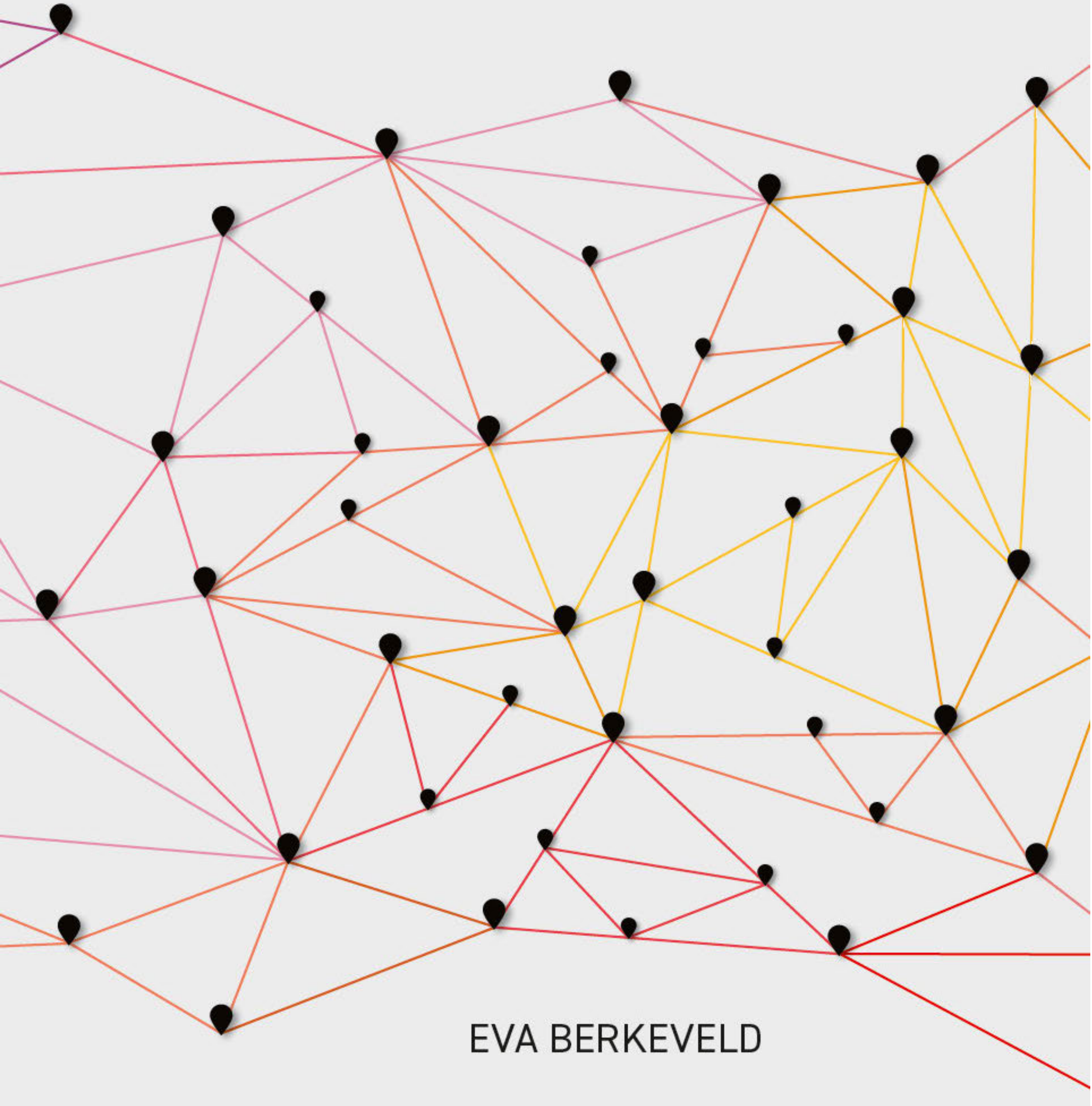
OPTIMIZATION OF INTEGRATED CARE IN TRAUMA AND COVID-19 PATIENTS: SIMILAR APPROACHES



EVA BERKEVELD

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Eva Berkeveld

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Voor mijn ouders

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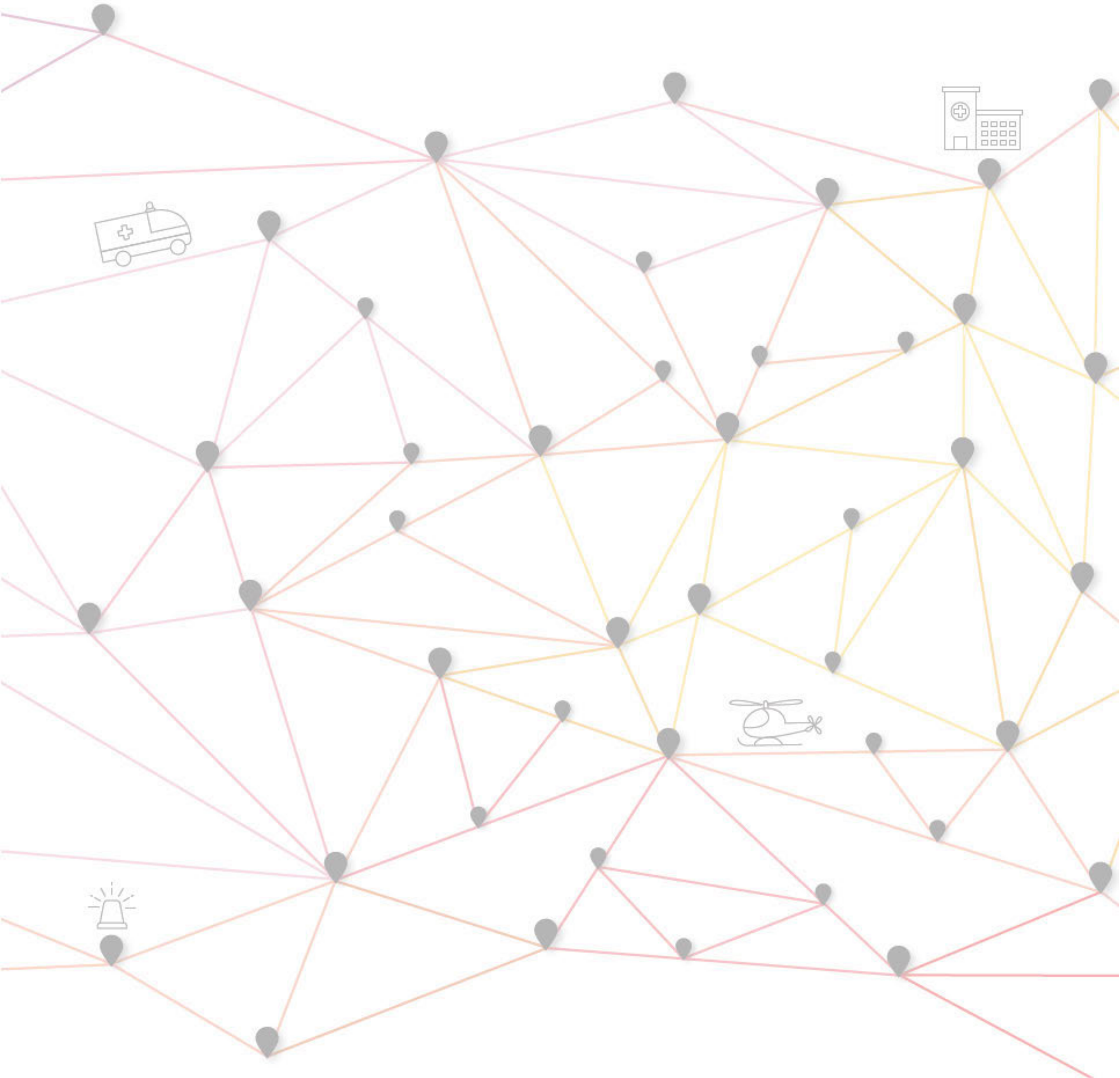
Chapter 1

General introduction and thesis outline



Integrated trauma care

Traumatic injury is a significant cause of morbidity and mortality in the Western world (1). In the younger Dutch population, injuries result in more years of life lost than all other causes of death combined (2). In the early phase after an injury, swiftly provided and appropriate care is crucial (3-10). The provided trauma care is based on an integral approach, as many professionals each contribute to the care process and collaborate together in a streamlined way.

The prehospital setting forms the first element of integrated trauma care. Dutch prehospital care is provided by highly trained and specialized Emergency Medical Services (EMS) personnel, backed if necessary by a prehospital critical care physician staffed HEMS – who allocate patient transport to the appropriate level trauma center (11). In total, four HEMS stations cover the Dutch prehospital HEMS care. In trauma region Noord-Holland Flevoland, HEMS is provided by the Lifeliner-1. Potentially life-saving treatment, that otherwise would be reserved for the inhospital setting, can be initiated on-scene by the HEMS crew. These treatment options include advanced airway management, prehospital administration of blood products, inotropic or vasopressor support, antibiotic treatment, or certain surgical procedures such as chest tubes and resuscitative thoracotomies.

Despite these treatment possibilities, determining the most appropriate duration of prehospital time is challenging, as various factors could affect both time and mortality risk (12). Generally, a short time until definitive care, that is, until lifesaving interventions are performed, is pivotal (13-19). The ''golden hour'' of trauma states that interventions performed within the first hour after injury show the greatest effects on survival (16-18). For specific patient conditions, such as the hemodynamically unstable trauma patient, the literature identified a short time to be beneficial for survival (13, 16, 19, 20), especially when sustaining Traumatic Brain Injury (TBI) (17). In contrast, a systematic review by Harmsen et al. showed that for patients with undifferentiated trauma who were hemodynamically stable, no rise in mortality odds was identified with increasing prehospital time (13). However, evidence derived from prehospital systems where care is provided by both EMS and HEMS is limited.

Once arrived at the Emergency Department (ED), the patient is treated according to a protocolled decision tree. The adagio ''treat first what kills first'' is reflected in the Advanced Trauma Life (ATLS) guideline used during resuscitation. A multidisciplinary trauma team in close collaboration provides the appropriate care as swiftly as possible in a horizontal approach, aiming to decrease the time until definitive care (21). Depending on the further interventions required, after ED, a patient can be dispositioned to the

Operating Room (OR), Intensive Care Unit (ICU), or clinical ward to continue the required treatment further. After hospital discharge, outpatient clinic care and continued care at (nursing) homes or rehabilitation clinics are essential elements in integrated care and contribute to patient’s recovery.

Dutch trauma system's organizational structure

Altogether, the integrated trauma care process depends on swift decision-making and acting of the prehospital and inhospital professionals. To warrant treatment to be provided at the right place at the right time for each patient, proper triage is crucial. Undertriage, defined as the proportion of severely injured patients who are not primarily presented at a level-1 trauma center, is undesirable and causes additional health risks (6, 22). In contrast, overtriage results in inefficient use of valuable resources and affect's a system's sustainability. According to the American College of Surgeons, an undertriage of 5% is considered acceptable and unavoidable to prevent disproportionate overtriage (23).

In the Netherlands, prehospital trauma triage is guided by the Dutch National Field Triage Protocol (Landelijk Protocol Ambulancezorg (LPA)) (24). A mature inclusive trauma system is adhered to, which composed of a collaborative trauma system among ten trauma regions. Due to the structure of level-1, -2, and -3 trauma centers, trauma care on various levels of complexity can be provided within each region. This organizational structure supports the concentration of high complexity, low volume care in level-1 trauma centers and the lateralization of selected care pathways and lower complexity, high volume care in level-2 and -3 centers. In level-1 trauma centers, appropriate equipment and expertise are in place to provide care for physiologically unstable patients after trauma, severely injured patients (Injury Severity Score (ISS) ≥ 16), patients requiring cardiothoracic- or neurosurgical interventions, or patients with complex or multiple moderate isolated injuries. In comparison, level-2 trauma centers are equipped to treat patients with moderate to severe injuries and physiologically stable patients, while in level-3 trauma centers, care is provided for patients with mild traumatic injuries or isolated injuries (25). Within each region, the trauma centers closely collaborate and the responsibility for providing all trauma care is shared collectively among the region's trauma centers. Due to this system within each region, the total pallet of trauma care can be delivered whilst contributing to qualitative and sustainable care.

For severely injured patients (Injury Severity Score (ISS ≥ 16)), direct transport to a level-1 trauma center showed to reduce morbidity and mortality rates (6, 10). Despite the Dutch Health Institute for over 90% of severely injured patients to be directly transported to a level-1 trauma center (26), various studies have shown that this goal is not met in most regions. Undertriage rates varying between 21.6% and 34.6% were identified in different Dutch trauma regions concerning severely injured patients who were transported directly to a level-2 or -3 trauma center (27-30). Supporting the early recognition of severe anatomical injury in the prehospital setting is vital for triage optimization and assisting the (H)EMS crew decision-making. Furthermore, concerning level-1 trauma care necessity, previous studies showed that the anatomical-based marker ISS does not always correlate with early critical resource use (e.g., ICU admission, emergency intervention within 24 hours, death within 24 hours) (31, 32), making a comprehensive approach to identify patients requiring level-1 trauma care even more vital.

To continuously evaluate processes of integrated trauma care, regionally organized focus groups contribute to the quality of care optimization. Attended by representative trauma surgeons of centers throughout the region, a collaborative framework is adhered to in which sharing of knowledge and encouragement of collaboration is the central factor. An advanced regional trauma registry forms the basis of quality evaluation (33). Embedded within a managerial system for acute care (Regionaal Overleg Acute Zorg (ROAZ)) for the Amsterdam region by the Network for Acute Care Noord-Holland Flevoland, trauma care functions as a center of excellence for insight into the acute integral care system (34).

Capacity optimizing strategies

Qualitative and sustainable care is a key focus in the organization of trauma and other emergency care. Concentration of experience and expertise is a strategy that contributes to warranting the quality of care. Therefore, a national standard was installed with so-called level-1 criteria. For example, 90% of all severely injured patients have to be transported directly to a level-1 trauma center per 2024. In addition, a minimum of 240 severely injured patients should be treated at a level-1 trauma center annually (25, 26, 35).

Recently, in the Amsterdam area, a merger of level-1 trauma centers occurred for the first time in the Netherlands. The merger of these two trauma centers was enacted as part of the merger of two academic hospitals in the city of Amsterdam. The latter aims to ensure the most qualitative care for patients with complex and rare diseases and high-quality emergency care on a 24/7 basis (36). The merger supports meeting the required 240 severely injured to be treated at a level-1 trauma center annually. Maintaining the quality and accessibility of trauma care comes hand in hand with ensuring its capacity availability. Therefore, sufficient capacity to ensure level-1 trauma care availability is essential. Process-based assessment of the capacity demand for integrated level-1 trauma care is pivotal.

Application of integrated care processes in managing COVID-19 patient demand

Due to the existing organizational structure of ROAZ and collaborative framework among hospitals, during the high demand on surge capacity due to COVID-19, region Noord-Holland Flevoland rose to the occasion. To prevent hospitals from being overwhelmed and to facilitate load-sharing of COVID-19 care, a novel task force was installed led by board-certified academic trauma surgeons experienced in managing Mass Casualty Incidents (37, 38). Building further from the foundation of the ROAZ structure, the regional task force coordinated intraregional patient transfers in a close collaborative framework of novel appointed local hospital coordinators (39). Together with the coordinating national task force (Landelijk Coördinatiecentrum Patiënten Spreiding (LCPS)) (40), interregional patient transfers could be achieved.

Outline of thesis

This thesis aims to evaluate the aspects of time and triage in the integrated trauma care system. Further process optimization strategies in managing high demands on acute patient care capacity are explored.

The first part of the thesis focuses on current integrated trauma care. **Chapter 2** is a retrospective analysis of the effect of prehospital time on mortality in polytrauma patients (ISS ≥ 16) by examining a cohort of patients presented at a level-1 trauma center. **Chapter 3** describes a large retrospective cohort study that examines the cancellation rate of HEMS Lifeliner-1 dispatches. The type of dispatch and reason for cancellation is evaluated. In **Chapter 4**, a retrospective observational study in a large Dutch trauma region examines the prehospital undertriage in trauma patients. **Chapter 5** is a prospective double cohort study examining the effect of a clock's presence in the trauma resuscitation room in the ED. Insights into the times of various phases of the resuscitation process are obtained.

The second part of the thesis adheres to a process-based approach in integrated care. **Chapter 6** describes the expected demand on the capacity for the post-merger setting in the merger of two level-1 trauma centers. In this retrospective cohort study, all phases of integrated trauma care are assessed, and strategies to ensure the availability of level-1 trauma care in the post-merger setting are proposed. **Chapter 7** is a review that describes the experience of the novel task force in managing the high COVID-19 care demand by coordinating intra- and interregional patient transfers. The initial installment, decision-making process, and collaboration structure are illustrated. **Chapter 8** describes the process optimization strategies of the regional task force between the first and second COVID-19 pandemic wave. The prioritized improvement according to three crucial pillars: process standardization, implementation of new strategies, and continuous evaluation of the decision tree are described.

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PART I

Early trauma care

Chapter 2

Prehospital time and mortality in polytrauma patients: a retrospective analysis

E. Berkeveld, Z. Popal, P. Schober, W.P. Zuidema, F.W. Bloemers, G.F.Giannakopoulos

BMC Emergency Medicine, 2021

Abstract

Background

The time from injury to treatment is considered as one of the major determinants for patient outcome after trauma. Previous studies already attempted to investigate the correlation between prehospital time and trauma patient outcome. However, the outcome for severely injured patients is not clear yet, as little data is available from prehospital systems with both Emergency Medical Services (EMS) and physician staffed Helicopter Emergency Medical Services (HEMS). Therefore, the aim was to investigate the association between prehospital time and mortality in polytrauma patients in a Dutch level I trauma center.

Methods

A retrospective study was performed using data derived from the Dutch trauma registry of the National Network for Acute Care from Amsterdam UMC location VUmc over a 2-year period. Severely injured polytrauma patients (Injury Severity Score (ISS) ≥ 16), who were treated on-scene by EMS or both EMS and HEMS and transported to our level I trauma center, were included. Patient characteristics, prehospital time, comorbidity, mechanism of injury, type of injury, HEMS assistance, prehospital Glasgow Coma Score and ISS were analyzed using logistic regression analysis. The outcome measure was in-hospital mortality.

Results

In total, 342 polytrauma patients were included in the analysis. The total mortality rate was 25.7% (n=88). Similar mean prehospital times were found between the surviving and non-surviving patient groups, 45.3 minutes (SD 14.4) and 44.9 minutes (SD 13.2) respectively (p=0.819). The confounder-adjusted analysis revealed no significant association between prehospital time and mortality (p=0.156).

Conclusion

This analysis found no association between prehospital time and mortality in polytrauma patients. Future research is recommended to explore factors of influence on prehospital time and mortality.

Background

Traumatic injury accounts for 9% of all global fatalities (1). Depending on injury severity, a prompt medical assessment, lifesaving onsite treatment and transportation to an appropriate trauma center are considered imperative to optimize survival rates (2, 3). Therefore, constant improvement of Emergency Medical Services (EMS) care in resuscitation and rapid transportation might be of substantial impact on survival rates.

In the Netherlands, additional to the care provided by EMS, assistance from physician staffed Helicopter Emergency Medical Services (HEMS) can be requested to provide advanced specialized care and interventions on-scene, such as tracheal intubation, administration of advanced analgesia, chest tube placement and surgical procedures. Ultimately, the aim is to stabilize severely injured patients and rapidly transport them to an appropriate trauma center.

Despite these available methods, the optimal duration of prehospital time for severely injured patients is difficult to determine, as there is an assumption that a broad variety of factors could influence the prehospital time and mortality risk (4). A previous systematic analysis has shown that for patients suffering penetrating or traumatic brain injury, a brief prehospital time would decrease mortality rates. This is in contrast with undifferentiated hemodynamically stable patients, who showed no increase in mortality odds with increasing prehospital time (5). However, little empirical data exists considering severely injured patients in a prehospital setting characterized by both EMS or EMS and HEMS.

Therefore, this retrospective single center analysis aimed to examine the association between prehospital time and mortality in polytrauma patients in a Dutch level I trauma system. We hypothesize that short prehospital times reduce mortality rates and improve polytrauma patients' outcome.

Methods

Study design and data extraction

A retrospective analysis was performed based on data derived from the Dutch trauma registry of the National Network for Acute Care. Adult polytrauma patients (ISS ≥16) presented at the Amsterdam UMC, location VUmc (admitting approximately 1200 trauma patients annually of whom roughly 20% are considered polytrauma patients), over a 2-year period, were included. Inclusion criteria consisted of treatment on-scene by EMS or both EMS and HEMS, followed by a direct transport to the trauma center. Patients below the age of 18 years, patients with missing data on the method of transportation to our center, patients with missing prehospital times and patients secondarily referred from surrounding hospitals were excluded from the analysis. Total prehospital time was calculated from when the EMS dispatch center received the initial call about the incident until the patient arrived at the trauma center. Patient characteristics, comorbidity (based on the American Society of Anesthesiologists Physical Status (ASA-PS)), mechanism of injury (MOI), type of injury (blunt or penetrating injury), HEMS assistance, prehospital Glasgow Coma Scale (GCS) and the injury severity score (ISS) were collected. The outcome measure was in-hospital mortality.

Data Analysis

Continuous variables were expressed as mean (standard deviation (SD)) or as median (interquartile range (IQR)) and were compared using independent sample t-tests or Mann Whitney U tests. Categorical variables were described as frequencies and percentages and compared using Pearson's chi-squared tests. A binary logistic regression analysis was performed to investigate the association between prehospital time and mortality (6). Initially, we used simple logistic regression to explore the unadjusted relationship. Next, to control for potential confounding, the following covariates were simultaneously included in the regression analysis: gender, age, comorbidity (based on the ASA-PS score), mechanism of injury, type of injury (blunt versus penetrating), HEMS assistance, prehospital GCS and ISS. These variables were selected based on previous literature, theoretical considerations and clinical relevance, rather than statistical significance in univariate testing, as currently recommended (7, 8). To relax the assumption of a linear relationship between non-categorical independent variables and the logit of mortality, such variables were modelled as restricted cubic splines. Calibration and discrimination of the multivariable model were assessed using a Hosmer–Lemeshow test and the area under the receiver operating characteristic curve (AUROC), respectively (9).

Several explorative and sensitivity analyses were performed. First, to determine whether the association between prehospital time and mortality depends on other factors, specifically, ISS, prehospital GCS, comorbidity, injury mechanism, type of injury, as well as HEMS assistance, interactions between these factors and prehospital time were modelled. Second, instead of using spline variables, we modelled time as (A) a continuous variable and (B) as a categorical variable with cutoffs chosen at 35, 43 and 54 minutes to obtain 4 roughly equally sized groups. Third, the main analysis was repeated with multiple imputation of missing prehospital GCS scores. No power analysis was performed. The sample size was predetermined by the number of patients included in the Dutch trauma registry of the National Network for Acute Care over a 2-year period.

A P-value of <0.05 was considered significant. Data were analyzed using IBM® SPSS® Statistics version 24.0 (IBM, New York, NY, USA) and STATA® version 16 (StataCorp LLC, College Station, TX, USA).

Results

In total, 467 polytrauma patients were presented at our center during the study period. After exclusion of 125 patients due to missing data, an age below 18 years, objection to participate or secondary referrals, 342 patients were eligible for inclusion in the analysis.

The total study population consisted predominantly of male patients (67.5%), with a mean age of 52.1 (SD 20.5) years (**Table 1**). The majority of the injuries were caused by blunt trauma (94.2%), mainly due to traffic accidents. A median ISS of 22.0 (IQR 17.0-26.3) was found, with a total mortality rate of 25.7% (n=88).

Overall, the mean prehospital time was 45.2 minutes (SD 14.1). Similar mean prehospital times were found between the surviving and non-surviving patient groups, 45.3 minutes (SD 14.4) and 44.9 minutes (SD 13.2) respectively (p=0.819). However, significant differences were found for prehospital GCS (p<0.001) and ISS (p<0.001) between the surviving and non-surviving group.

Table 1. Patient and prehospital characteristics

Variable	Survivors (n= 254, 74.3%)	Non-survivors (n= 88, 25.7%)	Total (n= 342)	P-value
Prehospital time, mean (SD)	45.3 (14.5)	44.9 (13.2)	45 2 (14.1)	0.501
Gender, male (%)	68.9	63.6	67 5	0.364
Age, mean (SD)	49.0 (19.2)	61.1 (21.5)	52.1 (20.5)	<0.001*
Comorbidity (%)				
ASA 1	65.7	42.0	59.6	<0.001*
ASA 2	30.4	38.7	32 5	0.151
ASA 3,4	3.9	19.3	7.9	<0.001*
Mechanism of injury (%)				
Traffic	46.9	38.6	44 7	0.182
Fall from height	36.6	40.9	37.8	0.474
Other	16.5	20.5	17 5	0.401
Type of injury, blunt (%)	94.5	93.2	94 2	0.653
HEMS assistance, Yes (%)	46.1	62.5	50 3	0.008*
Prehospital GCS, median (IQR)	13.5 (6.0-15.0)	3.0 (3.0-13.0)	11.0 (3.0-15.0)	<0.001*
ISS, median (IQR)	20.0 (17.0-25.0)	25.0 (25.0-29.8)	22.0 (17.0-26.3)	<0.001*

Abbreviations: ASA, American Society of Anesthesiologists Physical Status; HEMS, physician staffed Helicopter Emergency Medical Services; prehospital GCS, prehospital Glasgow Coma Scale; ISS, Injury Severity Score; SD, standard deviation; * Statistically significant (p<0.05).

Mortality analysis

The unadjusted association between prehospital time and mortality seemed to be non-linear in our sample (**Figure 1**). However, the unadjusted logistic regression analysis actually did not provide evidence for any association between prehospital time and mortality (p=0.754). Likewise, the confounder-adjusted analysis showed no association between prehospital time and mortality (p=0.156). Significant relationships with mortality were observed for age, comorbidity, prehospital GCS and ISS (all p<0.001). The model was characterized by an appropriate model fit (Hosmer-Lemeshow p=0.551) and calibration (AUROC=0.872).

In the sensitivity analyses, the analysis after multiple imputation of the missing GCS values (n=32) consistently also did not show any association between prehospital time and mortality. Also, when modeling time as continuous variable assuming a linear relationship or as a categorical variables, no association was found (p=0.818 and p=0.088, respectively). Moreover, no evidence for interactions between prehospital time and markers of injury characteristics, injury severity, comorbidities or HEMS involvement was observed.

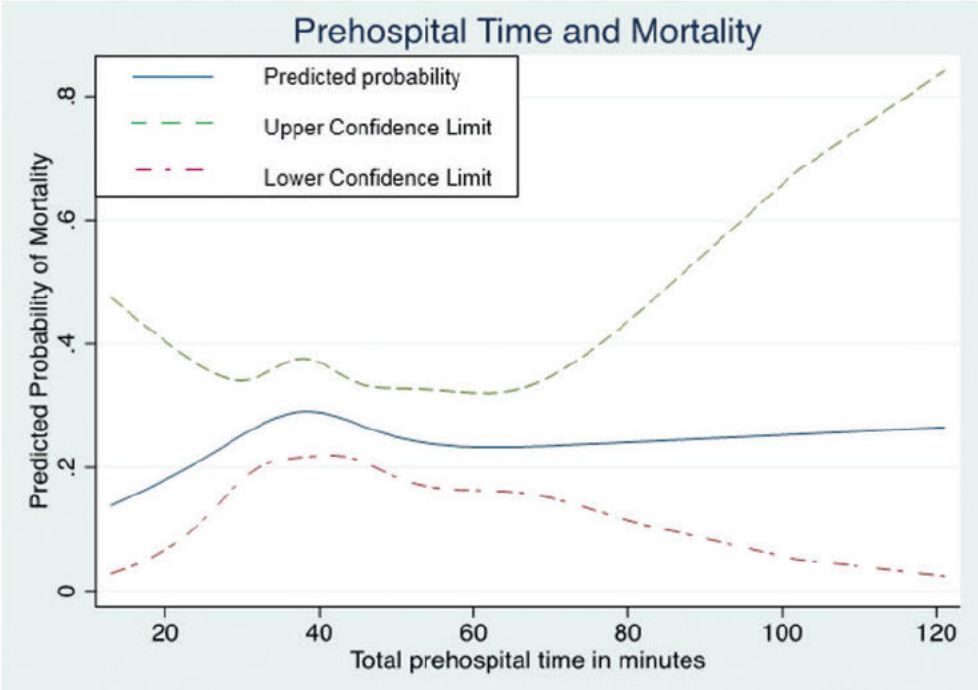

Figure 1. Association between prehospital time and mortality

Discussion

This study analyzed 342 severely injured polytrauma patients, who had received advanced prehospital care and were transported directly to a level I trauma center. We hypothesized that a shorter prehospital time would decrease a patient's mortality rate. However, in this analysis, no association between prehospital time and mortality was found.

Previous literature on the association between prehospital time and mortality in trauma patients is controversial. While some studies suggest that a short prehospital time seems beneficial in at least some patient categories (5, 10, 11), others – similarly to our results – did not observe an association between prehospital time and mortality (12-20). In our study, the fact that we found no evidence for an association could be explained by several factors:

First, distances to trauma centers are generally short in the Netherlands, and most patients in our region can be transported to our level I trauma center within fifteen to twenty minutes from any location. Indeed, we observed a mean prehospital time – including activation time, response time, on-scene time and transport time until arrival at the hospital – of only 45.2 minutes, which is relatively short compared to studies conducted in other trauma systems (21, 22). It is thus possible that prehospital time is less relevant for the outcome within the rather short time-frame as observed in our study, but it could plausibly become increasingly important in systems in which patients have to be transported from remote areas.

Second, even though patients in this study population were all polytrauma patients as defined by an ISS≥16, each individual patient, trauma mechanism and subsequent injury are unique, and thus, the group of polytrauma patients is highly heterogeneous. It is likely that a short prehospital time and quick in-hospital treatment is more important for some patients than for others, potentially explaining why overall no association was observed in the heterogeneous population. We have explored interactions between prehospital time and markers of injury characteristics or injury severity, but could not find evidence that the effect of time on mortality depends on any of these factors. Nonetheless, such interactions cannot be excluded, and it seems plausible based on previous literature that certain patients – such as those with penetrating injury or traumatic brain injury (5, 10, 11)– should be quickly transported to a trauma center. As it is often unclear which individual patient will versus will not benefit from quick transportation, we believe that it is generally prudent to avoid unnecessary delays and to initiate transport to a trauma center as soon as feasible.

Third, our trauma system is characterized by a wide array of treatment options for trauma patients. Stabilization is performed by highly trained and specialized EMS nurses, when required with the assistance of a physician-based HEMS crew. Potentially life-saving treatments, that otherwise would be reserved for the hospital setting, can be initiated on-scene. These treatments include advanced airway management, prehospital administration of blood products, inotropic or vasopressor support, antibiotic treatment for open fractures, or certain surgical procedures such as chest tubes and clamshell thoracotomies. Therefore, while HEMS involvement may prolong the prehospital time, it actually often shortens the time to advanced treatment (15-17). This, in turn, may at least partially explain why a longer prehospital treatment time is not necessarily associated with worse outcomes in our patient cohort.

In this study, a limiting factor was the retrospective observational nature of the dataset with all the inherent limitations, such as confounding and missing data on prehospital GCS scores. However, the amount of missing values was moderate (<10%), and sensitivity analysis with multiple imputation of prehospital GCS scores provided consistent results. In addition, we rigorously adjusted for potential confounders. Consistent with the literature, increased age, comorbidity, a low prehospital GCS and high ISS showed a significant association with mortality. Our analysis controlled for all of these factors, as well as for other potential confounders such as gender, type and mechanism of injury, and HEMS assistance. Nonetheless, residual confounding due to unobserved variables – such as hemodynamic, respiratory and physiologic parameters that are known to affect mortality in trauma patients (5, 10, 11, 23) – cannot be excluded. The single center design is another limitation. Our findings – likely at least partially explained by specific characteristics of our prehospital operation such as availability of highly trained EMS nurses and HEMS physicians in combination with short distances to trauma centers – do not readily generalize to settings with other logistic and geographic characteristics.

Conclusion

This retrospective analysis based on polytrauma patients from a level I trauma center found no association between prehospital time and mortality. This could be explained by a trauma system characterized by short transport times and a high level of the prehospital care, in which treatments that are otherwise reserved to the hospital are in part already provided at the accident scene. Nonetheless, our data do not exclude that individual patients may benefit from short prehospital times, and we suggest avoiding unnecessary delays in transporting patients to an appropriate trauma center. Future research is recommended to explore additional factors of influence on prehospital time and mortality, especially focusing on physiologic parameters in the severely injured patients.

Ethical considerations

The Medical Research Ethics Board of the Amsterdam University Medical Center, location VUmc, reviewed the study protocol, under reference number 2019.079, and concluded that the research is not subject to the Dutch Medical Research Involving Human Subjects Act (Wet medisch wetenschappelijk onderzoek met mensen (WMO)). The necessity for obtaining informed consent was waived by the medical research ethics committee of Amsterdam UMC location VUmc, and all participants were informed by information letters and provided the opportunity to object to participating in the study, according to the Dutch 'no objection procedure'.

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Chapter 3

Characteristics of Helicopter Emergency Medical Services (HEMS) dispatch cancellations during a six-year period in a Dutch HEMS region

E. Berkeveld, T.C.N. Sierkstra, P. Schober, L.A. Schwarte, M. Terra, M.A. de Leeuw, F.W. Bloemers, G.F. Giannakopoulos *BMC Emergency Medicine, 2021*

Abstract

Background

For decades, Helicopter Emergency Medical Services (HEMS) contribute greatly to prehospital patient care by performing advanced medical interventions on-scene. Unnecessary dispatches, resulting in cancellations, cause these vital resources to be temporarily unavailable and generate additional costs. A previous study showed a cancellation rate of 43.5% in our trauma region. However, little recent data about cancellation rates and reasons exist, despite revision of dispatch protocols. This study examines the current cancellation rate in our trauma region over a six-year period. Additionally, cancellation reasons are evaluated per type of dispatch and initial incident report, upon which HEMS is dispatched.

Methods

This retrospective study analyzed the data of the Dutch HEMS Lifeliner 1 (North-West region of the Netherlands, covering a population of 5 million inhabitants), analyzing all subsequent cases between April 1st 2013 and April 1st 2019. Patient characteristics, type of dispatch (primary; based on dispatcher criteria versus secondary, as judged by the first ambulance team on site), initial incident report received by the EMS dispatch center, and information regarding day- or nighttime dispatches were collected. In case of cancellation, cancel rate and reason per type of dispatch and initial incident report were assessed.

Results

In total, 18,638 dispatches were included. HEMS was canceled in 54.5% (95% CI 53.8-55.3%) of cases. The majority of canceled dispatches (76.1%) were canceled because respiratory, hemodynamic, and neurologic parameters were stable. Dispatches simultaneously activated with EMS (primary dispatch) were canceled in 58.3%, compared to 15.1% when HEMS assistance was requested by EMS based on their findings on-scene (secondary dispatch). A cancellation rate of 54.6% was found in trauma related dispatches (n=12,148), compared to 52.2% in non-trauma related dispatches (n=5,378). Higher cancellation rates exceeding 60% were observed in the less common dispatch categories, e.g., anaphylaxis (66.3%), unknown incident report (66.0%), assault with a blunt object (64.1%), obstetrics (62.8%), and submersion (61.9%).

Conclusion

HEMS cancellations are increased, compared to previous research in our region. Yet, the cancellations are acceptable as the effect on HEMS' unavailbility remains minimized. Focus should be on identifying the patient in need of HEMS care while maintaining overtriage rates low. Continuous evaluation of HEMS triage is important, and dispatch criteria should be adjusted if necessary.

Background

Helicopter Emergency Medical Services (HEMS) are increasingly used to provide specialized medical care in the out-of-hospital setting (1-8). For the severely injured patients, HEMS were shown to have an additional survival benefit (1-4). In the Netherlands, HEMS exist since 1995 and have the main purpose of assisting Emergency Medical Services (EMS) on-scene. Dispatches can coincide with EMS, based on information received by the EMS dispatch center (primary dispatch) often provided by a layperson, or upon request by EMS, based on their findings on-scene (secondary dispatch).

As the availability of specialized lifesaving care is considered imperative, it is pursued to maintain HEMS undertriage as low as possible, with an undertriage rate below 5% considered acceptable according to the American College of Surgeons (ACS) (9). Efforts to identify the severely injured requiring HEMS assistance were made by previous studies (10, 11), deducing predictors of major trauma based on criteria related to the mechanism of injury (MOI), physiologic parameters, and injury anatomy (10).

HEMS overtriage, resulting in dispatch cancellation, causes vital resources to be temporarily unavailable and generate additional costs. Besides, each dispatch constitutes a risk for the HEMS crew flying by helicopter. Yet, a certain amount of overtriage remains unavoidable (9). A cancellation rate of 43.5% has been found by a previous study in our HEMS region (12). Additionally, cancellations were more frequent in incidents where the mechanism of trauma was minor, and the injury was located at the extremities, compared to dispatches that resulted in an arrival at the scene (10, 12). However, no recent empirical data exists despite HEMS increasing experience and renewal of dispatch protocols. New insights in our cancellation rate and reasons for cancellation might contribute to the optimization of HEMS triage.

This study aimed to examine the current cancellation rate in our trauma region over a six-year period. Reasons for cancellation were evaluated per type of dispatch (primary versus secondary dispatch) and per initial incident report upon which HEMS is dispatched. We hypothesized that the cancellation rate would be lower compared to previous studies because of iterative improvement of dispatch questionnaire script over the last 10 years and increased experience with HEMS involvement in the prehospital setting.

Methods

Study setting

In the Netherlands, prehospital advanced medical and interventional trauma care is provided on a 24-hours, seven days a week basis by EMS and four additional HEMS services. The main purpose of HEMS is to provide a specialized, physician-based team on-scene that can perform additional lifesaving care such as advanced airway management, administration of specialized medication, blood products, and provide selected surgical interventions (including resuscitative thoracotomy, chest tube placement, surgical airway and amputation of extremities). Given the short distance to the trauma centers on average, patient transportation by helicopter only occurs occasionally, as the HEMS physician accompanies the patient in the ambulance during transport to the trauma center (13).

The Dutch HEMS crews consist of a HEMS physician (trauma surgeon or anesthesiologist), HEMS nurse (Emergency Department's (ED) nurse, or EMS nurse who acquired special training in navigating and assisting the pilot as a HEMS Crew Member (HCM)), HEMS pilot and chauffeur. Depending on weather conditions or scene access, a chauffeur is used to transport the crew in the rapid response vehicle.

Dispatch and cancellation

HEMS dispatch can occur either as a primary dispatch, in which HEMS is dispatched simultaneously with EMS, based on a layperson's call to the EMS dispatch center, or as a secondary dispatch when assistance is requested by the EMS crew already on-scene (e.g., the situation is worse than initially appeared or assistance with tracheal intubation is required).

HEMS triage is performed by the EMS dispatch center's centralist, a specially trained nurse, who, after receiving the initial call, can activate a HEMS dispatch request according to a systematic triage protocol. Primary dispatches are often based on a description of the mechanism of injury (MOI) or pronounced pathophysiologic or anatomical abnormalities. Also, an additional lower threshold is adhered to when incidents concern a child's involvement (14).

Once EMS has arrived on-scene, they provide a situation report through a continuous line to the EMS dispatch center's centralist and the already dispatched HEMS crew. Based on EMS's clinical judgment and experience, they could state that HEMS assistance is no longer required. Subsequently, the HEMS physician ultimately decides whether to cancel a dispatch, taking into account the HEMS cancellation criteria (10). In general, a dispatch is canceled in case of respiratory, hemodynamic, and neurologic stable parameters with no expected physiologic deterioration within one hour, an indication for "Scoop and Run" to the nearest trauma center, a patient already being deceased, or a false incident report (14).

For the patient to receive hospital-level care as soon as possible, HEMS' duration to arrive at the scene versus EMS' duration to transport the patient to a hospital is under constant consideration. An option to limit the time spent on-scene is by arranging a rendezvous between EMS and HEMS, in which the HEMS physician joins in the patient and EMS during transportation in the ambulance. Sometimes, arrival at the hospital would be faster than HEMS would take to arrive at the patient, then a joint decision between EMS and HEMS is made to cancel the HEMS dispatch. The HEMS physician could still provide treatment advice if contributing.

Study design and data extraction

This retrospective study analyzed all data of the Dutch HEMS Lifeliner 1 (Trauma Region North West Netherlands covering a population of about five million inhabitants). Patient characteristics, type of dispatch, and initial incident report received by the EMS dispatch center were collected. Additionally, in case of a canceled dispatch, the reason for- and time of cancellation was obtained. Time until cancellation was calculated as the difference between the time of cancellation and HEMS dispatch time. Times exceeding 30 minutes without logical explanation were excluded from the analysis due to the suspicion of outliers by data entry errors. Dispatches without resulting information regarding arrival at the scene or cancellation were also excluded from the analysis. Cancellation rates and reasons were calculated for each type of dispatch and initial incident report.

Statistical analysis

Descriptive statistics were used. Cancellation rates were presented as percentages and 95% confidence intervals (CI), whereas continuous variables were presented as median with interquartile range (25^{th} to 75^{th} percentile). Data were analyzed using IBM SPSS Statistics version 24.0 (IBM, New York, USA).

Results

In total, out of 18,706 HEMS dispatches, 18,638 were eligible for inclusion. Dispatches with missing data concerning whether the dispatch resulted in an arrival at the scene or a cancellation (n= 68) were excluded from the analysis. Overall, a cancellation rate of 54.5% (n= 10,166; 95% CI 53.8-55.3%) was found, compared to 45.5% (n= 8,472; 95% CI 44.7-46.2%) for dispatches resulting in arrival at the scene. Over the examined years, a relatively stable cancellation rate was found (**Figure 1**).

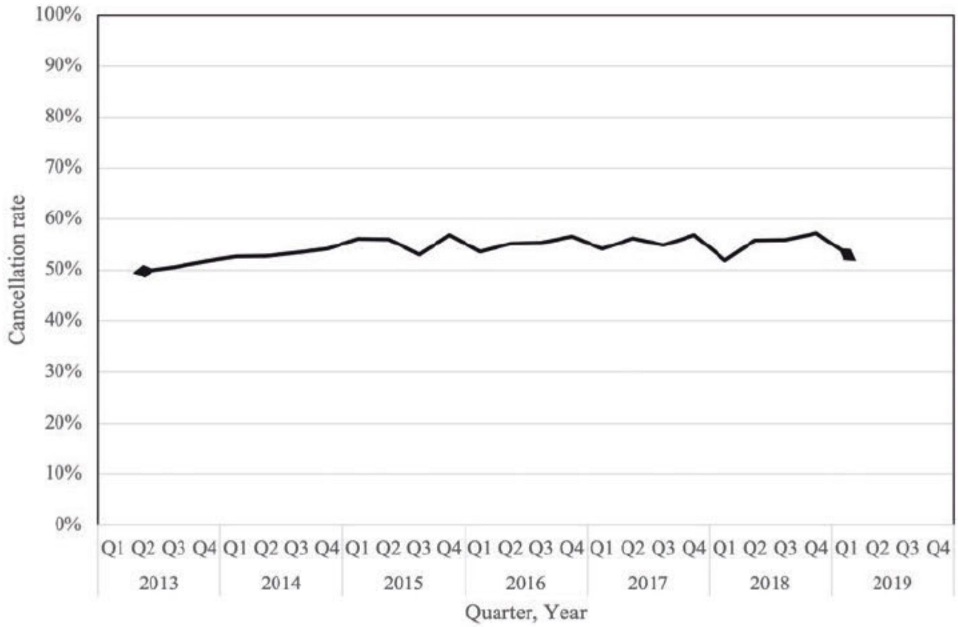

Figure 1. HEMS cancellation rate over the years.

Type of dispatch

Of all dispatches, the vast majority consisted of primary dispatches (n= 16,704; 89.6%) compared to secondary dispatches (n= 1,695; 9.1%) and in 1.3% (n= 239) data was missing regarding type of dispatch. A mean cancellation rate of 58.3% (n= 9,731; 95% CI 0.575-0.590) was found for primary dispatches compared to 15.1% (n= 256; 95% CI 0.134-0.169) for secondary dispatches.

Figure 2 illustrates the different reasons for canceled dispatches. For the total study population, "No HEMS indication," which refers to stable respiratory, hemodynamic, and neurologic parameters in a patient, was the most common cancellation reason (n= 7,733; 76.1%). Stratified by dispatch-type, "no HEMS indication" was the main reason for cancellation for primary dispatches (n= 7,559; 77.7%), whereas "anticipated HEMS transport time to scene too long" was most common in secondary dispatches (n= 108; 42.2%).

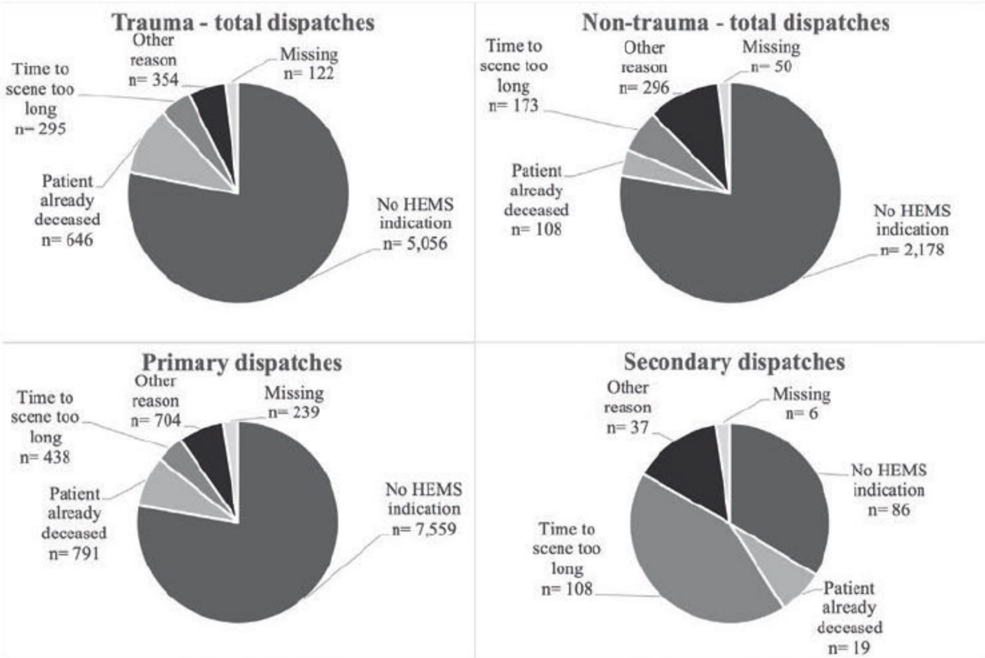

Figure 2. Reason for dispatch cancellation per type of dispatch.

Initial incident reports

As shown in **Table 1**, the majority of initial incident reports were trauma related (n= 12,148; 65.2%) compared to non-trauma related (n= 5,378; 28.8%) and unknown (n= 1,112; 6.0%), the latter in which no description was mentioned in the report. Specifically, dispatches concerning incidents involving "fall from height" (n= 3,485; 18.7%), "respiratory, hemodynamic or neurologic instability" (n= 2,007; 10.8%) or "unspecified traumatic incident" (n= 1,715; 9.2%) were most common. Highest cancellation rates were seen in "anaphylaxis" (n= 285; 66.3%), "unknown incident report" (n= 734; 66.0%) or "assault with a blunt object" (n= 123; 64.1%). Lowest cancellation rates were found in incidents involving "unspecified non-traumatic incident" (n= 21; 29.2%), "intoxication" (n= 58, 30.4%) and "assault with a firearm" (n= 112; 40.3%).

The major reason for dispatch cancellation in all initial incident reports was "No HEMS indication" (**Table 2**). In contrast, for incidents involving "pedestrian accident" or "strangulation," the main reason for cancellation was a "patient already deceased," 42.8% (n= 169) and 64.0% (n= 174), respectively. In the report category "pedestrian accident," 40% (n= 150) of cancellations concerned pedestrian accidents with involvement of a train.

Overall, time from HEMS alarm to cancel, including both dispatches facilitated by helicopter and rapid response vehicle, was available in 95.9% (n= 9,745) of dispatches. Median time until cancellation was 7 minutes (IQR 5-10). Specifically, median airborne time, indicated as the time from helicopter departure until cancellation, was available in 89.3% (n= 9,083) of helicopter facilitated dispatches. Median airborne time was 5 minutes (IQR 3-7).

In total, 64.9% (n= 12,095) dispatches were performed during daylight, compared to 35.1% (n= 6,543) dispatches being performed at nighttime. The cancellation rate for daylight dispatches was 54.5% (n=6,591), compared to 54.6% (n= 3,575) for nighttime dispatches.

Dispatches for incidents involving newborns and babies, aged between zero until one year of age (1.1%, n= 208) showed a cancellation rate of 60.6% (n= 126). Children under the age of 18 were involved in 16.4% (n= 3,065) of dispatches and had a cancellation rate of 61.0% (n= 1,870). Dispatches involving adult patients (53.6%, n=9,992) were most common and showed a cancellation rate of 46.6% (n=4,659.). In 240 cases (1.3%) patient age data was missing.

Table 1. Frequencies and cancellation rate per initial incident report.

Initial incident report	**Frequency of all dispatches, No. (%)**	**Cancellation per initial incident report. No. (%)**
Trauma	12,148 (65.2%)	6,627 (54.6%)
Pedestrian accident	704 (3.8%)	395 (56.1%)
Bicycle accident	1,487 (8.0%)	795 (53.5%)
Scooter accident	598 (3.2%)	287 (48.0%)
Motorcycle accident	365 (2.0%)	158 (43.3%)
Motor vehicle accident	1,175 (6.3%)	597 (50.8%)
Fall from height	3,485 (18.7%)	2,013 (57.8%)
Assault	1,279 (6.9%)	621 (48.6%)
- Blunt	192	123 (64.1%)
- Stabbing	809	386 (47.7%)
- Firearm	278	112 (40.3%)
Heavy object on body	148 (0.8%)	86 (58.1%)
Entrapment	295 (1.6%)	145 (49.2%)
Strangulation	464 (2.5%)	272 (58.6%)
Blast, fire or chemical Injury	433 (2.3%)	231 (53.3%)
Unspecified traumatic Incident	1,715 (9.2%)	1,027 (59.9%)
Non-trauma	5,378 (28.8%)	2,805 (52.2%)
Advanced airway management required	748 (4.0%)	335 (44.8%)
Respiratory, hemodynamic or neurologic instability	2,007 (10.8%)	927 (46.2%)
Anaphylaxis	430 (2.3%)	285 (66.3%)
Intoxication	191 (1.0%)	58 (30.4%)
Submersion	1,525 (8.2%)	944 (61.9%)
Obstetrics	86 (0.5%)	54 (62.8%)
Neonatal resuscitation	319 (1.7%)	181 (56.7%)
Unspecified non-traumatic incident	72 (0.4%)	21 (29.2%)
Unknown	1,112 (6.0%)	734 (66.0%)
Unkown report	1,112 (6.0%)	734 (66.0%)

Table 2. Reasons for cancellation per initial incident report

	Cancellation reason					
Initial incident report	No HEMS indication No. (%)	Patient already deceased No. (%)	Time to scene too long No. (%)	HEMS dispatch impossible No. (%)	Other reason No (%)	Missing No (%)
Trauma						
Pedestrian accident	173 (43.8%)	169 (42.8%)	18 (4.6%)	2 (0.5%)	24 (6.1%)	9 (2.3%)
Bicycle accident	691 (86.9%)	12 (1.5%)	50 (6.3%)	8 (1.0%)	24 (3.0%)	10 (1.3%)
Scooter accident	248 (86.4%)	9 (3.1%)	12 (4.2%)	2 (0.7%)	12 (4 2%)	4 (1.4%)
Motorcycle accident	124 (78.5%)	13 (8.2%)	9 (5.7%)	0	9 (5 7%)	3 (1.9%)
Motor vehicle accident	475 (79.6%)	55 (9.2%)	18 (3.0%)	4 (0.7%)	37 (6 2%)	8 (1.3%)
Fall from height	1,743 (86.6%)	114 (5.7%)	63 (3.1%)	9 (0.4%)	50 (2 5%)	34 (1.7%)
Assault	439 (70.7%)	33 (5.3%)	66 (10.6%)	1 (0.2%)	69 (11.1%)	13 (2.1%)
- Blunt	116 (94.3%)	0	3 (2.4%)	1 (0.8%)	3 (2.4%)	0 9
- Stabbing	276 (71.5%)	7 (1.8%)	51 (13 2%)	0	43 (11.1%)	(2.3%) 4
- Firearm	47 (42.0%)	26 (23.2%)	12 (10 7%)	0	23 (20.5%)	(3.6%)
Heavy object on body	75 (87.2%)	0	2 (2.3%)	0	7 (8.1%)	2 (2.3%)
Entrapment	111 (76.6%)	18 (12.4%)	8 (5.5%)	0	4 (2.8%)	4 (2.8%)
Strangulation	64 (23.5%)	174 (64.0%)	6 (2.2%)	2 (0.7%)	21 (7 7%)	5 (1.8%)
Blast, fire or chemical Injury	154 (66.7%)	9 (3.9%)	29 (12.6%)	4 (1.7%)	31 (13.4%)	4 (1.7%)
Unspecified traumatic incident	831 (80.9%)	53 (5.2%)	62 (6.0%)	6 (0.6%)	45 (4.4%)	30 (2.9%)
Non-trauma						
Advanced airway management required	271 (80.9%)	13 (3.9%)	25 (7.5%)	2 (0.6%)	20 (6.0%)	4 (1.2%)
Respiratory, hemodynamic or neurologic instability	719 (77.6%)	38 (4.1%)	82 (8.8%)	12 (1.3%)	59 (6.4%)	17 (1.8%)
Anaphylaxis	224 (85.6%)	0	21 (7.4%)	2 (0.7%)	14 (4.9%)	4 (1.4%)

Table 2. Reasons for cancellation per initial incident report continue

	Cancellation reason					
Initial incident report	No HEMS indication No. (%)	Patient already deceased No. (%)	Time to scene too long No. (%)	HEMS dispatch impossible No. (%)	Other reason No (%)	Missing No (%)
Non-trauma						
Intoxication	45 (77.6%)	3 (5.2%)	5 (8.6%)	1 (1.7%)	4 (6.9%)	0
Submersion	703 (74.5%)	47 (5.0%)	9 (1.0%)	7 (0.7%)	160 (16.9%)	18 (1.9%)
Obstetrics	27 (50.0%)	2 (3.7%)	17 (31.5%)	0	4 (7.4%)	4 (7.4%)
Neonatal resuscitation	157 (86.7%)	5 (2.8%)	12 (6.6%)	0	4 (2 2%)	3 (1.7%)
Unspecified non-traumatic incident	12 (57.1%)	0	2 (9.5%)	0	7 (33.3%)	0
Unknown						
Unknown report	427 (58.2%)	50 (6.8%)	42 (5.7%)	26 (3.5%)	83 (11.3%)	106 (14.4%)

Discussion

Availability of HEMS for patients in need of their care is essential. According to the ACS, an overtriage level up to 35% is accepted to keep undertriage below 5% concerning the in-hospital setting (9). However, for HEMS systems, the necessity to accept a certain amount of cancellations due to overtriage in order to ensure low levels of undertriage might apply as well. In the literature, various rates of overtriage were found for different patient categories (15-17). This study aimed to provide insight into a Dutch HEMS region's cancellation characteristics by analyzing a large cohort of more than 18,000 dispatches. In the total study population, a mean cancellation rate of 54.5% was found.

The cancellation rate found in this study is increased compared to previous research in this HEMS region, as Giannakopoulos et al. have found a cancellation rate of 43.5% in data originating from 2006 (12). Despite the current study's hypothesis that increasing experience would cause a lower cancellation rate, the opposite finding might be explainable as well. HEMS' fast and dynamic development could have caused a noticeable cancellation increase over the years. Their added value was scientifically demonstrated, and their presence at the scene is more established (1, 3, 4, 18-22). Therefore, a lower threshold is adhered to utilizing HEMS, consequently increasing the cancellation rate. In our study's dataset, a relatively stable cancellation rate was found over the examined years. These rather stable values contrast the findings of a previous study conducted in a different Dutch HEMS region by Gerritse et al. They found a steady increase in cancellation rate from 36 to 54% between 2001 and 2008 (23). Therefore, the current stable cancellation rate might be caused by the increased maturation of HEMS in the prehospital system, consequently maintaining cancellation rates over time relatively stable.

Primary versus secondary dispatches

Primary dispatches were most common and showed a relatively high cancellation rate of 58.3%, compared to secondary dispatches in which a cancellation rate of 15.1% was found. Similar results have been found by McQueen et al. concerning medical-related dispatches, showing a higher cancellation rate for primary dispatches (26.2%) than secondary dispatches (8.4%) in a UK HEMS system (24). The difference between primary and secondary dispatches was anticipated, as the decision for primary dispatch is often based on information provided by a layperson (9). Therefore, the EMS dispatch center adheres to a low dispatch threshold for primary dispatches. Cancellation of a dispatch occurs by EMS as soon as they consider HEMS assistance unnecessary (or in case a scoop-and-run is more feasible than waiting for HEMS). This is in contrast to secondary dispatches, wherein HEMS assistance is requested by EMS themselves because additional assistance on-scene is required - and this makes it less likely that they will subsequently cancel it. However, in some cases, HEMS' assistance is initially requested by EMS, while soon after, the patient's respiratory, hemodynamic and neurologic parameters stabilize (e.g., as a response to treatment provided by EMS). This could explain the current study's cancellations for the reason of 'no HEMS indication' in secondary dispatches.

Triage

Previous studies contributed to HEMS system's improvement by examining measures to optimize HEMS triage. An earlier study conducted in our HEMS region identified predictors for major trauma and, with that, contributed to improvement of the triage algorithm (10). Major trauma patients often show both anatomical injury and abnormalities in vital signs. For this reason, a combined MOI description, physiologic parameters, and anatomical injury would provide the most accurate prediction of HEMS requirement [12, 14]. Moreover, besides algorithms for a sensitive and specific dispatch protocol (25), we assume that an essential aspect in reducing overtriage concerns familiarity with criteria and, above all, the professionals' experience and clinical judgment. Studies showed that increased practice and familiarity with dispatch criteria could reduce overtriage (19, 26-28). Therefore, training of dispatch centralists, EMS – and HEMS crews might contribute to minimization of overtriage.

To the best of our knowledge, no previous study assessed the cancellation characteristics for various types of incidents in such detail. Incidents involving anaphylaxis, unknown incident report, or assault with a blunt object showed the highest cancellation rates. The lowest rates were seen in incidents involving an unspecified non-trauma incident, intoxication, and assault with a firearm. The majority of dispatches were canceled because a patient's physiologic, hemodynamic, and neurologic parameters were stable, which is in line with previous research (12, 23). Noticeably, considering penetrating injury, most cancellations were for the reason' time to scene too long'. Therefore, it might be indicating a positive sign of patient-orientated decision-making.

Incidents with pediatric involvement

In this study, 17.5% of dispatches involved a child (below 18 years). Compared to incidents involving adult patients, this group had a higher cancellation rate, 61.0% compared to 46.6%, respectively. In contrast, a lower cancellation rate for pediatric involvement of 27% was found in another Dutch HEMS region (23). Concerning incidents involving a child, it was shown that HEMS have an increased success rate for Advanced Life Support restricted procedures, and an additional 2.5 lives are saved per 100 dispatches (18, 20, 29). However, identifying children in need of acute trauma care remains challenging, as van der Sluijs et al. showed an undertriage rate of 16.3% based on data derived from several Dutch trauma regions (30). Moors et al. showed in a different Dutch HEMS system that the variables Glasgow Coma Scale (GCS), Injury Severity Score, systolic blood pressure, and respiratory rate might serve as good predictors for mortality in pediatric trauma patients in the out-of-hospital setting (18). However, none of them is available at a primary HEMS dispatch. Therefore, adhering to a low dispatch threshold for incidents involving a child is recommended(6, 14, 31). Even more, a patient's neurologic state was already identified as a triage criterion, with a sensitivity of 97.9% and a specificity of 96% for using GCS (15, 23). Besides, a neurologic triage criterion might be estimated roughly by a layperson, making it more applicable in the prehospital setting.

Cancellation costs

HEMS' cost efficiency has already been demonstrated in (inter-)national literature (12, 32, 33). In the Netherlands, a HEMS crew is available on a 24-hour, seven days a week basis. Therefore, variable costs are influenced by a canceled dispatch, whereas HEMS' sunk costs remain unaffected. In this study, despite a cancellation rate of 54.5%, the median (one-way) airborne time of 5 minutes and an average of 5 cancellations per 24-hours contribute to 50 extra flight minutes per 24-hours due to cancellations. Besides, on average, only 2/3 of dispatches are facilitated by helicopter, compared to 1/3 of dispatches in which the rapid response vehicle is used. However, as there is a window of inoperability to other patients requiring HEMS care concomitantly, opportunity costs are also involved in a dispatch cancellation. To overcome this, the dispatch center is notified when a cancellation is made during the flight, making HEMS immediately available for another incoming dispatch request. Therefore, the unavailability of HEMS is minimized. Moreover, the intervention of HEMS teams constitutes a risk due to the use of a helicopter. Optimization of overtriage would therefore also create possibilities to limit this risk.

In our HEMS system, even though the cancellation rate is increased compared to previous studies, the level of overtriage seems acceptable. We believe that the priority is to maintain low undertriage and ensure that overtriage stays within reasonable limits. Focus should be in particular on the effect that overtriage may have on HEMS' availability. As our system is characterized by a fast time until cancel, with limited canceled dispatches per 24-hours and confined related cancellations costs, we believe that the current cancellation rate is tolerable. That being said, continuous critical evaluation of the triage criteria and the consequences of overtriage remains vital to secure optimal efficiency of the HEMS system.

Limitations

This study's strengths are the large number of included dispatches and the duration of the study period, creating a substantial amount of data available. However, there are also some limitations. The retrospective descriptive design provides a lower level of evidence than a well organized randomized controlled trial or prospective design. However, for this study question, a randomized design would not be possible. Second, no information was available regarding ''false negative'' dispatches wherein dispatches were canceled, but HEMS could still have contributed. Unfortunately, variables that indicate severe instability are scarce and often not well recorded in prehospital databases. Future research could focus on examining the over-and undertriage per initial incident report. This, in order to consider per initial incident report whether HEMS dispatch would be accurate and possibly contribute to a revision of triage criteria.

Conclusion

HEMS cancellation rates have been stable for the last six years, however, this current plateau is considerably higher than the cancellation rates 10-15 years ago. Constant focus should be the identification of patients in need of HEMS care while maintaining overtriage rates low. Consequences of overtriage, such as HEMS' unavailability and additional costs, should be frequently evaluated. Dispatches for incidents involving pediatric patients had rather high cancellation rates, while trauma and non-trauma dispatch cancellation rates were similar. Continuous evaluation of HEMS triage is important, and dispatch criteria should be regularly adjusted in a data-driven manner.

Ethical considerations

The Medical Research Ethics Committee of Amsterdam UMC location VUmc, reviewed the study protocol, under reference number 2019.130, and concluded that the research is not subject to the Dutch Medical Research Involving Human Subjects Act (Wet medisch wetenschappelijk onderzoek met mensen (WMO)), and therefore, ethics approval was waived.

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Chapter 4

Prehospital undertriage of trauma patients: results from a large Dutch trauma region

E. Berkeveld, S. Oud, Z. Popal, F.O. Kooij, F.W. Bloemers, G.F. Giannakopoulos, on behalf of the SpoedZorgNet collaborative group

* collaborative group: R.N. van Veen, R. van den Berg, J. Winkelhagen, B. van Dijkman, R. van Velde, B. Twigt

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Chapter 5

The effect of a trauma clock's presence in the trauma resuscitation room in a Dutch level-1 trauma center: a prospective double cohort study

E. Berkeveld. K. Azijli, F.W. Bloemers, G.F. Giannakopoulos

Submitted

Abstract

Purpose

Interventions performed within the first hour after trauma increase survival rates. Literature showed that measuring times can optimize the trauma resuscitation process as time awareness potentially reduces acute care time. This study examined the effect of a digital clock placement on trauma resuscitation times in an academic level-1 trauma center.

Methods

A prospective observational double cohort study was conducted for six months before and after implementing a visible clock in the trauma resuscitation room, indicating the time passed since starting the in-hospital resuscitation process. Trauma patients (age ≥ 16) presented during weekdays between 9.00 AM and 9.00 PM were included. Time until diagnostics (X-Ray, FAST, or CT scan), time until therapeutic intervention, and total resuscitation time were measured manually with a stopwatch by a researcher in the trauma resuscitation room. Patient characteristics and information regarding trauma- and injury type were collected. Times before and after clock implementation were compared.

Results

In total, 100 patients were included, 50 patients in each cohort. The median total resuscitation time (including CT scan) was 40.3 minutes (IQR 23.3) in the cohort without clock compared to 44.3 (IQR 26.1) minutes in the cohort with clock. The mean time until the first diagnostic and until the CT scan was 8.25 minutes (SD 3.08) and 25.49 minutes (SD 7.14) without a clock compared to 8.57 minutes (SD 6.54) and 26.55 minutes (SD 11.53) with a clock. Severely injured patients (Injury Severity Score (ISS) ≥ 16) showed a median resuscitation time in the cohort without a clock (n= 9) of 54.6 minutes (IQR 50.5) compared to 46.0 minutes (IQR 21.6) in the cohort with a clock (n= 8).

Conclusion

This study found no significant reduction in trauma resuscitation time after clock placement. Nonetheless, the data represent a heterogeneous population, not excluding specific patient categories for whom literature has shown that a short time is essential, such as severely injured patients, might benefit from the presence of a trauma clock. Future research is recommended into resuscitation times of specific patient categories and practices to investigate time awareness.

Introduction

Time and trauma are inextricably linked. Directly after traumatic injury, receiving adequate and timely care is essential (1-3). The golden hour of trauma states that therapeutic interventions performed within the first hour after traumatic injury have the greatest effect on survival rates (4-6). Therefore, providing swift and appropriate care in both the prehospital and in-hospital phases directly after trauma is crucial.

In the Dutch, mature, inclusive trauma system, prehospital care is provided by trained and experienced Emergency Medical Services (EMS) crews, if necessary, assisted by a Helicopter Emergency Medical Services (HEMS) crew (7). A patient is subsequently triaged and transported to a level-1,-2, or -3 trauma center. A level-1 trauma center is equipped to provide care for severely injured patients (Injury Severity Score (ISS) ≥ 16), physiologic- and hemodynamically unstable patients, and patients sustaining complex isolated injuries. Additional neurosurgical- and cardiothoracic care is available on a 24-7 base (8). Since the adagio treat first what kills first is crucial in trauma, patients are treated according to a protocolled decision tree, the Advanced Trauma Life Support (ATLS), during the resuscitation process in the Emergency Department (ED) (9). A multidisciplinary trauma team in close collaboration provides the appropriate care as swiftly as possible in a horizontal approach, aiming to decrease the time until definitive care (10).

Insight into the duration of time-critical work is crucial to contribute to protocol development, education, and optimization of the process (11-13). Previous studies identified trauma resuscitation times varying between 19.1 minutes and 45.9 minutes for in-hospital trauma activations in various level-1 trauma centers(11, 14, 15, 16). Besides, it was shown that the elapsed time as perceived by the healthcare professionals in time critical work can differ from the actual time (17, 18). Concerning trauma resuscitations in ED, Kuhlenschmidt identified that involved residents had a distorted perception of elapsed time, which was proportionate to the duration of the process (18).

The contributing effect of awareness of time to the process has been identified by Curtis et al. They showed a reduction in prehospital scene time for specific trauma patient categories after the HEMS crew was via audio made aware of the time elapsed (19). Moreover, to facilitate time awareness, various time representation techniques, such as clocks showing the time elapsed since the start of the resuscitation, showed an appropriate option in trauma resuscitations (20). Therefore, this study aimed to examine the effect of a clock's presence on trauma resuscitation time. Additional insight into level-1 trauma center's resuscitation times is obtained, and time durations of different phases of the resuscitation process will be evaluated.

Methods

Study setting

This study was conducted in level-1 trauma center Amsterdam UMC location VUmc. The trauma center is located in the trauma region of North West Netherlands and provides care for approximately 250 severely injured patients annually (21). Trauma resuscitations in the Emergency Department (ED) are performed in one of two dedicated trauma resuscitation rooms, based on advanced triage criteria either a complete or selected trauma team is activated to provide the resuscitation (22). During day time, a complete team consists of a trauma surgeon, emergency physician, two ED nurses, anesthesiologist, nurse anesthetist, radiologist, two diagnostic radiographers, intensivist, and neurologist. During evening and night shifts, a surgical registrar and resident are present at the start of the resuscitation and the on-call trauma surgeon is present within 15 minutes. In comparison, a selective trauma team consists of an emergency physician, emergency resident, ED nurse, radiology resident, and diagnostic radiographer (23). In both activated teams, ATLS-based trauma care is provided in close multidisciplinary collaboration (22).

Study design and data collection

A prospective observational double cohort study was conducted six months before and after implementing a visible clock in the trauma resuscitation room, indicating the absolute time and elapsed time since the start of the in-hospital resuscitation process. The measurements for cohort I, in which no clock was implemented, were performed between May 1st, 2019, and Augustus 1st, 2019. In contrast, in cohort II, with the presence of a clock, patients between October 1st, 2020, and January 1st, 2021, were included. All trauma patients (age ≥ 16) presented at the trauma resuscitation room during weekdays between 09.00 AM and 09.00 PM were included.

As part of standard care, a visible clock was installed in each of the two trauma resuscitation rooms after the measurements of cohort I were completed. The clock contained digital information regarding the elapsed time from the start of the resuscitation process and the current time (Figure 1). A familiarization period was introduced wherein all trauma team members could accustom themselves to the presence of the clock. The trauma team leader would start the clock at the moment of the patient's arrival at the resuscitation room. After it was established that the team leader started the clock in over 90% of all trauma resuscitations, the inclusion period of cohort II commenced.

Figure 1. Trauma clock

Data were collected by conducting measurements by trained researchers using a structured observation form. By no means interfered the researcher's presence with the resuscitation process. Time until diagnostics (chest X-Ray, FAST, or pelvic X-ray), time until CT scan, time until therapeutic intervention and total resuscitation time were measured manually with a stopwatch. Therapeutic interventions could be either one of the following: tracheal intubation, thoracotomy, thoracotomy, CPR, placement of a pelvic binder, placement of a second IV access, placement of an arterial line, placement of intraosseous access, administering a Mass Transfusion Protocol, reposition, wound treatment or suturing or placement of a bladder catheter. Patients- and type of injury and mechanism characteristics were collected. The ISS was calculated based on the injuries classified by the Abbreviated Injury Score (AIS). Resuscitation times before and after trauma clock implementation were compared.

Total resuscitation time comprised the moment a patient entered the trauma resuscitation room on a stretcher until the definitive end of trauma resuscitation care. The ending of trauma resuscitation care concerned either the patient's disposition from the trauma resuscitation room or when all resuscitative-related care was performed, and the patient was only still located there due to logistical reasons (e.g., a patient waiting for ICU or operation room availability).

After the inclusion period of cohort II was completed, a survey questionnaire was performed among trauma team leaders (i.e., trauma surgeons and emergency physicians) regarding their experience with the clock. Based on a five-point scale from strongly agree to strongly disagree, the following questions were surveyed, compatible with surveys from the current literature (24, 25).

1. The use of the clock is intuitive and easy to understand.
2. Overall, the clock makes the resuscitation more time efficient.
3. The clock supports with timely disposition of patients with priority findings.
4. I am satisfied with the current use of a clock in trauma resuscitations.

Data analysis

Continuous variables were presented as mean (standard deviation (SD)) or as median (interquartile range (IQR)) and were compared using independent sample t-tests or Mann Whitney U tests. Categorical variables were described as frequencies and percentages and compared using Pearson's chi-squared tests. Data were analyzed using IBM SPSS Statistics version 24.0 (IBM, New York, USA).

Results

In total, 100 patients were included, 50 in each cohort. The total study population consisted predominantly of male patients (70.0%), with a median age of 48 years (SD 19.8) (Table 1). Blunt injury was the most common type of injury (91.0%), and a motor vehicle collision (34.0%) was the main caused mechanism of injury. Overall, median ISS was 5.5 (IQR 8.3). For 51.0% of resuscitations, the complete trauma team was activated, whereas for 49.0% the selected trauma team was activated.

Table 1. Baseline characteristics

	Cohort I Without clock (n= 50)	Cohort II With clock (n= 50)	Total (n= 100)	P value
Gender, male, n (%)	38 (76.0)	32 (64)	70 (70)	0.213
Age, years, mean (SD)	45.0 (19.4)	50.6 (20.0)	48.0 (19.8)	0.162
Comorbidity, n (%)				0.121
- ASA 1	32 (64.0)	37 (74.0)	67 (67.0)	
- ASA 2	9 (18.0)	13 (26.0)	22 (22.0)	
- ASA 3	8 (16.0)	0	8 (8.0)	
- ASA 4	1 (2.0)	0	1 (1.0)	
Type of injury, blunt, n (%)	46 (92.0)	45 (90.0)	91 (91.0)	0.347
Mechanism of injury				0.315
- Motor vehicle collision	21 (42.0)	13 (26.0)	34 (34.0)	
- Non-motorized traffic accident	11 (22.0)	8 (16.0)	19 (19.0)	
- Shooting or stabbing incident	4 (8.0)	3 (6.0)	7 (7.0)	
- Incident with blunt object	1 (2.0)	4 (8.0)	5 (5.0)	
- High energy fall	7 (14.0)	11 (22.0)	18 (18.0)	
- Low energy fall	5 (10.0)	9 (18.0)	14 (14.0)	
- Explosion	0	1 (2.0)	1 (1.0)	
- Thermic accident	0	1 (2.0)	1 (1.0)	
- Drowning	1 (2.0)	0	1 (1.0)	
ISS, median (IQR)	8.0 (9.25)	5.0 (8.25)	5.5 (8.25)	0.719
Trauma team, large, n (%)	27 (54.0)	24 (48.0)	51 (51)	0.548
Disposition after ED, n (%)				0.730
- Own living environment	11 (22.0)	11 (22.0)	22 (22.0)	
- Clinical admission	24 (48.0)	26 (52.0)	50 (50.0)	
- ICU admission	6 (12.0)	6 (12.0)	12 (12.0)	
- Operating room	6 (12.0)	3 (6.0)	9 (9.0)	
- Inter-hospital transfer	2 (4.0)	4 (8.0)	6 (6.0)	
- Death in ED	1 (2.0)	-	1 (1.0)	

ASA, American Society of Anesthesiologists Classification; ISS, Injury Severity Score; ED, Emergency Department

As illustrated in table 2, the median total resuscitation time (including CT scan) was 40.3 minutes (IQR 23.3) in the cohort without a clock compared to 44.3 (IQR 26.1) minutes in the cohort with clock. The mean time until the first diagnostic and until the CT scan was 8.3 minutes (SD 3.1) and 25.5 minutes (SD 7.1) without a clock compared to 8.6 minutes (SD 6.5) and 26.6 minutes (SD 11.5) with a clock. In total, nine patients were considered severely injured (ISS ≥ 16) in the cohort without a clock and they showed a median resuscitation time of 54.6 minutes (IQR 50.5) (Table 3). In the cohort with a clock, eight patients were considered severely injured (ISS ≥ 16) with a median resuscitation time of 46.0 minutes (IQR 21.6).

Furthermore, the survey was sent out to twelve trauma team leaders, of whom ten responded. Forty percent (n= 4) of respondents agreed that the clock made the resuscitation more time efficient, whereas 40% (n= 4) were neutral, 10% (n= 1) strongly agreed, and 10% (n= 1) disagreed (Table 4). With the statement that the clock supports the timely disposition of patients with priority findings, 50% (n= 5) of respondents were neutral, 20% (n= 2) agreed, 10% (n= 1) strongly agreed, and 20% (n= 2) disagreed.

Table 2. Duration characteristics

	Cohort I Without trauma clock (n= 50)	**Cohort II With trauma clock (n= 50)**	**P value**
Total resuscitation time, median (IQR)	40.3 (23.3)	44.3 (26.1)	0.970
Time until first diagnostic, mean (SD)	8.3 (3.1) (n= 45)	8.6 (6.5) (n= 43)	0.637
Time until CT scan, mean (SD)	25.5 (7.1) (n= 43)	26.6 (11 5) (n= 45)	0.610
Time until first intervention, median (IQR)	9.4 (8.1) (n= 27)	13.5 (19.5) (n= 20)	0.589

Time in minutes

Table 3. Duration characteristics for severely injured patients (ISS ≥16)

	Cohort I Without trauma clock (n= 9)	**Cohort II With trauma clock (n= 8)**
Total resuscitation time, median (IQR)	54.6 (50 5)	46.0 (21.6)
Time until first diagnostic, mean (SD)	7.2 (2.5) (n= 8)	7.5 (1.3) (n= 8)
Time until CT-scan, mean (SD)	23.5 (3.1) (n= 7)	20.1 (3.4) (n= 8)
Time until first intervention, median (IQR)	08.2 (11.1) (n= 7)	12.09 (35 3) (n= 5)

Time in minutes

Table 4. Survey questionnaire

	Strongly agree	**Agree**	**Neutral**	**Disagree**	**Strongly disagree**
The use of the clock is intuitive and easy to understand	5 (50%)	5 (50%)	-	-	-
Overall, the clock makes the resuscitation more time efficient	1 (10%)	4 (40%)	4 (40%)	1 (10%)	-
The clock supports with timely disposition of patients with priority findings	1 (10%)	2 (20%)	5 (50%)	2 (20%)	-
I am satisfied with the current use of the clock in trauma resuscitations	1 (10%)	2 (20%)	3 (30%)	4 (40%)	-

Discussion

This study examined the effect of a clock on trauma resuscitation times in a Dutch level-1 trauma center. Based on data in this study, no statistically significant reduction in resuscitation time was found after clock placement. The fact that we found no evidence for an association could be explained by several factors.

In trauma, a short time until definitive care is essential (1-6, 26). In the (inter-)national literature, short time was found to benefit patients' survival in the case of hemodynamically unstable trauma patients (1, 4, 26, 27), especially when concurrently suffering from Traumatic Brain Injury (TBI) (5). Therefore, it might be that during trauma resuscitation, a short time is more vital for patients with specific types of injury, such as TBI, severe hemorrhage, or severely injured patients (ISS ≥ 16). This current study was characterized by a heterogeneous study population, consisting of patients with various severities of injury, mechanism of injury, and anticipated required trauma team (i.e., complete or selected) as triaged based on the prehospital situation report by (H)EMS. Likewise, experience from the prehospital setting in a previous study by Curtis et al. showed that awareness of time can reduce scene time for specific patient categories (i.e., patients with a prehospital GCS below eight or patients requiring anesthesia) (19). Therefore, it might be that for some patient categories, for whom we know the time to definitive care is crucial, a time awareness intervention through a clock might have a greater effect than for others. It is thus possible that a clock's presence in the trauma resuscitation room is less relevant for time duration within the rather heterogeneous population, as observed in our study.

In our study, the clock was implemented as a form of standard care practice. Rigorous efforts were in place for the trauma team to familiarize with the presence of the clock and the team leader to activate the elapsing time the moment the patient entered the resuscitation room. The observational design left the actual use of the clock's information up to the professional team member's expertise. However, it might have been that the current implementation did not properly support time awareness within the trauma teams. For half of the team leaders, awareness of the elapsed time did occur (50%), whereas neutrality (40%) or absence (10%) were less frequent. In comparison, Curtis et al., examining the effect of a prehospital audible scene timer, found a vast majority (91.0%) of the HEMS crew aware of the elapsed time. However, in 57.0%, no perceived change in practice was experienced by the crew, while they did find a time reduction for specific patient categories (19). Perhaps room for improvement of the clock's utilization exists, as for the minority (30%) the clock was used to their satisfaction during the resuscitation. The placement location on the patient's left-hand side contributed to a clear view for the clinician performing the primary survey and a rather easy view for the trauma team leader. However, placement of a visual time indicator near the vital signs monitors, similar to Kusunoki et al., might benefit awareness due to the already allocated attention to this information source (20).

Furthermore, it might have been that other factors during the trauma resuscitation have had a more substantial influence on the resuscitation's duration than the clock alone. In the acute settings of trauma resuscitations, team structure and collaboration are essential, as team functioning and organization errors can lead to significantly more alteration in treatment (11). Additionally, leadership attributes play a crucial role in the resuscitation process (10). Previous studies showed that the presence of an attending trauma surgeon upon patients' arrival could significantly reduce the time till diagnostics (28, 29) and total resuscitation time (30, 31). Moreover, the degree of experience of the trauma team leader has a major impact on process functioning (32, 33), with an empowering leadership style being more appropriate in situations with less severely injured patients or an experienced team (33).

The total resuscitation time in this study is rather similar to some of the previous studies conducted in Dutch level-1 trauma centers (14, 16). Spanjersberg et al. found median resuscitation times of 45.9 minutes and 34.8 minutes for patients suffering from blunt injury and resuscitated by the "minor" versus "major" trauma team, respectively. The mean ISS of patients assessed by the "minor" team was 7.0, whereas, for patients assessed by the "major" team, it was 22.0 (14). Van Olden et al. showed, similar to our results, resuscitation times with medians of 41.3 minutes and 44.0 minutes for severely injured patients (ISS ≥ 16) receiving prehospital HEMS and EMS care versus EMS care alone, respectively (16).

In comparison, in line with a reached consensus in a Delphi study by Hoogervorst et al. who advocated for a maximum ED resuscitation time of 30 minutes (34), some studies observed a relatively shorter resuscitation time to ours. Lubbert et al., found a median of 32.9 minutes (11). Van Maarseveen et al. found mean resuscitation times of 23.4 minutes and 19.1 minutes for severely injured patients (ISS ≥ 16) resuscitated in a setting with an on-call versus in-house trauma surgeon, respectively (15). These shorter resuscitation times compared to our findings might plausibly be caused by differences in the severity of the included patients, as our study's population median ISS of 5.5 (8.3) was relatively low. Previous recent studies conducted in Dutch level-1 trauma centers showed that in their resuscitated population, the shorter the resuscitation time, the higher the severity of the injury was (14, 31).

In this study, a strengthening factor was the prospective nature of the design. Moreover, as far as we know, this was the first study examining the effect of a trauma clock on resuscitation times. A limiting factor was the small group sizes. Furthermore, a certain degree of bias caused to the two different inclusion periods between the cohorts cannot be excluded. Influences of COVID-19, which existed at the start of the inclusion period of the cohort with trauma clock, cannot be ruled out. However, the cohort with a clock did not consist of (suspected) COVID-19-positive patients, so no influence of COVID-19 measurements on trauma resuscitation time is expected. Consistent with peak hours in patient influx in the literature, the inclusion occurred from 09.00 AM until 09.00 PM. However, this limits the generalizability of a trauma clock's effect on resuscitation time outside these hours. Interpersonal variability was limited due to the use of structured observation forms and identical training of the observers. Due to the equal presence of a researcher in the trauma resuscitation room in both cohorts, we believe a possible Hawthorne effect, at which a team functions differently because they are being observed, would be equally negated. The heterogeneous study population, in line with the general trauma population, contributes to the generalizability of the study. Future research into resuscitation times of specific patient categories and practices is recommended to investigate time awareness.

Conclusion

This study found no significant reduction in resuscitation time after clock placement in the trauma resuscitation room of a Dutch level-1 trauma center. Nonetheless, the data represent a heterogeneous population, and it does not exclude specific patient categories for whom literature has shown that a short time is essential, such as severely injured patients, might benefit from the presence of a trauma clock. Future research is recommended into resuscitation times of specific patient categories and practices to investigate time awareness.

Ethical considerations

The Medical Research Ethics Committee of Amsterdam UMC location VUmc, reviewed the study protocol, under reference number 2019.187, and concluded that the research is not subject to the Dutch Medical Research Involving Human Subjects Act (Wet medisch wetenschappelijk onderzoek met mensen (WMO)), and therefore, ethics approval was waived.

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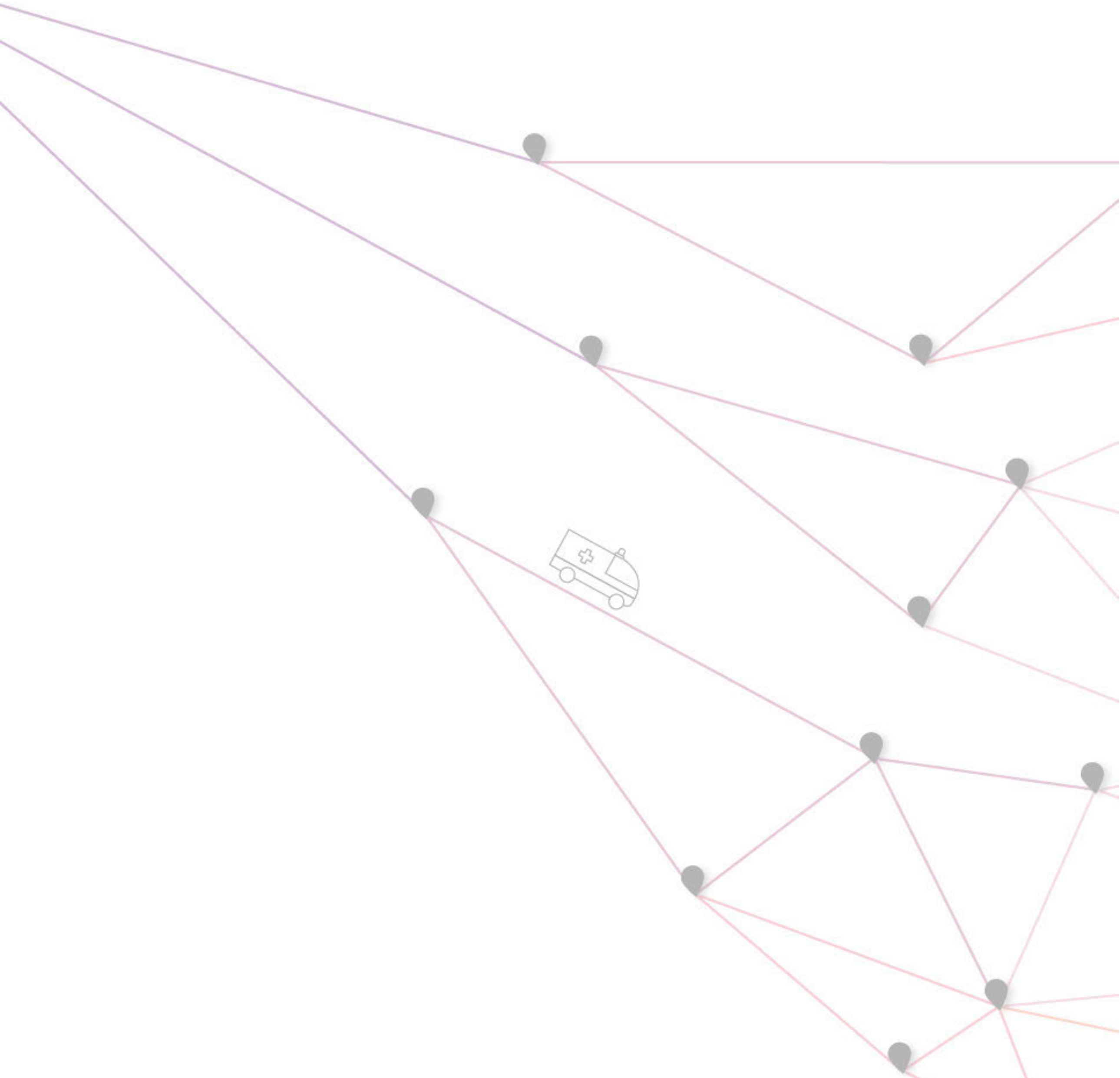
PART II

Process optimizing strategies



Chapter 6

Merging of two level-1 trauma centers in Amsterdam: premerger demand in integrated acute trauma care

E. Berkeveld, W.P. Zuidema, K. Azijli, M.H. van den Berg, G.F. Giannakopoulos, F.W. Bloemers, on behalf of the trauma surgery collaborative group

* collaborators: V. Cuijpers, A. Mahraoui, J. Moorees, G.Z. Nasim

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Abstract

Purpose

Availability of adequate and appropriate trauma care is essential. A merger of two Dutch academic level-1 trauma centers is upcoming. However, in the literature, volume effects after a merger are inconclusive. This study aimed to examine the premerger demand for level-1 trauma care on integrated acute trauma care and evaluate the expected demand on the system.

Methods

A retrospective observational study was conducted between 1-1-2018 and 1-1-2019 in two level-1 trauma centers in the Amsterdam region using data derived from the local trauma registries and electronic patient records. All trauma patients presented at both centers' Emergency Departments (ED) were included. Patient- and injury characteristics and data concerning all prehospital and in-hospital-delivered trauma care were collected and compared. Pragmatically, the demand for trauma care in the post-merger setting was considered a sum of care demand for both centers.

Results

In total, 8,277 trauma patients were presented at both EDs, 4,996 (60.4%) at location A and 3,281 (39.6%) at location B. Overall, 462 patients were considered severely injured patients (Injury Severity Score ≥ 16). In total, 702 emergency surgeries (< 24 hours) were performed, and 442 patients were admitted to the ICU. The sum care demand of both centers resulted in a 167.4% increase in trauma patients and a 151.1% increase in severely injured patients. Moreover, on 96 occasions annually, two or more patients within the same hour would require advanced trauma resuscitation by a specialized team or emergency surgery.

Conclusion

A merger of two Dutch level-1 trauma centers would, in this scenario, result in a more than 150% increase in the post-merger setting's demand for integrated acute trauma care.

Introduction

Worldwide, inclusive centralized trauma systems have shown to be beneficial for patients' survival, warranting the appropriate care at the right place (1, 2). In the Netherlands, a mature, inclusive trauma system is adhered to, composed of a collaborative trauma system among eleven trauma regions. Due to the structure of level-1, -2, and -3 trauma centers, trauma care on various levels of complexity can be provided within each region (3).

High-complexity trauma care is provided in level-1 trauma centers, as these centers are equipped with the required expertise and resources to provide care for the severely injured (Injury Severity Score (ISS) ≥ 16). Additionally, patients with physiologic-or neurologic instability with, if necessary, requirements for emergent neurosurgical or cardiothoracic interventions and patients sustaining a complex isolated injury can receive adequate treatment accordingly (3). The literature showed that for severely injured patients, direct transportation to a level-1 trauma center decreases morbidity and mortality rates (4-6). To support this, novel Dutch standards aim for > 90% of severely injured patients to be directly transported to a level-1 trauma center (7-9). Due to the expertise role that level-1 trauma centers fulfill, ensuring the continuous availability of level-1 trauma care is essential.

Currently, in the Amsterdam area, for the first time in the Netherlands, a merger of two academic level-1 trauma centers is upcoming. Due to the consequent change in the catchment area in case of mergers (10), changes in patient input could be expected. Therefore, assessing and early intercepting potential capacity barriers along the integrated acute trauma care system seems imperative to warrant the continuity of trauma care in the post-merger setting.

However, anticipating the expected capacity demand in the post-merger setting is challenging, as, in the literature, effects on volume after a merger are inconclusive (11-14). Some studies found a reduction in demand for capacities, such as reduced activity or total staffing, after analyzing large cohorts with different hospital sizes and merger types (11, 12). In contrast, disappearing effects in operating efficiency were found after adjusting for the control group by Alexander et al. in a large sample of mergers (13). The variety of volume effects after a merger is further underlined in a report by The Netherlands Authority for Consumers and Markets (ACM), demonstrating a range from a fall of 12% to a volume rise of more than 25% concerning twelve general hospital mergers in the Netherlands (14).

Moreover, due to the novel situation of merging two academic level-1 trauma centers in a mature, inclusive trauma system, extrapolating the volume effects of previous mergers to our upcoming post-merger setting is challenging. Therefore, this study aimed to examine the current demand for level-1 trauma care in integrated acute trauma care and evaluate the expected demand on the system by providing a comprehensive baseline situation in the premerger setting.

Methods

Study setting

The level-1 trauma centers Amsterdam UMC location VUmc (location A) and Amsterdam UMC location AMC (location B) are situated in Amsterdam and provide level-1 trauma care for two trauma regions, i.e., the provinces of North Holland and Flevoland (15). Together, these regions cover an area of more than 3.5 million inhabitants. Both trauma centers are equipped with two modern trauma resuscitation rooms to resuscitate severely injured patients with (suspected) respiratory-, physiologic- or neurological abnormalities. A two-tiered trauma team activation is adhered. Based on a standardized triage protocol either a complete or selective trauma team is activated to treat the patient in the trauma resuscitation room (16). During day time, a complete team consists of a trauma surgeon, emergency physician, two ED nurses, anesthesiologist, nurse anesthetist, radiologist, two diagnostic radiographers, intensivist, and neurologist. During evening and night shifts, a surgical registrar and resident are present at the start of the resuscitation and the on-call trauma surgeon is present within 15 minutes. In contrast, a selective trauma team consists of an emergency physician, emergency resident, ED nurse, radiology resident, and diagnostic radiographer (17) Specially set up Emergency Departments (ED), Operating rooms (OR), and Intensive Care Units (ICU) function to provide adequate level-1 trauma care. Together, these essential components form a streamlined, collaborative integration to provide patients with definitive treatment as swiftly as possible. In the prehospital setting, care is provided by highly trained and experienced Emergency Medical Services (EMS) crews additionally supported by a physician-staffed Helicopter Emergency Medical Services (HEMS) crew to provide A(T)LS care (18). Both level-1 centers feature a helicopter landing platform, whereas the permanent pitch of the HEMS Lifeliner-1 is situated at location A.

The merger of the two level-1 trauma centers was enacted as part of the merger of two academic hospitals in Amsterdam. The latter aims to ensure the most qualitative care for patients with complex and rare diseases and high-quality emergency care on a 24-7 basis. Additionally, it provides an opportunity to expand scientific knowledge, and educational practices benefit from shared expertise (19). Concerning trauma care, the merger supports meeting the required 240 severely injured to be treated at a level-1 trauma center annually, required to warrant quality and staff efficiency. Following the decision to merge the two academic hospitals, locations A and B, it was decided in the interest of the entire healthcare system to concentrate all acute care at location B. Consequently, for this reason, the two level-1 trauma centers were planned to merge into location B.

Study design

This retrospective study analyzed all data of two academic level-1 trauma centers in Amsterdam between January 1st, 2018, and January 1st, 2019. All trauma patients presented at the trauma centers' Emergency Departments (ED) were included. Patient characteristics, prehospital, in-hospital, and outpatient clinic information were derived from the Dutch National Trauma Registry and complemented with Electronic Patient Record information. Prehospital characteristics included the location of the scene, method of transportation, transport time, and HEMS assistance. In-hospital information was composed of arrival date and time, length of stay (LOS) at ED, OR, ICU, and clinical departments. In addition, resuscitation-specific information was collected, such as trauma resuscitation team activation at ED, patient's ISS, and CT-scan usage at ED. ISS from non-admitted patients was considered as an ISS below 16.

If a patient required an intervention, information regarding the urgency of the intervention (performed within 24 hours after arrival) and the number of interventions performed were collected. Additionally, admissions of ICU- and clinical (trauma surgical -, pediatric -or neurologic department where the trauma surgeon provides (co-)treatment) were collected. In-hospital mortality, destination after discharge, and the number of outpatient clinic visits were retrieved.

Data analysis

Descriptive statistics were used. Categorical variables were presented as percentages, whereas continuous variables were presented as mean (standard deviation (SD)) or median with interquartile range (25th to 75th percentile). Data were analyzed using IBM SPSS Statistics version 24.0 (IBM, New York, USA). Prehospital time distances were calculated using a route planner accounting for one day of the week and the time of day. Data from level-1 trauma center locations A and B were added to provide an overview of the sum of both capacities in case of concentration at location B in the post-merger setting. Patient input per shift (i.e., day 8.00 AM till 4.00 PM, evening 4.00 PM till 11.00 PM, and night 11.00 PM till 8.00 AM) per 24 hours and annum were examined.

Results

Descriptives

In total, 8,277 trauma patients were presented at both EDs during the study period, 4,996 (60.4%) at location A, and 3,281 (39.6%) at location B (Table 1). Excluded were duplicates, patients not presented at the ED, and patients left on their behalf before diagnostics commenced. The total study population predominantly consisted of male patients (59.6%) with a mean age of 40.9 (SD 25.0), as shown in Table 1. Overall, 462 patients were considered severely injured (ISS ≥ 16), of which 278 (60.2%) were presented at location A and 184 (39.8%) at location B. In total, 1,799 patients were resuscitated at the trauma resuscitation room by a trauma team, including all severely injured patients (n= 462). The mean ISS of the admitted patients (n= 2,509) was 9.3 (SD 9.2).

Table 1. Demographic characteristics

	Location A (n= 4,996)	**Location B (n= 3,281)**	**Total (n= 8,277)**
Age, mean (SD)	41.6 (25.0)	39.8 (23.9)	40.9 (25.0)
Gender, male (%)	2,911 (55.3)	2,025 (61.7)	4,936 (59.6)
ISS, mean (SD) admitted patients only	9.7 (9.7)	8.7 (8.5)	9.3 (9.2)
Destination after discharge, n (%)			
- Home	4,417 (88.4)	2,915 (88.8)	7,332 (88.6)
- Nursing home	162 (3.2)	30 (0.9)	192 (2.3)
- Physical rehabilitation center	54 (1.1)	33 (1.0)	87 (1.1)
- Other hospital	270 (5.4)	230 (7.0)	500 (6.0)
- Left against medical advice	19 (0.4)	19 (0.6)	38 (0.5)
- Deceased in-hospital	74 (1.5)	54 (1.7)	128 (1.5)

Abbreviations: ISS; Injury Severity Score.

Integrated acute trauma care

Table 2 shows that for the total study population, the vast majority of patients arrived at ED directly from the accident scene (95.7%), and the most common method of transportation was by EMS (55.1%). For both trauma centers, patients' arrival time at ED shows highest during day and evening shifts (Figure 1). Similarly, advanced trauma resuscitations by a specialized team, including for severely injured patients, occurred most frequently during the day and evening shifts (Figure 2). Most emergency interventions were performed during day and evening shifts and were required for 702 patients in total (Table 3), whereas the necessity for ICU admission (n= 442) was most prevalent during the evening (38.5%) and night (35.5%) shifts (Figure 3).

Table 2. Prehospital characteristics

	Location A (n= 4,996)	Location B (n= 3,281)	Total (n= 8,277)
Transported from, n (%)			
- Accident scene	4,837 (96.8)	3,080 (93.9)	7,918 (95.7)
- Hospital referral	51 (1.0)	76 (2.3)	127 (1.5)
- General practitioner referral	43 (0.9)	20 (0.6)	63 (0.8)
- Missing	64 (1.3)	105 (3.2)	169 (2.0)
Method of transportation, n (%)			
- EMS	2,758 (55.2)	1,801 (54.9)	4,559 (55.1)
- Own transportation	905 (18.1)	1,449 (44.2)	2,354 (28.5)
- HEMS	12 (0.2)	-	12 (0.1)
- Other	1,321 (26.5)	31 (0.9)	1,352 (16.3)
HEMS assistance n (%)	251 (5.0)	86 (2.6)	337 (4.1)

Abbreviations: EMS; Emergency Medical Services, HEMS; physician staffed Helicopter Emergency Medical Services.

Table 3. In-hospital characteristics

	Location A (n= 4,996)	Location B (n= 3,281)	Total (n= 8,277)
Emergency Department			
Trauma resuscitation room presentation, n (%)	941 (18.8)	858 (26.2)	1,799 (21.7)
General ED room presentation, n (%)	4,055 (81.2)	2,423 (73.8)	6,478 (78.3)
CT-scan, n (%)	1,823 (36.5)	1,226 (37.4)	3,049 (36.8)
LOS ED with trauma resuscitation (hh:mm), median (IQR)	3:55 (2:50)	2:54 (2:30)	
LOS ED general (hh:mm), median IQR	2:44 (2:37)	2:33 (2:19)	
Operating room			
Emergency surgery (< 24 hours), n (%)	392 (7.8)	310 (9.4)	702 (8.5)
Clinical departments			
Admission, n (%)			
- ICU	237 (4 7)	205 (6.2)	442 (5.3)
- Clinic	1,209 (24.2)	847 (25.8)	2,056 (24.8)
LOS, median (IQR)			
- ICU	3.0 (5.0)	2.0 (3.0)	
- Clinic	4.0 (7.0)	3.0 (5.0)	

Abbreviations: ED; Emergency Department, LOS; length of stay, ICU; Intensive Care Unit.

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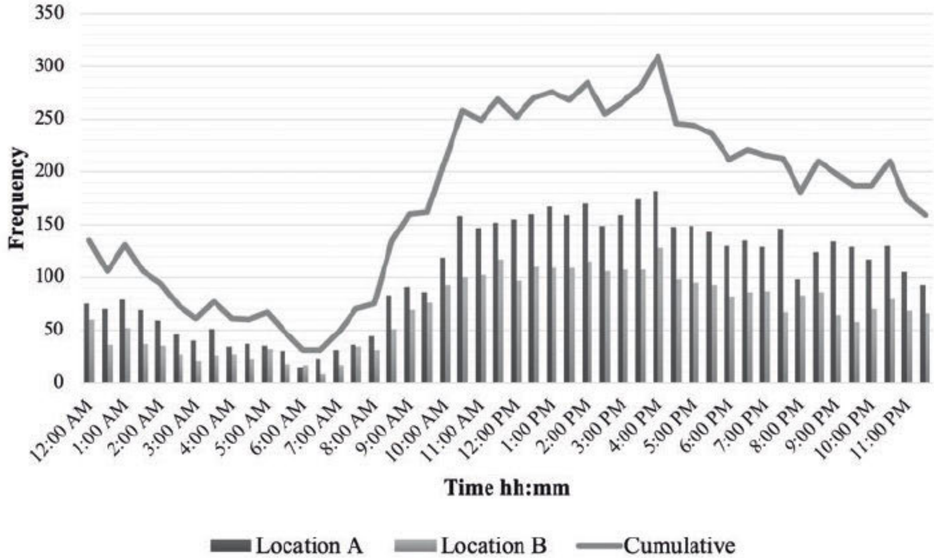
Sum of trauma care

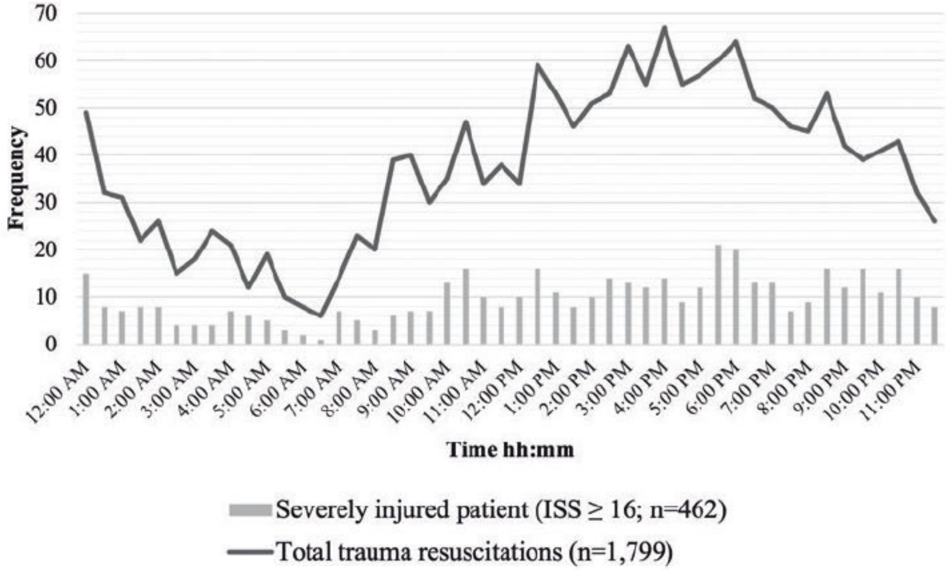
Adjustment for trauma care from both centers to be solely concentrated at location B resulted in a 167.4% increase in trauma patients and a 151.1% increase in severely injured patients. Median transport time from the scene to location B increased by 5.4 minutes (IQR 4.0) from 12 to 17 minutes (n= 1,029). The number of advanced trauma resuscitations (including for severely injured patients) at the ED increased by 109.7%, from 858 to 1,799. This increase would be 150.0%, 160.9%, and 153.5%, respectively, during the day-evening and nighttime shifts. For severely injured patients specifically (n= 462), an increase of 124.7% during the daytime, 170.0% during the evening, and 165.9% during nighttime shifts was found. In total, on 34 occasions arrival of two or more consecutive patients would occur within one hour, requiring advanced trauma resuscitation by a specialized trauma team in ED (Figure 4). During the evening and nighttime shifts, two or more patients within one hour requiring either advanced trauma resuscitation at ED or emergency surgery would occur on 59 occasions annually.

Figure 1. Timing of trauma patients' arrival at ED (n= 8,277)



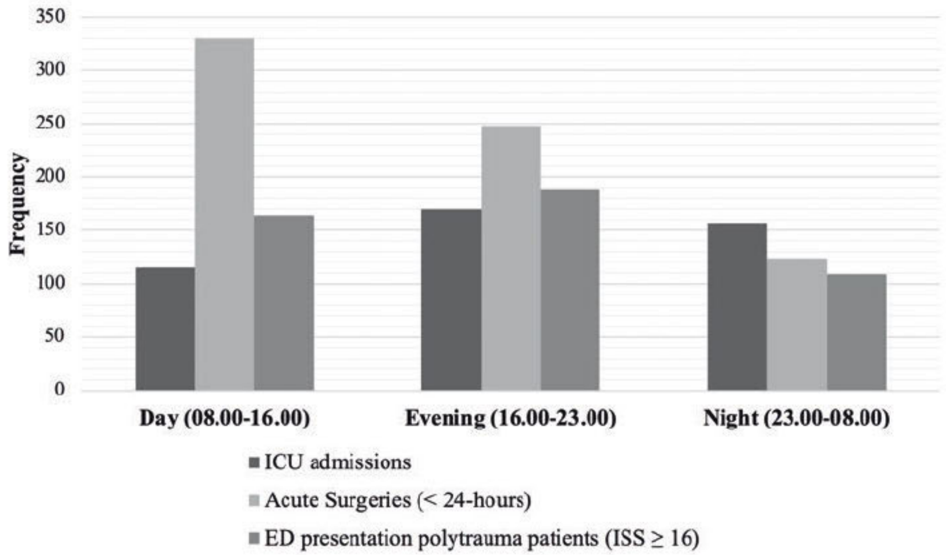
Abbreviations: ED; Emergency Department

Figure 2. Timing of patients' arrival resuscitated by a specialized trauma team at the trauma resuscitation room in ED.



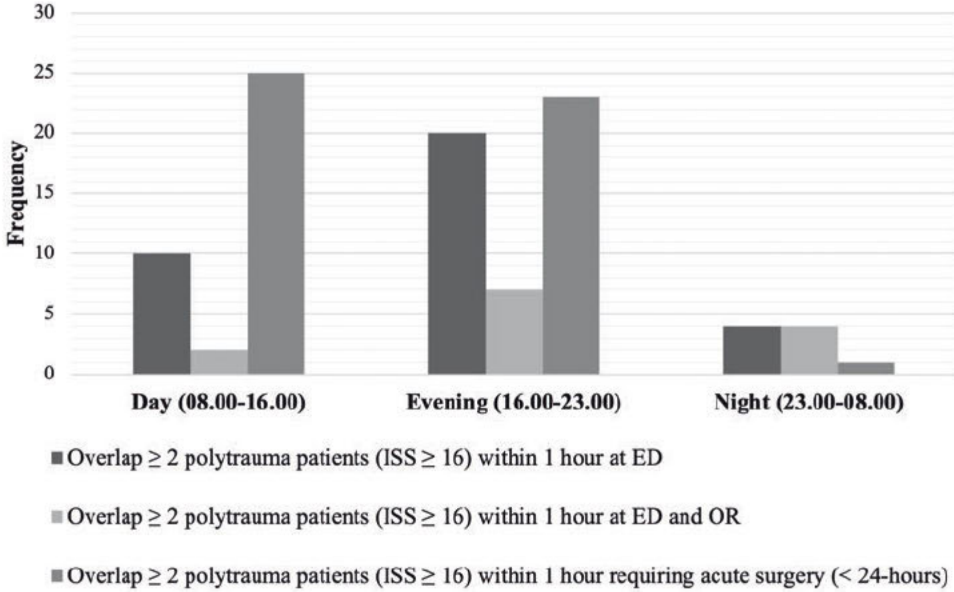
Abbreviations: ED; Emergency Department, ISS; Injury Severity Score

Figure 3. Trauma care necessity per shift in both trauma centers



Abbreviations: ED; Emergency Department, ICU; Intensive Care Unit, ISS; Injury Severity Score

Figure 4. Severely injured patients' (Injury Severity Score ≥ 16) overlap in both trauma centers



Abbreviations: ED; Emergency Department, OR; Operating Room, ISS; Injury Severity Score

Discussion

This study examined the current premerger demand for level-1 trauma care in integrated acute care involving two level-1 trauma centers in the Amsterdam region. During the study period, 8,277 patients required trauma care, of which 60.4% at location A and 39.6% at location B. Overall, 462 patients were considered severely injured. Due to the expert care delivered in level-1 trauma centers, it is crucial to ensure the appropriate availability of capacity of staff and resources. Based on varying volume effects after merger described in the literature (11-14), the extrapolation of an expectation model to the current situation is challenging. Pragmatically, the demand for trauma care in the post-merger setting considered as a sum of care demand of both centers resulted in a 167.4% increase in trauma patients and a 151.1% increase in severely injured patients for location B. Moreover, on 96 occasions annually, two or more patients within the same hour would require advanced trauma resuscitation by a specialized team or emergency surgery.

To manage increased patient input on a tactical and operational level, the literature emphasizes the importance of optimizing throughput and output components of acute care flow (20). Early assessment of potentially required adaptations in the post-merger center seems preferable. Mentzoni et al. detected an increased input of 40.9% and a corresponding rise in LOS of 20.9% the first year after their Norwegian catchment area was reconfigured by 44%. This increased input expanded further during peak hours (21). To prevent crowding and a prolonged LOS in ED, several capacities-enhancing strategies include optimizing triage, increasing the number of staffed beds, and installing additional wards as temporary inpatient dispositions (3, 20-23).

Generally, reducing LOS in academic hospitals is challenging due to the complexity of care and treatments (24, 25). Together with the admission rate, it forms a substantially important factor influencing hospital-level flow through a unit (26), and is highly dependent on the urgency of admission and admission season (27, 28). This current study found a median LOS in ED of 2:44 hours for location A and 2:33 hours for location B, which is similar to the national ED LOS in our inclusive trauma system (29) and mirrors previous findings from a different Dutch level-1 trauma center (30). For patients requiring advanced care at the trauma resuscitation room, mean times of 3:55 hours (location A) and 2:54 hours (location B) were found. This duration included the time spent in a regular ED bed after their trauma resuscitation was completed when no further care at the trauma resuscitation room was required. Furthermore, It was shown by McCarthy et al. that decreasing the number of patients waiting to 'board' to their in-patient disposition has the greatest benefits for flow efficiency and overcoming ED crowding (22). Therefore, considering the two merging academic level-1 trauma centers, one strategy to reduce LOS could be increasing the number of staffed beds in the clinical trauma wards and temporary disposition wards (31). This would contribute to ED output by decreasing ED boarding time and aid the overall increase in patient input over all three shifts ranging from 150.0% and 160.9%, as depicted in this study's results.

In addition, due to the emergent character of trauma care, a specialized team can be 'fixed and saturated' with resuscitating one severely injured patient. This study found that the arrival of severely injured patients in the ED would mainly occur during the evening and night shifts. The overlap of two patients requiring advanced trauma resuscitation in ED within one hour would be most common during evening shifts. Therefore, attention to providing adequate staffing and resources for initial trauma resuscitation in ED during these shifts could contribute to optimizing patient throughput. To achieve this in the post-merger setting, installment of 24-7 in-house trauma surgeon presence and stand-by coverage by an additional trauma surgeon can aid in warranting continuity of care.

Moreover, besides, after severe trauma, a patient often requires further resuscitative management, such as damage control surgery or primary fracture care in an emergency setting and further definitive care at the ICU. Consequently, OR and ICU admission availability is essential to warrant level-1 trauma care delivery. In total, the amount of ICU admissions accounted for 17.7% of all trauma related admissions. Adding up both centers would result in a 115.6% increase in trauma-related ICU admissions, mainly during the evening and night shifts. Therefore, to comply with the current standards from the Dutch Trauma Society (NVT) for a level-1 trauma center to always have one ICU bed available at all times to admit a severely injured patient (3), expanding the minimum availability to two ICU beds might be required to cope with the potential increase in the post-merger setting. Capacity-enhancing strategies include facilitation for ICU patients who require observation due to, for example, costal fractures to be monitored at the Post Anesthesia Care Unit (PACU). Also, to preserve the continuity of the OR schedule, the intensivist will aim to replace the anesthesiologist's role during trauma resuscitation activations in ED. This way, the (emergency) OR will be minimally impacted regarding staffing availability.

Concerning staff expansion, it is advantageous that the attending intensivists already work in a shared staffing pool between the two centers. However, high demand exists for (specialized) nurses in the trauma resuscitation room, OR, intensive care unit, and clinical ward (32). Therefore, concerning capacity expansion, the most significant bottleneck will likely be facilitating adequate nursing staffing. Overall, investment in staffed beds in the clinical trauma ward benefits a two-tiered strategy, as it supports both output flow in ED and ICU (33). Naturally, optimal flow towards the clinical trauma ward comes hand in hand with ensuring adequate availability by preventing a stagnating output flow in the clinical department. The majority of patients in the clinical ward were discharged to their own living environment (74.7%), with additional home care if necessary, whereas 9.6% of patients were discharged to a nursing home and 4.6% to a rehabilitation clinic. The corresponding arrangements and transfer to continue the required care at home, nursing home, or rehabilitation clinic usually only occur during weekdays. In the case of admitted clinical patients for whom hospital care is no longer necessary, delays concerning organizational and logistical aspects of discharge disposition cause unnecessary hospital bed occupancy. While the number of nursing- or rehab capacity would not change in the catchment area due to the merger, arranging the patients to be dispositioned to these beds might be more challenging. The literature showed that multidisciplinary attention to discharge planning has effectively reduced unnecessary LOS (34). An additional improvement to overcome this could include optimizing discharge possibilities on a 7-day per week basis and continuing the required care in the (nursing-)home or rehabilitation setting.

Altogether, the in-hospital care flow forms a connected entity dependent on individual departments' flow and collective collaboration. Besides the anticipated volume effects caused directly by the merger, due to the integral character of trauma care, regional restructuring of patient flow seems necessary to meet the novel > 90% standards for severely injured in the post-merger setting (7). Several studies showed undertriage rates between 21.6% and 34.6% among various Dutch trauma regions (35, 36). To aim for severely injured patients to be directly transported to the level-1 trauma center, triage should be enhanced for the 'potentially severely injured patients' to be evaluated in the level-1 trauma center and thus reduce undertriage. A clear two-way interaction with level-2 trauma centers should be established to mitigate this increased patient input. That way, patients who, after evaluation in the level-1 trauma center, do not sustain severe injury and otherwise do not benefit from level-1 trauma care can be transferred safely to a surrounding level-2 trauma center when necessary.

In this study, the retrospective inclusion of all trauma patients presented through the ED with acute traumatic injury might have caused to some extent, selection bias. Patients admitted via other (e.g., elective) routes might have been missed. However, focusing on the patients admitted via ED provided a thorough insight into the patient's integrated care flow. Patient flow is rather erratic and non-linear (37). In addition, the analysis of the transport time difference in the post-merger setting only included admitted patients from location A from whom the scene location was available. The present study was conducted assuming that a merger would directly translate into a sum of the demand for care from both trauma centers. Despite it being uncertain whether a merger results in this input, in the literature, effects on volume after a merger are controversial (14) and do not readily generalize to the trauma system setting. Nevertheless, generally, in acute care, one large unit is more efficient than two small ones (33), which is in line with one of the general strategies of hospital mergers to reduce duplication of services (10, 12). Therefore the sum of capacity adhered in this current study might function as a maximum baseline for the required capacity.

Conclusion

This study examined the current premerger demand for level-1 trauma care involving two level-1 trauma centers in the Amsterdam region. Based on premerger data from 2018, a sum of capacity demand would result in a more than 150% increase in the post-merger setting's integrated acute trauma care, including for the severely injured. These data are essential for successfully integrating two major trauma centers in Amsterdam. Future research is recommended to evaluate volume effects in the post-merger setting.

Ethical considerations

The Medical Research Ethics Committee of Amsterdam UMC location VUmc, which is under collaboration with location AMC, reviewed the study protocol, under reference number 2020.127, and concluded that the research is not subject to the Dutch Medical Research Involving Human Subjects Act.

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Chapter 7

Experience of the Coronavirus Disease (COVID-19) Patient Care in the Amsterdam Region: Optimization of Acute Care Organization

E. Berkeveld*, S. Mikdad*, H.R. Zandbergen, A. Kraal, M. Terra, M.H.H. Kramer, F.W. Bloemers

*shared first authorship

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Abstract

The Coronavirus (COVID-19) pandemic causes a large number of patients to simultaneously be in need of specialized care. In the Netherlands, hospitals scaled up their ICU and clinical admission capacity at an early stage of the pandemic. The importance of coordinating resources during a pandemic has already been emphasized in the literature. Therefore, in order to prevent hospitals from being overwhelmed by COVID-19 admissions, national and regional task forces were established for the purpose of coordinating patient transfers. This review describes the experience of ROAZ region Noord-Holland Flevoland, in coordinating patient transfers in the Amsterdam region. In total, 130 patient transfers were coordinated by our region, of which 73% patients were transferred to a hospital within the region. Over a two-month period, similarities regarding days with increased patient transfers were seen between our region and the national task force. In parallel, an increased incidence in hospital admissions in the Netherlands was observed. During a pandemic, an early upscale (an increase in surge spaces) of hospital admission capacity is imperative. Furthermore, it is preferred to establish national and regional task forces, coordinated by physicians experienced and trained in handling crisis situations, adhering full transparency regarding hospital admission capacity.

Introduction

The Coronavirus (COVID-19) pandemic has spread rapidly across the globe, already claiming lives of over a quarter-million people at the moment of writing (1). Currently, the surging number of COVID-19 cases in need of acute specialized care pushes hospital capacity and health care systems to their limits (2-7). An imperative step in the anticipation of delivery of care for a large number of patients, would be for hospitals to call upon their surge capacity (i.e., capacity to upscale in case of an increased demand for medical resources) (8). Therefore, as a response to the expected increased demand on hospital care, a national upscale of ICU capacity was initiated (9,10). In addition, a crisis deliberation was held on March 13th 2020 that aimed to prevent hospitals from being overwhelmed and to guarantee patient safety, as defined by the World Health Organization's (WHO) statement on i.e. organizational leadership (11). As a result, patients would be distributed among hospitals and a full transparency would be adhered regarding hospital's admission capacity.

Therefore, an existing framework involved in organizing acute care was identified to coordinate the patient distribution. An acute care network (ROAZ (Regionaal Overleg Acute Zorg)), formed in eleven regions in the Netherlands, was utilized to appoint dedicated regional task forces (12). In ROAZ region Noord-Holland Flevoland, coordination was handled by physicians trained and experienced in managing Mass Casualty Incidents (MCI), who took responsibility of the regional distribution of COVID-19 patients in our region during the pandemic. Additionally, a national task force (Landelijk Coordinatiecentrum Patiënten Spreiding (LCPS)) was created in order to coordinate interregional transfers (13).

The importance of equal distribution of resources among multiple institutions in case of a pandemic, has already been emphasized in the literature (14,15). Adhering a three tiered framework in a pandemic has been proposed previously, appointing coordinators on hospital, regional and national level (15,16). The multilevel collaboration encourages situational awareness among those involved and the possibility to timely decide for patient transfer (15). Full transparency among all levels is ought to be of great importance (17).

This review describes the experience of a regional ROAZ network in coordinating the distribution of COVID-19 ICU and clinical patients during the COVID-19 pandemic in the Netherlands, region Amsterdam. By sharing our experience, we aim to emphasize the importance of transparency among hospital, regional and national coordinators in case of a crisis such as a pandemic. Additionally, the process of creating national, regional and individual hospital level task forces in a setting of national up scaling are highlighted.

Methods

Acute care regions

As shown in **Figure 1**, the medical crisis coordination in the Netherlands is arranged in eleven ROAZ regions, overarched by the body of National Network of Acute Care (Landelijk Netwerk Acute Zorg (LNAZ)) (12,18). Each ROAZ region consists of at least one academic level 1 trauma center, regional hospitals, chairmen of the hospital's board of directors, Emergency Medical Services (EMS), EMS dispatch centers, general practice centers, obstetricians, mental health care facilities, Public Health Service and GHOR (Geneeskundige Hulpverleningsorganisatie in de Regio) (12). The collaboration among the involved stakeholders in the integrated acute care chain, is characterized by short lines of communication and the ability to consult the acute care portal, a web application showing real time medical capacity in the region (19). The aim of ROAZ is to minimize avoidable delay for acute vitally compromised patients. Their main tasks consists of gaining insights in the providers of acute care in the region, aligning the activities among different acute care providers and prepare for medical aid in case of disasters and crisis situations. In the North-West region of the Netherlands, a population of about 3.5 million inhabitants is covered by ROAZ region Noord-Holland Flevoland.

Figure 1. Eleven ROAZ regions in the Netherlands, ROAZ region Noord-Holland, Flevoland is highlighted in grey (20).

Task force set up

In response to the expected saturation of hospital capacity in the region, initially affected by an overflow of COVID-19 patients, the Ministry of Health, Welfare and Sport requested the LNAZ to create a national task force in order to coordinate patient distribution on a national level. Therefore, on March 21th 2020, the National Coordination of Patient Distribution (Landelijk Coordinatiecentrum Patiënten Spreiding (LCPS)) was created (13). Similarly, regional task forces for patient distribution on a regional level were created, with each task force represented by a ROAZ region. The coordinating center within the ROAZ region was a large volume academic Level-1-Trauma center. Adding the large hospital bed capacity for COVID-19 patients with expertise in high complexity care, previous experience with crisis coordination and task force organization, Level-1-Trauma centers took responsibility to coordinate the task forces (21,22). In our region, ROAZ coordination was performed by physicians with MCI management experience to fulfill the role of 24/7 regional crisis coordinator. Additionally, a team of PhD students and medical students supported with the electronic transfer of patient's medical records and administrative tasks.

Coordination process

The ROAZ team endorsed a roadmap to ensure patient safety and minimize errors in judgement. A standardized protocol was developed guided by the Institute of Medicine's (IOM) six (safe, effective, patient centered, timely, efficient and equitable) quality aims for healthcare (**Figure 2**) (23). Three times a day capacity updates were acquired consisting of ICU beds for COVID-19 patients and clinical COVID-19 patient hospital admission availability from hospital crisis coordinators from each hospital within the region. At the same time, to provide insight in the total ICU capacity within the region, daily ICU bed admission capacity reports were gathered for non-COVID patients. Based on this information, the ROAZ coordinator had insight in the current status on regional capacity, upon which transfer requests could be managed. After the capacity update had been received, it was shared with the LCPS, creating full transparency on individual hospital, regional and national level.

In case of a transfer request from a hospital within the region, the relocating hospital would send a Patient Movement Request (PMR) form with information regarding necessity of ICU or clinical level care and specifics regarding amount of oxygen provided. The ROAZ coordinator would verify current hospital availability by communicating with other hospitals within the region that had stated available admission capacity in the most recent update (**Figure 2**). If an admission would be possible, the ROAZ coordinator would connect physicians from both hospital with one another in order for them to deliberate the medical content and to finalize the transfer. As a result, the treating physicians could primarily focus on patient care.

PMR forms would be send to both the receiving hospital for medical information and to the LCPS for the sake of a national transfer registration. An encrypted online tool was developed to safely send medical patient information between the sending and receiving hospital and to further lower the administrative burden of the physicians. Transportation would be arranged by the relocating hospital, options including EMS, Mobile Intensive Care Unit (MICU) and Helicopter Emergency Medical Services (HEMS), dependent on the extent of care required. In every transfer between hospitals, patient information was registered by ROAZ.

When a patient could not be transferred within the region, a transfer request would be passed on to the LCPS, who would approach ROAZ coordinators from other regions with the request to check their regional capacity. For relocating outside the own region, transportation was arranged by the LCPS. In case of ICU transportation, the LCPS coordinated the use of MICU and HEMS with the respective ROAZ coordinators. A special arrangement was in place regarding EMS transportations, as EMS from the receiving region would pick up the patient, whereas during non-pandemic circumstances a patient would be transported by EMS from the relocating region. Similarly, the LCPS could send a request to ROAZ region Noord-Holland Flevoland to receive a COVID-19 patient from another region. Weekly, two to three times, national tele meetings were held to discuss the situation in each region among the regional coordinators.

Data collection

All patient transfers coordinated by ROAZ region Noord-Holland Flevoland between 21-03-2020 and 22-05-2020 were prospectively collected. This acute care region, including Amsterdam, is the largest region in the country with over three million inhabitants. Information regarding a patient's required level of care (e.g. ICU or clinical level of care) was obtained. Descriptive data was presented as percentages. In addition, the number of transfers coordinated by the LCPS was retrospectively obtained from the LCPS database. The number of transfers coordinated by our region were compared over time to the number of transfers coordinated by the LCPS and to the total number of COVID-19 hospital admissions in the Netherlands.

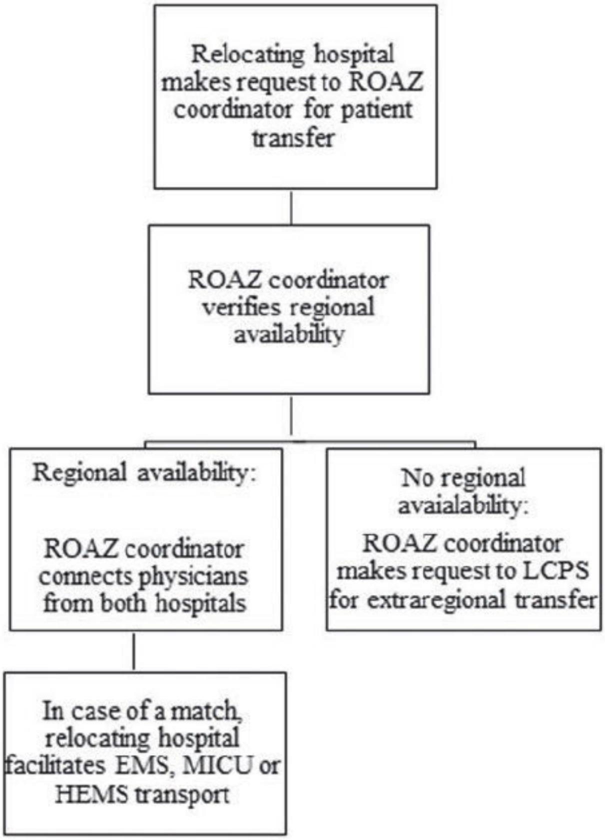

Figure 2. Flow chart of ROAZ activities in case of a patient transfer request.

Results

In total, 130 patient transfers were coordinated by ROAZ region Noord-Holland Flevoland. Forty-one (31.5%) transfers originating from outside our region, were coordinated to a receiving hospital within our region. Thirteen (10.0%) transfers occurred from inside our region to outside the region, of which two transfers had an international destination. Forty-eight (36.9%) transfers took place within our region, of which the majority of patients was transferred to one of the two academic trauma centers. In addition, eight (6.2%) transfers were made to one of our region's hospitals, but data regarding the relocating hospital was missing. After the demand on hospital capacity decreased, 20 patients were transferred back from ROAZ region Noord-Holland Flevoland to their original relocating hospital (15.4%). In addition, 59 (45.4%) transferred patients required ICU level care and 71 (54.6%) patients required clinical level care.

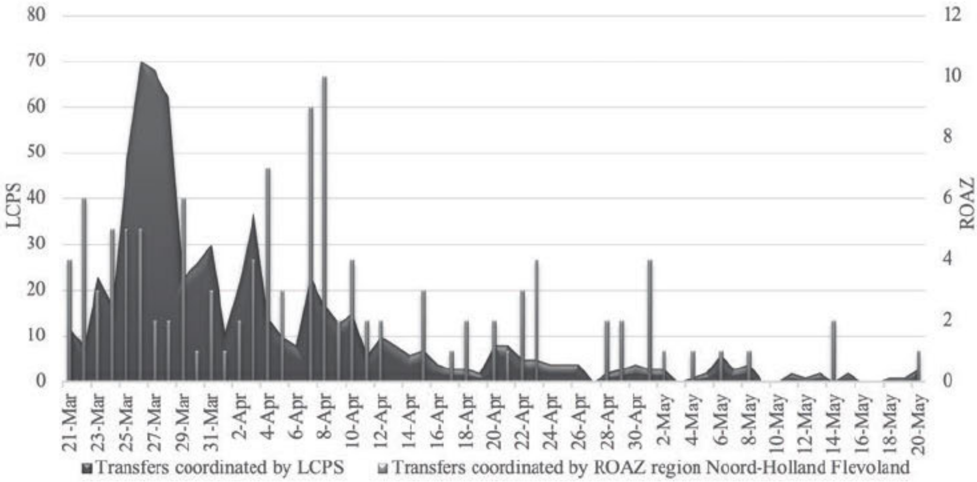

Figure 3. Patient transfers during the COVID-19 pandemic in the Netherlands.

The national task force LCPS coordinated a total of 707 interregional patient transfers in the Netherlands. As illustrated in **Figure 3**, patient transfers coordinated by ROAZ region Noord-Holland Flevoland and the LCPS both show increases during the months March and April, with peak incidence on March 26th and April 8th.

Discussion

This review described the coordination process of patient distribution in a setting of nationally up scaled hospital admission capacity in the Amsterdam region of the Netherlands during the COVID-19 pandemic. ROAZ region Noord-Holland Flevoland, coordinated a total of 130 patient transfers over a two-month period, of which 73% were transfers to hospitals in our region. In comparison, the national task force LCPS coordinated a total of 707 interregional patient transfers. Similar increases regarding patient transfers in March and April between our region and the LCPS were found. However, the peak incidence did differ between the coordinating centers. Full transparency was adhered regarding hospital's admission capacity among crisis coordinators on individual hospital, regional and national level. This contributed to the ability to guarantee patient safety for an extraordinary number of patients and prevented hospitals from being disproportionately affected.

From our experience, an imperative aspect in multilevel coordinating, is to apply full transparency in hospital admission capacity to the individual hospitals in the region and the national task force. The importance of transparency within health care systems during a pandemic, has recently been emphasized in the literature (17). Short lines of communication between facilities and the sharing of information regarding scarce resources (i.e. hospital's admission capacity) is recommended accordingly (17). Therefore, within the first days, ROAZ region Noord-Holland Flevoland developed protocols to guide the sharing of capacity, coordination process and collaboration between hospital, regional and national level. Timely set up of protocols has been a contributing factor to the collaboration, resulting in situational awareness and individual task delegation among the involved stakeholders.

During a pandemic, there is no guarantee of the number of patients involved. As all cities are affected and demands on hospital capacity are similar, it is less feasible to acquire the help and resources from other cities or regions. A previous study by Hick et al. emphasized the importance of resource balancing between hospitals and regions (14). Coordination between institutions assures a consistent standard of care among regional hospitals. Quick upscaling of capacity should be prioritized and during the early days an appeal should be made on hospital's surge capacity. Preferably, crisis coordinators and task forces should be appointed, mirroring findings from the study by Sprung et al. who recommended that during a pandemic, a management system should be created with coordinators at facility, local or national level in order to manage resources (16), as non-timely transfers of COVID-19 patients and 'empty' EMS returns can be considered a waste of valuable resources.

In the Netherlands, although different than MCI's where the primary focus lays within gaining insight in the expected number of casualties and triage, the regional task force coordination was formed by staff experienced with medical crisis coordination (24). Therefore, the treating physicians were saved time of communicating to other hospitals in case of a transfer necessity. A swift collaboration between crisis coordinators from individual hospitals, on regional and national level was feasible due to the already existing network among involved stakeholders.

Few adjustments in workflow design and process were necessary to create a patient safety framework. Although highly complex and timely decisions are common during a pandemic, ethical and human factors cannot be overlooked in the thought process to choose for patient transfer. As a standardized protocol was developed that guaranteed safe and timely patient transfers, complex transfer requests were adequately managed. Factors such as age, mental status, previous prolonged hospitalization were taken into account by both the treating physician and the ROAZ coordinator in the decision making process. Physicians from local hospitals could express their patient movement request (PMR) to the regional coordinator, who subsequently searched for the nearest hospital available. The treating physician, in charge of the medical handover, had a final say in whether or not a transfer would be executed.

Conclusion

Experience with organizing patient distribution on regional level informs that, in the case of a pandemic, an early upscale of capacity in every hospital in the country is pivotal. This contradicts the management of a MCI, where the early phase is characterized by obtaining knowledge about the number of patients involved. However, as a pandemic affects a country as a whole, upscaling of all capacity avoids hospitals of being affected disproportionally and therefore guarantees patient safety. Furthermore, in the early days of a pandemic, establishing individual hospital, regional and national crisis coordinators is preferable. Physicians with MCI experience can contribute to combat a pandemic in a coordinating role. Additionally, complete transparency among individual hospital crisis coordinators, regional and national taskforces, can facilitate patient distribution and limits the waste of valuable resources by unnecessary long distance transports.

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Chapter 8

Optimization of a patient distribution framework: Second wave COVID-19 preparedness and challenges in the Amsterdam region

E. Berkeveld, S. Mikdad, M. Terra, M.H.H. Kramer, F.W. Bloemers, H.R. Zandbergen, on behalf of the ROAZ Regional Network

* collaborators: A. van den Brink, E. van der Does de Willebois, D. van Embden, A. Furumaya, M. de Haan, L. Mailette de Buij Wenniger, L. Nooijen, D. Penning, I. Zinger, M.H. van den Berg, D. Bonink, J. Dokter, T. Fresen, P. Homma, A. Janse, M.D.F. Rhebergen, M.F. van der Steeg, L. van der Voort, M. Wessel, M. Al-Dulaimy, P. Benner, M. de Bruin, S. Balkema, R.A. Douma, M. de Geus, F. de Groot, P. Grotens, J.M. van Haarst, I. Hené, A.B. Hooker, A. Houwink, L. Huisman, P. Joosse, A.E. Kamphuis, E. Kapteijns, T. Koelman, M.L.T.B.M. Kohlen, C.B. Landveld, R. Lecluse, A. Lindeboom, E. Meijer, P. Nagel, R. van Nieuwenhuizen, J. van Nieuwmegen, K.J. Ponsen, N. Posthuma, M. Rebel, R. Sentjes, S. de Smit, D. Snijders, A. Stigter, J.N. Vermeulen, B. Vermin, N. Vieleers, M.B. Vroom, J. Wien, H. Witjes, and M. Poorthuis

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Abstract

To meet surge capacity and to prevent hospitals from being overwhelmed due to patients with coronavirus disease (COVID-19), a regional task force was developed during the first pandemic wave to coordinate the even distribution of COVID-19 patients. Based on a preexistent managerial regional framework involved in acute care, this crisis task force was led by physicians experienced in managing Mass Casualty Incidents. A collaborative framework consisting of the regional task force, national task force, and region's hospital crisis coordinators facilitated intra- and interregional patient transfers. After the hospital admission rate of the first COVID-19 wave declined, a window of opportunity was created to standardize and optimize processes within the regional and national task forces before a potential second wave would commence. Improvement was prioritized according to three crucial pillars; process standardization, implementation of new strategies, and continuous evaluation of the decision tree. Implementing the novel ''fair share'' model as a straightforward patient distribution directive supported the task forces' decision-making. Standardization of the digital patient transfer registration process contributed to a uniform, structured system in which every patient transfer was verifiable on intra- and interregional levels. Furthermore, the regional task force team was optimized, and evaluation meetings were standardized. Lines of communication were enhanced, resulting in increased situational awareness among all stakeholders, indirectly providing a safety net and an improved integral framework for managing COVID-19 care capacities . These adaptations could fulfill an exemplary role by providing critical insight on system development necessary to meet the challenges we collectively face during pandemics.

Introduction

The COVID-19 pandemic has emerged an imminent threat to the health care community (1,2). As most countries in Europe, a nationwide lockdown was imposed in the Netherlands to limit further spread of the virus, avoid exceeding maximum hospital capacity and to protect vulnerable groups (3). To meet surge capacity and to prevent hospitals from being overwhelmed, COVID-19 patients were evenly distributed throughout the Netherlands (4).

In the largest region of the Netherlands, Noord-Holland/Flevoland, covering about 3.5 million inhabitants, COVID-19 patient distribution was coordinated by a regional task force (ROAZ, Regionaal Overleg Acute Zorg). This crisis task force was set up at the start of the first COVID-19 wave based on a preexistent managerial regional framework involved in acute care (Table 1). The foundation and execution of the task force were led by a dedicated team of academic board-certified physicians experienced in managing Mass Casualty Incidents (MCI) who were appointed by the framework's chair physician. Due to the regional task force's novel crisis entity and overarching position in the region, a proportionate distribution of COVID-19 patients was achieved. Therefore, during the first wave between March 21, 2020, and May 22, 2020, 130 patient transfers were coordinated (4).

After the hospital admission rate of the first COVID-19 wave declined, the regional task force remained partially active, as necessity for patient distribution decreased. At the same time, literature regarding further evolution of the pandemic continued to grow and the value of second-wave scenario planning emerged (5). A window of opportunity arose to standardize and optimize the processes to warrant for potentially upcoming following waves. Therefore, between the first and second COVID-19 wave, from 22 May 2020 until 23 September 2020, various aspects of the patient distribution framework were identified and optimized according to three crucial pillars; process standardization, implementation of new strategies, and continuous evaluation of the decision tree. The optimized practices concerned the facilitation of proportional distribution of COVID-19 patients inter- and intra-regionally, standardization of the patient transfer registration process, and improvement of the regional task force and its communication with all stakeholders.

After our experience coordinating the COVID-19 patient distributions during the first pandemic wave (4), challenges and lessons learned could be identified to advance the process for upcoming surge demands. This review aims to describe the performed process optimizations to the COVID-19 patient distribution framework that were subsequently applied during the second COVID-19 wave in the Netherlands. These adaptations could potentially fulfill an exemplary role by providing critical insight on system development necessary to meet the challenges we collectively face during pandemics.

Table 1. Definitions

	Abbreviations	Description
LCPS	National task forces (Landelijk Coördinatiecentrum Patiënten Spreiding)	Coordination of inter-regional transfers of COVID-19 patients
ROAZ	Regional task forces (Regionaal Overleg Acute Zorg)	Coordination of all transfers within the Amsterdam region
PMR	Patient Movement Request	Online form with patient-characteristics to identify eligible patients for transfer
Fair share	Not applicable	Hospitals could request the need for patient transfer either when they exceeded their fair share, or special circumstances made it no longer safe to reach the fair share / forced otherwise.
MICU	Mobile intensive care unit	Transfer of intensive care COVID-19 patients. Team consists of an intensive care physician, intensive care nurse and an ambulance driver

Methods

Optimizing a patient distribution framework

After the first COVID-19 wave regressed, national protective measures relaxed, and the necessity for patient distribution diminished. The regional task force remained active in a pilot light mode in which fluctuations in COVID-19 hospital admissions were monitored but did not involve active coordination of patient distribution (Figure 1). If necessary, few patient transfers were arranged mutually between hospitals intra-regionally. As second-wave scenario planning was considered a national priority, meetings to evaluate practices as conducted during the first COVID-19 wave were implemented during the task force's decreased operational activity. The regional task force facilitated discussions with the region's hospital crisis coordinators to identify current strengths and factors for improvement based on their experience during the first COVID-19 wave. Similarly, on a national level, facilitating discussions were held among all regional task forces and were chaired by the national task force. In addition, direct feedback from all team members within the regional task force was evaluated, deriving from first-hand experience during the coordination shifts.

These evaluations identified critical areas for improvement to further enhance the acutely set up collaborative patient distribution framework (4). To support the patient coordination decision making process, the desire for more insight into a proportionate distribution was expressed. This would be particularly helpful in times of high overall demand for capacity affecting all regions, when effective coordination to prevent hospitals and regions from being overwhelmed is most crucial. Similarly, uniformly timed proportional increases in surge capacity among all regions would contribute to equal sharing of the load for COVID-19 care. Furthermore, the need for a more structured registration process for patient transfer requests was expressed to minimize errors and unnecessary delays. Additionally, expansion of the task force's team coverage could be beneficial to warrant adequate coordination availability even in times of high demand. Due to the experienced strengthening effect of short lines of communication among all stakeholders, the expansion of intra- and interregional meetings could be implemented.

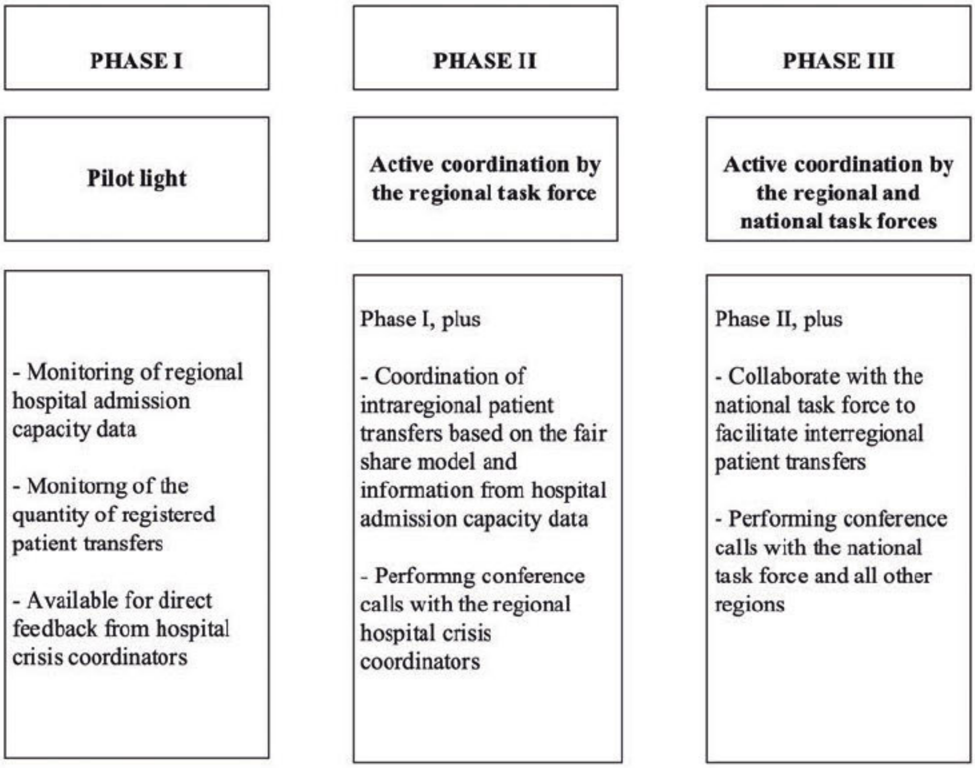

Figure 1. Phases of operational activity by the regional task force.

Results

Proportionate patient distribution by a novel "fair share" model

To optimize load sharing in the care for COVID-19 patients inter- and intra-regionally, the national task force designed a novel ''fair share'' proportionate distribution model after the first COVID-19 wave (6,7). The fair share provided a guideline for a proportional number of COVID-19 patients a hospital or region should be able to provide care for according to their volume and surge capacity (Table 2). Therefore, patient distribution proportionated, and the simultaneous increases in surge capacity were standardized by uniform adherence to the fair share. This benefitted the process of identifying and assisting hospitals in the highest need of relief, even during times of overall increased demand for capacity on a national scale.

Table 2. Performed process optimizations

Existing need	Optimization	Advantage
Support of proportional and solidary patient distribution intra- and interregional.	Design and implementation of the ''fair share'' model.	With incorporated hospital admission capacity data functioning as a directive in the patient distribution supporting the decision-making process by the task forces.
Advanced registration process of patient transfer requests.	Design and implementation of the Patient Movement Request (PMR) system.	Facilitation of a structured registration system that ensured the availability of complete information required to make informed patient distribution decisions.
Further enhanced lines of communication with stakeholders.	Implementing conference meetings with hospital crisis coordinators and the national task force.	Securing continuous evaluation of the decision-making process and continuity of knowledge of the region's and nation's current developments.
Improved task force's team coverage and accessibility.	Expansion of the task force's team and internal training of team members.	Enabling 24-7 roster availability during high influx periods. Uniformity in operations between the regional and national task force.

The principles that were followed in determining the fair share model's results consisted of the hospital's bed- and surge capacity, specific expertise functions (such as whether a hospital operates as a tertiary expertise oncology center, level-1 trauma center, or tertiary ICU with ECMO capabilities) and size of the catchment area. As the COVID-19 infection rate was erratic, the adequacy of the fair share rate was often evaluated on regional and national levels and could be scaled up proportionally to the expected COVID-19 patient influx. In the case of a fair share phase shift, hospitals were requested to increase their capacity within 24-48 hours. Additionally, in line with practices from the first COVID-19 wave, three times daily hospital admission capacity was collected from each hospital to assess the up-to-date capacity situations intra-regionally. Data fields included the number of occupied and available clinical- and ICU beds for COVID-19 and non-COVID-19 patients. In both the fair share model and three times daily collected hospital admission capacity, only patients admitted for the reason of illness due to their COVID-19 infection were included.

Each hospital performed manual data collection, which was then sent to the regional task force. The task force oversaw all the region’s data and incorporated the hospital admission capacities into the fair share model. In this way, a novel straightforward directive for coordination decisions was created. The fair share directive and the hospital admission data were subsequently shared transparently among all hospitals within the region. In addition, hospital admission availability for transfers outside our region was shared with the national task force. In turn, the national task force incorporated availability data from all regions into an interregional fair share and shared this among all regional task forces to provide a transparent overview. The thorough insight provided by the fair share model into inter- and intra-regional differences supported the prioritization of intra-regional transfers by the regional task force.

Technical improvement of data registration

Digital registration of clinical information was further advanced by using a newly developed admission system where requests for patient movement could be entered, a so-called Patient Movement Request (PMR) system. Patients admitted for COVID-19 infection, for whom primary diagnostics were completed and were expected to require a minimum of three days of treatment, were eligible to be admitted to the PMR system. Patient-specific factors, such as age, comorbidities, and oxygen requirements, were considered before a handover between transferring and receiving hospitals could be arranged. Moreover, the system's registration of patient transfer requests reduced over processing as only patients with illness from COVID-19 who met all transfer criteria could be registered. The performed standardization was in line with Lean Six Sigma's principles, 'First Time Right' and 'Poka Yoke,' ensuring that registrations are completed right on the first try while minimizing potential errors.[8] Therefore, by process standardization, the optimization of digital registration brought uniformity in registration criteria and processes. This ensured the complete information required to make informed coordination decisions, which was particularly crucial in inter-regional patient transfers.

Hospitals could request the need for patient transfer either when they exceeded their fair share or in case of particular circumstances that made it no longer safe to reach the fair share. The treating physician made a patient transfer request by telephone with the regional task force coordinator and by providing additional patient- and medical information as a digital registration in the PMR system. A minimum of three telephone calls was required per patient transfer. However, in practice, approximately eight phone calls were made in the coordination process of each patient transfer. The average time lag from transfer request to patient delivery varied from approximately two hours minimum to outliers during the following morning depending on all faces in the registration and coordination processes and the availability of logistical capabilities.

The decision as to which hospital could transfer a patient was the responsibility of the regional task force's on-duty coordinator. The treating physician discussed the morbidity of the clinical COVID-19 patients to prevent acute deterioration during transportation and was responsible for determining whether a patient transfer would be medically safe. An additional medical handover by phone between the treating and receiving physicians took place, which functioned as a final go in the patient transfer process. Altogether, digital registration of all transfers contributed to a safe, controlled system in which every patient transfer was verifiable on intra- and interregional levels.

In the case of a patient requiring extracorporeal membrane oxygenation (ECMO) or otherwise requiring academic level care at a tertiary ICU, the indication was made by the treating physician, and the necessity for specialized care was explicitly communicated to the regional task force coordinator, who subsequently arranged transfer to an appropriate hospital. Nearly all ICU patients underwent tracheal intubation before transport. Overall modes of transportation by Emergency Medical Services, Mobile Intensive Care Unit (MICU), and Helicopter Emergency Medical Services (HEMS) were expanded by a MICU-light option. Stable ICU patients, as determined by the treating intensivist, would be eligible for this mode of transport by EMS with an additional onboard intensivist in case of short-distanced transfer.

Team improvement and communication standardization

To cope with the high volume transfer coordination in phases of increased operational activity more effectively, the regional task force team was optimized and evaluation meetings were standardized. The regional task force was expanded by a front guard, being a physician or medical student, adhering to all digital PMR requests and telephone coverage. An experienced academic board-certified physician was available to supervise the coordination process and performed this task voluntarily in addition to their work in the academic hospital. The installment of a 24-hour shift roster contributed to the continuity of knowledge of the region's current developments and ensured 24-7 availability of coordination processes in phases of the highest operational activity, mirroring the approach of the national task force. Therefore, extensive uniformity in operations was achieved. Morning handovers among the front guards and supervisors between the shifts secured the transfer of knowledge regarding the current situation and prioritization of the most urgent actions.

Additionally, weekly facilitated discussions were implemented within the regional task force to continuously evaluate the team's functioning during all phases of operational activity and discuss potential challenges that were faced. A set agenda covered items such as hospitals coping with specific circumstances influencing their capacity, identifying bottlenecks in coordination and patient transfer during the past week, and subsequently exploring solutions collectively. Moreover, the collaboration with hospital crisis coordinators and the national task force was evaluated, and attention was given to the functioning and well-being of team members within the regional task force. Practical action points derived from the weekly meeting were managed accordingly by the regional task force's team leaders in a swift communication loop with the hospital crisis coordinators and the national task force.

Furthermore, communication among the regional task force and individual hospital crisis coordinators increased to maintain contact with all involved stakeholders and intercept challenges at an early stage**.** Weekly conference calls were held between the regional task force lead coordinators, and the individual hospital crisis coordinators. During peak phases of operational activity, the meetings were increased to three times weekly. Due to the short lines of direct communication and overall transparency among stakeholders, the evaluation of patient distribution decisions by direct feedback was feasible, which encouraged continuous reflection and performance improvement. Besides patient distribution-related discussions, the focus was also directed to maintaining materials required for COVID-19 patient care sufficient, including facial masks, sterile gloves, and oxygen-related supplies. Likewise, the national task force installed daily meetings with all region's task forces to enable facilitated discussions for evaluation on a national level. In weekly national conference calls, the capacity of supplies was evaluated and distributed as necessary.

Patient transfers

During the second COVID-19 wave between September 23rd, 2020, and January 8th, 2021, 794 patient transfers were coordinated by the regional task force ROAZ region Noord-Holland/Flevoland, of which 255 ICU (28.3%) and 569 (71.6%) clinical patients (Figure 2). The majority of patients, 60.9% (n = 137) ICU and 59.4% (n = 338) clinical, were transferred intraregional. Overall, 37.3% (n = 84) ICU and 38.2% (n = 303) clinical patients were transferred inter-regionally with region Noord-Holland/Flevoland and another region. No fatalities occurred. Four ICU (1.7%) and 16 (2.8%) clinical transfers took place due to transfers back to the original hospital. An acutely alternating patient influx was observed in the regional hospitals' requests for patient transfer, resulting in a peak incidence of 21 transfers per day. Within the region, a maximum of 114 COVID-19 patients received ICU care daily, and 346 patients received clinical care daily. During the same period, the national task force LCPS coordinated a total of 1,965 interregional patient transfers, of which 392 (19.9%) were for ICU and 1,573 (80.1%) for clinical patients.

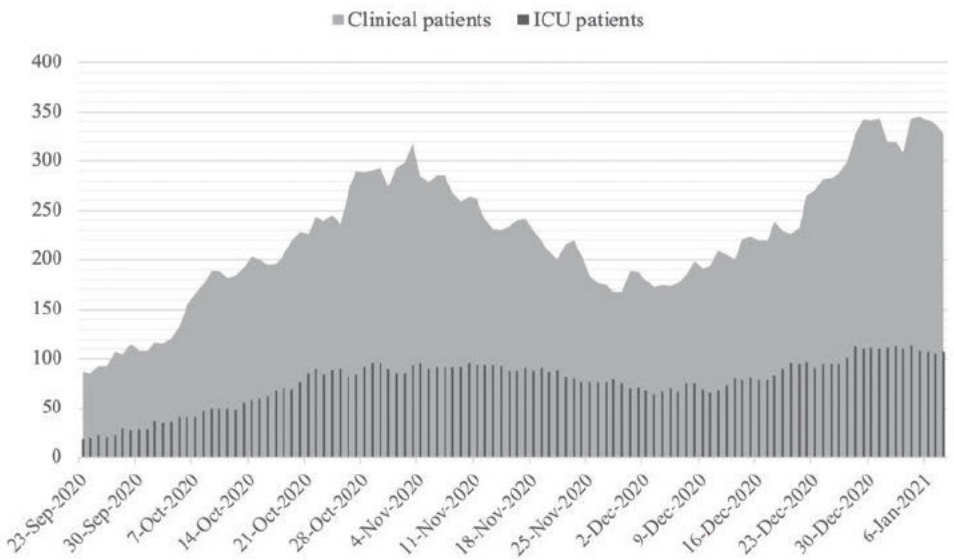

Figure 2. Number of admitted COVID-19 patients in region Noord-Holland/Flevoland during the second COVID-19 pandemic wave (9).

Discussion

This review described the implemented process optimizations in a COVID-19 patient distribution framework. After the first wave, as the COVID-19 hospital admission rate declined, patient distribution's necessity decreased (4). However, the regional task force remained partially active. The opportunity arose for improvement of structures and processes that were acutely developed during the first COVID-19 wave. Improvement was prioritized according to three crucial pillars; process standardization, implementation of new strategies, and continuous evaluation of the decision tree.

Process standardization was achieved by incorporating the collection of hospital admission capacity data into the novel fair share model and improving digitalized patient transfer registration while adhering to strict transfer considerations. Therefore, continuity was accomplished resulting in adequately coordinated regional patient distribution. At the same time mutual communication among all regional stakeholders contributed to the process evaluation. Due to the fluctuant character of the crisis situation transparency was imperative. Short lines of communication were established via frequent meetings between the regional task force team leaders and all hospital crisis coordinators. Therefore, the crisis situation was acknowledged at an early stage among all stakeholders and a working in unison was achieved.

During the second wave, the number of COVID-19 patient transports rapidly exceeded the first wave (4). Therefore, a precautionary triage committee at each regional hospital was appointed by the national task force. In case of crisis escalation, a predefined script could be adopted to ensure uniformity. As a result, overall commitment and willingness to assist secured a safety net for the transfer necessities in our region. Additionally, the regional task force's framework was used to allocate resources. An equipment committee was assigned to provide insight in the availability of materials, medication and transfer utilities in the ICU setting. The role of general practitioners (GP) as gatekeepers to determine whether referral to specialist care was needed remained pivotal during the second wave to reduce COVID-19 emergency admissions. At the same time, home oxygen treatment and pulse oximeters were coordinated by the GP.

Current vaccination practices are expected to substantially lower the total number of COVID-19 cases and reduce surge capacity significantly. In anticipation of going back to normalcy, the regional task force will continue to evaluate the transfer necessities in our region. Future perspectives include the exploration of possibilities to extrapolate the COVID-19 patient distribution framework concept to support other areas within the healthcare system.

The findings of this study have to be interpreted in light of the following limitations. In this study the operations of the regional task force, ROAZ region Noord-Holland Flevoland, were evaluated. However, the distribution of COVID-19 patients and operations of task forces in other regions in the Netherlands were not taken into account as they were not within the scope of this study.

Conclusion

After the regional task force's experience coordinating the COVID-19 patient distribution during the first COVID-19 pandemic wave, challenges and lessons learned could be identified to advance the process for upcoming surge demands. Process optimization was achieved according to three crucial pillars, process standardization, implementation of new strategies, and continuous evaluation of the decision tree. The implementation of novel fair share model functioning as a straightforward patient distribution directive supported the task force's decision-making. Standardization of the patient transfer digital registration process contributed to a uniform, structured system in which every patient transfer was verifiable on intra- and interregional levels. Furthermore, the regional task force team was optimized, and evaluation meetings were standardized. Lines of communication were enhanced, resulting in increased situational awareness among all stakeholders. Continuous evaluation of the decision tree provided a safety net and an improved and integral framework for the patient transfer necessities. These adaptations could potentially fulfill an exemplary role by providing critical insight on system development necessary to meet the challenges we collectively face during pandemics.

Ethical considerations

This study was approved by the privacy officer of the medical ethics committee of Amsterdam University Medical Centers at Vrije Universiteit (registrered with the US Office for Human Research Protections as IRB00002991/FWA00017598). Based on the Dutch legislation General Data Protection Regulation and professional confidentiality, this study was exempted from submission to the medical ethics committee of Amsterdam University Medical Centers at Vrije Universiteit.

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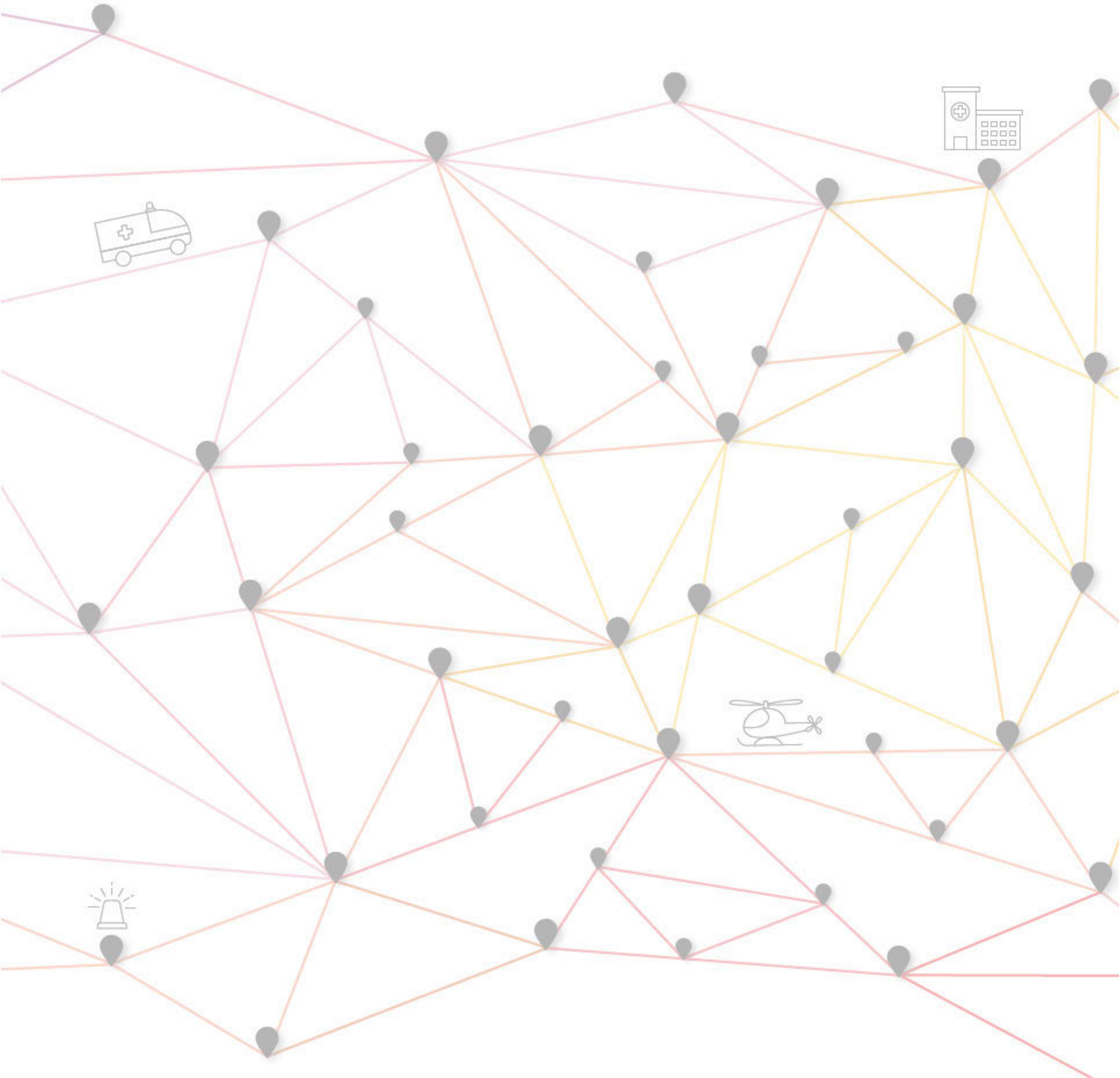
Chapter 9

General discussion and future perspectives



This thesis focuses on the optimization strategies of integrated care. Current insight into the effects of time and triage in early trauma care were evaluated. In addition, processes in integrated care were assessed from a capacity perspective in managing high demand in trauma and acute COVID-19 care.

Part I Early trauma care

A short time until receiving the required care is essential directly after a traumatic injury. In the Dutch trauma system, in addition to care provided by Emergency Medical Services (EMS), a physician-staffed Helicopter Emergency Medical Services (HEMS) crew can perform advanced stabilization on-scene. The literature regarding the optimal duration of the prehospital time is inconclusive and shows various results for different types of injury. **Chapter 2** described a rigorous statistical analysis based on variables commonly used in the literature and those deemed clinically important in the early phase after severe injury (Injury Severity Score (ISS) ≥ 16)). The study showed that no association between prehospital time and mortality could be identified for polytrauma patients (ISS ≥ 16) who received prehospital care by (H)EMS. Despite that no effect could be identified, this does not exclude that individual patients might benefit from a short prehospital time. A factor of influence might have been the characteristics of our Dutch trauma system. Few similar systems exist wherein patients can be treated by professionals in the prehospital setting and arrive on average within 45 minutes at the level-1 trauma center after the initial call to the EMS dispatch center. It might be that in systems with longer distances to trauma centers, time becomes a more important factor in the influence on mortality risk. Moreover, the available care options by HEMS in the Dutch prehospital system are highly advanced, in some instances even mirroring trauma center capabilities. Although these specialized interventions inherently prolong the prehospital time, it reduces the time until a patient receives definitive care. This might explain at least why we did not observe an association between a longer prehospital time and an increased chance of mortality. This study stirs up the question of how we can adequately identify patients requiring advanced specialized (prehospital) care.

To examine the prehospital triage from HEMS's perspective, a large six-year cohort of more than 18,000 dispatches was retrospectively assessed in **Chapter 3**. HEMS was canceled in 54.5% of all dispatches. Most dispatches were canceled due to a patient's respiratory, hemodynamic, and neurologic stable status (76.1%). Trauma-related dispatches were most frequent among all dispatches (65.2%), and dispatches for the reasons of assault involving a blunt object (64.1%), an unspecified traumatic incident (59.9%), or strangulation (58.6%) showed the highest cancellation rates. Although these dispatches can be considered overtriage, the majority of dispatches occur based on the initial call to the EMS dispatch center (58.3%), mostly by a layperson. Directly after an accident, often the MOI is known first, upon which bystanders can make the alarm 1-1-2 call. This way, HEMS can be activated as a primary dispatch. The decision-making for cancelling the mission is a meticulous process. It occurs under the HEMS physician's responsibility after receiving a situational report from the EMS crew on-scene. A patient's physiologic stable status without expected deterioration within one hour and the short distances to a level-1 trauma center in our system can explain a lot of cancellations. In addition, due to the short flight time until cancellation, the opportunity costs related to a canceled dispatch remain minimal. The consequent overtriage seems inherent to the low-threshold availability of HEMS and fall behind the often beneficial contribution of HEMS' assistance on scene after major incidents.

Chapter 4 analyzed the undertriage of patients potentially benefitting from level-1 trauma care based on retrospective data from the Regional Trauma Registry and HEMS Lifeliner-1 database to further examine the triage in our prehospital system. An undertriage of 17.3% was observed for trauma patients directly transported to a level-2 or -3 trauma center and met a minimum of one of the following criteria ISS ≥ 16, direct ICU admission, emergency intervention (within 24 hours), or death (within 24 hours). In the trauma landscape, severe injury based on an ISS ≥ 16 is widely recognized as a marker for level-1 care necessity. Reduced morbidity and mortality rates were identified in the literature in the case of direct level-1 trauma center transport (1, 2). MacKenzie et al. identified a significantly lower inhospital mortality risk in case of treatment in level-1 trauma centers compared to non-trauma centers in a large cohort of patients with moderate to severe injury in the USA, 7.6% compared to 9.5% respectively (relative risk 0.80; 95% CI 0.66-0.98). This beneficial effect increased as patients became more severely injured (1). Cudnik et al. examined the mortality difference between direct transport to level-1 an level-2 trauma centers in a large retrospective cohort in the USA. Their analysis showed that severely injured patients transported to level-1 trauma centers had a significant lower odds for mortality compared to patients transported to level-2 trauma centers (OR 0.76; 95% CI 0.58-0.98) (2). However, the applicability of anatomical markers to support triage decision-making in the prehospital setting is low due to the inability to profoundly determine a patient's complete anatomical injury in the prehospital setting. So regarding solely anatomical injury, a certain 'grey area' of potentially severely injured based on an ISS ≥ 16 should be accounted for. However, a disadvantage of this is that solely anatomical or physiological criteria independently accompany high levels of undertriage. Brown et al. demonstrated undertriage levels varying from 68% to 74% based on evaluation of the US ACS-COT/Center for Disease Control field triage decision scheme (3).

In addition, besides anatomical-based criteria, and physiologic instability, MOIs involving high energy or specific special considerations advocate for level-1 trauma care as well. Our study deepened the analysis of the patients meeting at least one early resource criterion. In case of identified indications for undertriage, we would be able to extrapolate patient-, injury- or mechanism-related markers that could assist the recognition of these patients. However, based on patients with an ISS < 16 who met at least one early resource criterion, we found little indication of level-1 care necessity. This suggests that, based on the early resource criteria per se, the triage in our region occurs rather accurately. It does not aid in the means of identifying the triage optimization. Nonetheless, based solely on the ISS ≥ 16 criteria, we identified an undertriage of 22.9%, which aligns with findings from previous studies conducted in different Dutch regions (4-8). Therefore, the novel standard for > 90% of severely injured patients (ISS ≥ 16) to be directly transported to a level-1 trauma center is not met yet (9).

The characteristics of this undertriaged population, as identified in our study, mirror previous literature (4, 7, 10). Namely, patients aged 65 or over and patients sustaining an injury caused by a low-energy fall are the most prevalent. Commonly affected body regions included the head, chest, and lower extremities. Interestingly we do not seem to adequately recognize these patients in the prehospital setting, despite having at least head (penetrating) and chest (penetrating and blunt) injuries included in the Dutch National Field Triage Protocol (Landelijk Protocol Ambulancezorg) to require level-1 trauma care (11). A way to close this triage gap is for patients by the EMS considered as 'potentially severely injured' to be transported directly to a level-1 trauma center as well. Only the question remains whether this form of 'doubt' is the case in the prehospital decision-making process. Perhaps these patients are just not easily recognizable, yet turn out to have seriously more severe injury upon examination. The recently developed Trauma Triage App might provide the required additional support in the triage decision-making process (12). Based on a validation study in a different Dutch trauma region, use of the Trauma Triage App in addition to the Dutch Field Triage Protocol resulted in a lowered undertriage of 11.2% (7). Besides, the combination of multiple injuries, together contributing to an ISS ≥ 16, might just not be recognized as multiple relevant injuries as well. Further research that benefits the recognition of this particular part of undertriaged patients would assist in supporting the > 90% standard. Additionally, further research into markers, besides anatomical-based criteria, to recognize patients requiring level-1 trauma care is recommended to be continued.

In **Chapter 5**, the inhospital times are assessed, and the effect of a clock's presence on trauma resuscitation times is evaluated. Despite the relevance of time awareness in time-critical acute care as identified by Curtis et al. (13), our study observed no association between the clock's presence and trauma resuscitation time. Although, we do know, based on best practices from other acute care specialties such as cardiology and neurology, that awareness of time benefits the team's task performance resulting in a shorter process time. Means to transfer awareness of time might be an important difference here. Our identified resuscitation times were consistent with a part of the literature (14, 15), contributing to the validity of our data. The heterogeneous character of the study population might have affected the absence of observed association. This underlines the direction for further research into the effects of integrated care for patients for whom we know time is important (16-20). If effects could be demonstrated, proper optimization strategies could be created for this. Therefore, future research is recommended to focus on exploring the influence of time awareness in severely injured patients or patients who sustain Traumatic Brain Injury (TBI) or severe blood loss.

Part II Process optimizing strategies

The merger of the two level-1 trauma 'expertise' centers, as described in **Chapter 6**, is a first in the Dutch already concentrated organization of the trauma care system. The study overviews the baseline premerger demand throughout integrated acute trauma care. Under the assumption that a post-merger situation could, at maximum, expect the demand of both independent trauma centers premerger, a safe baseline situation was created from which likely required potential areas for expansion could be identified. Based on premerger data from 2018, a sum of capacity demand would result in a more than 150% increase in the post-merger setting's integrated acute trauma care, including for the severely injured (ISS ≥ 16). Capacity-enhancing strategies include increasing staffing and hospital bed expansion in case of an increased input according to patient flow, optimizing the throughput and output components (21). These results, integrated with current literature on capacity-enhancing strategies and interpreted within the bigger picture of the inclusive trauma care system, provide a transportable approach that could benefit knowledge for future mergers or concentration of care in other forms.

Further in-depth modeling would be desirable to determine the most optimal capacity enhancements in the post-merger setting. Information on occupational goals for the post-merger center is necessary to accurately determine the most optimal occupancy rates. Generally, the relevance of concentration in trauma care relates at least partially to the current national social trends regarding the restructuring of acute care. The current healthcare landscape calls for sustainable solutions to ensure the continuous availability of acute care resources. Currently, the demand for acute care exceeds the available resources, and prospects predict that the gap will only continue to increase. Given the complexity of various factors influencing adequate health care's sustainability, maintaining the quality and accessibility of acute care is both challenging and crucial (22).

However, the current actuality of restructuring acute care to a sustainable form might have been catalyzed by the urgent collective need to implement novel strategies in managing the high levels (surge) capacity demand during the COVID-19 pandemic. During the COVID-19 pandemic, worldwide healthcare systems were strained rapidly, with patients requiring immediate medical attention and resources for an extended period (23). Due to this rapid demand on the health care system's capacity in staff, supplies, and systems, the continuity of care was stressed. Adequate staff encompasses appropriately trained and skilled healthcare workers, whereas supplies include the necessary equipment to provide the required care, and systems refer to the mode of working to ensure the overall continuation and smooth coordination (24). Staff and supply also influence the possibility of providing hospital admission availability.

Novel approaches were created and implemented to manage the call on surge capacity successfully. **Chapter 7** describes the experience of the novel set-up regional task force in ROAZ region Noord-Holland Flevoland that coordinated an even patient distribution among hospitals. In addition, inter-regional patient transfers were coordinated in collaboration with a novel created national task force. Local hospital coordinators were appointed who held short lines of communication with the regional task force and were up-to-date on the current in-hospital admission capacity status. Due to the regional task force's physician's experience in managing MCI and continuous insight into the capacity status within the region, swift coordination decision-making could be performed. In addition, operational protocols to support the coordination process were rapidly installed.

A window of opportunity between the first and second COVID-19 waves enabled the task forces to create, standardize, and optimize their patient transfer processes. **Chapter 8** describes the undergone process improvement strategies of the regional task force. This included standardization of processes, implementation of new strategies, and continuous evaluation of the decision tree. Implementing the novel “fair share” model as a straightforward patient distribution directive supported the regional task force’s decision-making. Standardization of the digital patient transfer registration process contributed to a uniform, structured system in which every patient transfer was verifiable on intraregional and interregional levels. The resulting optimized task force operating in its improved integral framework demonstrated an exemplary model to manage COVID-19 surge demands, supporting post-pandemic preparedness. Recommended next steps include the in-depth evaluation of the functionality of the model.

After the COVID-19 pandemic regressed, the Dutch healthcare system faced strained waiting lists for (semi-) emergent medical care in a climate of shortage of (specialized) medical and nursing staff. Moreover, current long-term prospects indicate an increased demand for acute care and an aging population (22, 25). Solutions to provide long-term sustainable care seem therefore vital. In the (inter-) national literature, trauma systems showed effectiveness in organizational integrated care (8, 26, 27). In addition, it provided a solid foundation from which collaborative frameworks could be created to manage the COVID-19 care demand strain on the healthcare system's capacity. Therefore, the potential of the trauma system's organizational structures to support the restructuring of integrated acute care to a sustainable form should be further explored.

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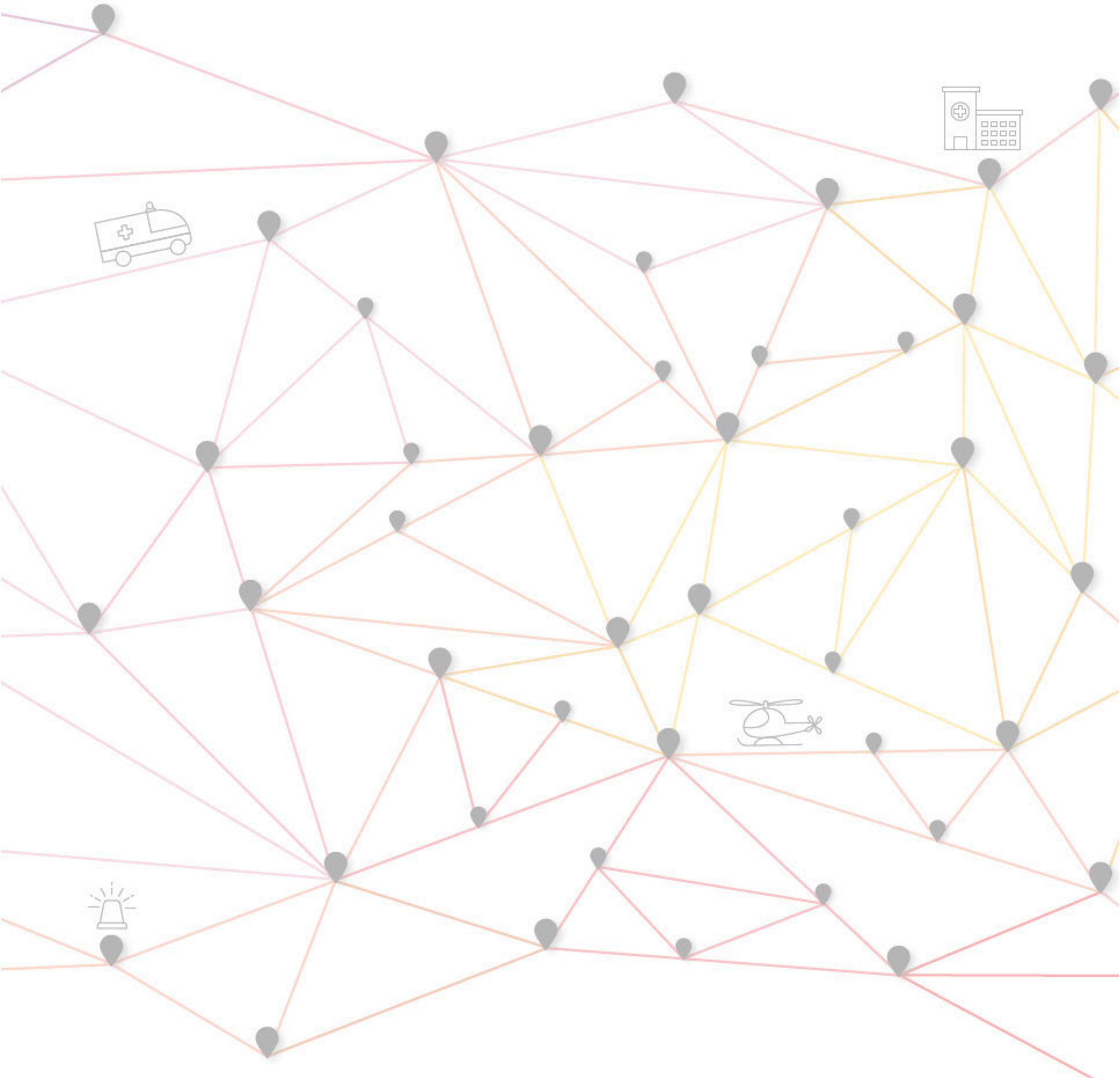
Appendices



Summary

This dissertation has focused on optimization strategies in the acute integrated care. Current insights into the effects of time and triage in early trauma care were evaluated. Additionally, from a capacity perspective, the processes in integrated care related to meeting the high demand in trauma and acute care were examined.

Part I Early trauma care

Directly after traumatic injury, receiving the appropriate care as swiftly as possible can be crucial. In the Dutch trauma system, Helicopter Emergency Medical Services (HEMS) can provide advanced medical care at the scene of the accident to support Emergency Medical Service (EMS) crew. **Chapter 2** describes a comprehensive statistical analysis of the early phase after severe injury (Injury Severity Score (ISS) ≥ 16), based on clinically relevant and common variables in the literature. A retrospective observational study was conducted using data from the regional trauma registry, focusing on severely injured patients (ISS ≥ 16) who were directly presented to a level-1 trauma center after having received prehospital care by (H)EMS.

Within the total study population (n=342), an average prehospital time of 45.2 minutes was identified. The study did not demonstrate a correlation between time and mortality in our study population of severely injured patients. Although no correlation could be identified, this does not rule out the possibility that individual patients may benefit from as short a prehospital time as possible.

In **Chapter 3** a retrospective cohort study involving over 18,000 HEMS dispatches was described. HEMS was canceled en route to the incident in 54.5% of the dispatches. The most common reason for cancellation was the physiologically and neurologically stable condition of the patient, with no expected deterioration within an hour (76.1%). Trauma-related dispatches were most frequent (65.2%), with dispatches for reasons such as ‘assault with a blunt object’ (64.1%), ‘undefined traumatic incident’ (59.9%), or ‘strangulation’ (58.6%) showing the highest cancellation rates. Despite these dispatches could being considered overtriage, most involved a primary HEMS dispatch. This means that HEMS is simultaneously dispatched with the EMS by the emergency medical dispatch center, often based on a description of the mechanism of the incident provided by a layperson. Due to the short flight time until cancellation (median five minutes), the simultaneous unavailability for other calls in case of a canceled flight remains minimal.

Chapter 4 analyzes the undertriage of trauma patients who potentially could benefit from level-1 trauma care based on data from the regional trauma registry and the HEMS Lifeliner-1 dataset. Trauma patients meeting at least one of the following criteria—ISS ≥ 16, direct ICU admission, emergency intervention (< 24 hours), or death (< 24 hours), and who are being directly presented at a level-2 or -3 trauma center—were included. Most patients were aged 65 and above, and injuries were most commonly caused by falls from a standing position. The most frequently affected body regions were the head, thorax, and lower extremities. An undertriage of 17.3% was demonstrated for patients who could potentially benefit from level-1 trauma care. Specifically, for patients with an ISS ≥ 16, meeting the definition of severe injury, an undertriage percentage of 22.9% was shown. Based on patients with ISS < 16 meeting one of the other criteria, indications supporting direct transport to a level-1 trauma center were largely not identified.

Chapter 5 describes the effect of the presence of a clock in the trauma resuscitation room. A prospective observational double-cohort study was conducted in a level-1 trauma center. Resuscitation times before and after placement of a digital clock at the trauma resuscitation room were compared. Median resuscitation times were found to be non-significantly different at 40.3 minutes and 44.3 minutes, respectively, without (n=50) and with the clock (n=50). Severely injured patients (ISS ≥ 16) showed median resuscitation times of 54.6 minutes and 46.0 minutes, respectively, without (n=9) and with the clock (n=8).

PART II Proces optimization strategies

Chapter 6 described a study on the merger of two academic level-1 trauma centers in Amsterdam. A retrospective cohort study was conducted to assess the care demand after the merger concerning the entire prehospital and inhospital integrated trauma care. The assumption that in the post-merger setting, the maximum expected care demand would be the sum of the demand from the two centers before the merger formed the basis of the analysis. In total, 462 patients were considered severely injured (ISS ≥ 16). There were 702 emergency interventions performed (< 24 hours), and 442 patients were admitted to the ICU. The sum of healthcare demand resulted in an expected increase post-merger of 167.4% for trauma patients and 151.1% for severely injured patients (ISS ≥ 16).

Chapter 7 describes the experience of a novel established task force in coordinating the distribution of COVID-19 patients in region Noord-Holland Flevoland. Building upon an existing acute trauma care network (Regionaal Overleg Acute Zorgketen (ROAZ)), regional collaboration was enhanced, and the novel crisis task force was established. The task force was led by trauma surgeons with experience in managing mass casualty incidents. Local crisis coordinators were appointed in regional hospitals, maintaining close communication with the regional crisis organization and having knowledge of the current capacity in their respective hospitals. Together, the task force and local crisis coordinators formed a regional collaborative framework for COVID-19 patient distribution.

Protocols for the manner of reporting and the associated criteria for admitting COVID-19 patients were developed. After requests for patient transfers were reported to the task force, coordination decision-making occured through frequent insights into hospital capacity and streamlined communication with local hospital coordinators. Interregional patient transfers were organized in collaboration with the novel installed national task force (Landelijk Coördinatiecentrum Patiënten Spreiding (LCPS)). During the first wave of the COVID-19 pandemic, a total of 130 COVID-19 patient transfers were coordinated by the regional task force.

After the first wave of the COVID-19 pandemic regressed, a window of opportunity occurred to optimize the processes of the collaborative regional framework. **Chapter 8** outlines the process improvement strategies undertaken by the regional task force. This was achieved through the standardization of processes, the implementation of new strategies, and continuous evaluation of decision tree. Capacity increases were standardized on regional and national levels based on the expected influx of COVID-19 patients. Additionally, standardization of the admission procedure through a new digital tool ensured uniformity of admission criteria and processes.

A newly designed 'fair share' distribution key was applied as a guideline for a proportional distribution of COVID-19 patients, taking into account factors such as hospital size. Together with the current hospital admission capacity, the fair share results supported the task force's coordination decision-making. Short lines of communication by the regional task force with local hospital coordinators and the national task force were enhanced. The implementation of a 24-hour shift schedule contributed to the continuity of the regional situation and ensured 24/7 coordination availability.

Regional meetings between all hospital coordinators, chaired by the task force, were established and scaled up in frequency as needed. This approach allowed capacity issues affecting distribution in the region to be addressed early and transparently shared within the region, contributing to increased situational awareness among all stakeholders. Additionally, weekly facilitated discussions within the task force team facilitated the continuous evaluation of team performance and allowed attention to evaluate specifics regarding coordination decisions.

PhD Portfolio

Name PhD student:	Eva Berkeveld
PhD period:	October 2019 – April 2023
Promotor:	Prof. dr. F.W. Bloemers
Copromotores:	Dr. G.F. Giannakópoulos Dr. H.R. Zandbergen

Name	Year	ECs
Courses		
Smart Literature Search	2019	0.1
Writing a Scientific Article	2020	3.0
Writing a Data Management Plan	2021	1.0
Epidemiologic research: basic principles (V10)	2021	1.5
Research Integrity Course	2021	2.0
PhD Success and Personal Efficacy	2021	2.0
Systematic review and meta-analysis (K71)	2022	2.0
Presenting and pitching your research in English	2022	2.0
Project Management	2022	0.6
Talents in PhD	2022	0.2
Clinical Epidemiology: Observational Epidemiology	2022	0.6
BROK	2022	1.5
Seminars, workshops and master classes		
Research meetings Trauma surgery and general Surgery	2022	2.0
Conference attendances		1.5
- Symposium Lateralisation of Trauma care	2023	
- Annual NVvH meeting	2022	
- STN Trauma Residents symposium, webinar	2021	
- Symposium pelvic ring fractures, webinar	2021	
- Trauma Night symposia, Alkmaar and Amsterdam	2021	
- Congress for Acute Care, Breda	2021	
- Complication congress Trauma Surgery, Amsterdam	2020	
- European Congress of Trauma and Emergency Surgery, Valencia	2018	
Presentations		
Trauma days RAI, Amsterdam	2018	1.0
European Congress of Trauma and Emergency Surgery, Prague	2019	2.0
Trauma days RAI, Amsterdam	2021	-
European Congress of Trauma and Emergency Surgery, Oslo	2022	2.0
STN Trauma Residents symposium, webinar	2022	-

Name	Year	ECs
Parameters of esteem		
Dr. G.J. Heijmans prize, best oral presentation STN Trauma Residents symposium	2022	-
Teaching and supervising		
Danique Bekkers, Master thesis	2019	1.0
Eefje Verhees, Master thesis	2019	1.0
Noor Kamel, Master thesis	2020	1.0
Mohanad al Masoudi, Master thesis	2020	1.0
Bachelor study group tutor	2021	2.4
Michiel Beltman, Bachelor thesis	2021	-
Tessa Boschkor Bachelor thesis	2022	-
Bachelor internship Academic development	2021	-

Authors' contribution statement

Prehospital time and mortality in polytrauma patients: a retrospective analysis

E. Berkeveld, Z. Popal, P. Schober, W.P. Zuidema, F.W. Bloemers,
G.F. Giannakopoulos

BMC Emergency Medicine, 2021

Concept and design: EB, ZP, PS, WZ, FB, GG. Acquisition, analysis or interpretation of data: EB, ZP, PS. Drafting of the manuscript: EB. Critical revision of the manuscript: EB, ZP, PS, WZ, FB, GG. Supervision: GG. All authors read and approved the final version.

Characteristics of Helicopter Emergency Medical Services (HEMS) dispatch cancellations during a six-year period in a Dutch HEMS region

E. Berkeveld, T.C.N. Sierkstra, P. Schober, L.A. Schwarte, M. Terra, M.A. de Leeuw, F.W. Bloemers, G.F. Giannakopoulos

BMC Emergency Medicine, 2021

Concept and design: EB, TS, PS, GG. Acquisition, analysis or interpretation of data: EB, TS, PS, LS, GG. Drafting of the manuscript: EB, TS. Critical revision of the manuscript: PS, LS, MT, ML, FB, GG. Administrative, technical or material support: PS. Supervision: GG. All authors read and approved the final version.

Prehospital undertriage of trauma patients: results from a large Dutch trauma region

E. Berkeveld, S. Oud, Z. Popal, F.O. Kooij, F.W Bloemers, G.F. Giannakopoulos,
on behalf of the region SpoedZorgNet collaborative group

Submitted

Concept and design: EB, FB, GG. Acquisition, analysis or interpretation of data: EB, SO. Drafting of the manuscript: EB. Critical revision of the manuscript: SO, ZP, FK, FB, GF. Supervision: GG. All authors read and approved the final version.

The effect of a trauma clock's presence in the trauma resuscitation room in a Dutch level-1 trauma center: a prospective double cohort study

E. Berkeveld, K. Azijli, F.W. Bloemers, G.F. Giannakopoulos

Submitted

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Merging of two level-1 trauma centers in Amsterdam: premerger demand in integrated acute trauma care

E. Berkeveld, W.P. Zuidema, K. Azijli, M.H. van den Berg, G.F. Giannakopoulos, F.W. Bloemers, on behalf of the Trauma research collaborative group

European Journal of Trauma and Emergency Surgery

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Experience of the Coronavirus Disease (COVID-19) Patient Care in the Amsterdam Region: Optimization of Acute Care Organization

E. Berkeveld*, S. Mikdad*, H.R. Zandbergen, A. Kraal, M. Terra, M.H.H. Kramer, F.W. Bloemers

Disaster Medicine and Public Health Preparedness, 2020

*shared first authorship

Concept and design: EB, FB. Acquisition, analysis or interpretation of data: EB, SM, HZ, FB. Drafting of the manuscript: EB, SM. Critical revision of the manuscript: EB, SM, HZ, AK, MT, MK, FB. All authors read and approved the final version.

Optimization of a patient distribution framework: Second wave COVID-19 preparedness and challenges in the Amsterdam region

E. Berkeveld, S. Mikdad, M. Terra, M.H.H. Kramer, F.W. Bloemers, H.R. Zandbergen, on behalf of the ROAZ collaborative group

Health Security, 2023

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Het is zo ver, er zit een kaft omheen! Met plezier en trots kijk ik terug op een periode vol interessante onderzoeksprojecten en inspirerende samenwerkingen. Promoveren is een echte rollercoaster. Van ongekende hoogtes, hier en daar een looping en soms een *bumpy ride*. Gelukkig sta je gedurende dit avontuur nooit alleen. Dit proefschrift is een resultaat van de steun en betrokkenheid van velen. Hierbij wil ik graag een aantal van jullie persoonlijk bedanken.

Promotor, **prof. dr. Bloemers**, beste Frank, je bent hoofd traumachirurgie en pionier op het gebied van regionale crisismanagement in respons op COVID-19. Onder jouw leiderschap heb ik de kracht van solide samenwerkingsverbanden en collectieve inzet *first hand* ervaren. Dit was uniek en gaf een onverwachte extra dimensie aan mijn promotietijd. Met jouw tomeloze energie, doordachte denkwijze, teamgevoel en enthousiasme voor de trauma(keten)zorg weet je altijd te motiveren. Je relativerende perspectieven hielpen om de te bewandelen paden scherp te krijgen. Dank voor de mogelijkheid dit promotieonderzoek te verrichten, wat was het een geweldig avontuur! Je passie voor het vak en je vermogen tot verbinding vormen voor mij een continue bron van inspiratie.

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Collega's van **Netwerk Acute Zorg Noord-Holland Flevoland**, wat hebben we nauw samengewerkt in een dynamische tijd tijdens COVID-19. Ook daarbuiten zorgde jullie betrokkenheid voor een scherp beeld van de integrale ketenzorg, dank voor jullie hulp bij de dataverzameling van verschillende studies. **Dr. Marleen van den Berg, Drs. Paulien Homma, Dr. Martijn Rhebergen, Drs. Annelies Toor, en Dr. Corline Brouwers** jullie expertise in het onderzoek met registratiedata en ketenkennis waren erg waardevol. **Drs. Danielle Bonink**, directeur, bedankt voor de geboden mogelijkheid om onderzoek te verrichten binnen het regionale netwerk. **Dr. van Schoten**, beste Steffie, wij leerden elkaar kennen helemaal aan het begin van dit promotietraject, waarbij jouw enthousiasme voor ketenzorg mij inspireerde, bedankt voor je visie op het theoretisch kader.

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Curriculum Vitae

Eva Berkeveld werd geboren op 3 maart 1995 in Alkmaar. In 2013 behaalde zij haar atheneum diploma aan het Petrus Canisius College en werd zij toegelaten tot Geneeskunde aan de Vrije Universiteit Amsterdam. Gedurende haar bachelor tijd was zij werkzaam als student assistent op de afdeling Moleculaire Celbiologie en Immunologie en als technisch oogheelkundig assistent. Haar interesse in netwerken en mensen met elkaar verbinden kon zij invullen als voorzitter van de Carrièreavond commissie van de Medische Faculteitsverenging VU Amsterdam en lid van de Vereniging Chirurgie voor Medisch Studenten.

Eva startte haar masteropleiding in 2016 middels een wetenschappelijke stage op de afdeling Fysica en Medische Technologie van het VUmc. Gedurende haar coschappen werd enthousiasme voor de acute zorg gewekt en startte zij met het verrichten van wetenschappelijk onderzoek binnen de afdeling Traumachirurgie van het VUmc. Na het doorlopen van een leerzame semi-arts stage heelkunde in het Rode Kruis Ziekenhuis te Beverwijk werd haar passie voor de acute zorg bevestigd. Gecombineerd met een indrukwekkende reis langs de oostkust van Australië verrichte zij haar keuzecoschap op de spoedeisende hulp afdelingen in Brisbane (Redland Hospital) en Gold Coast (Gold Coast University Hospital), waar zij zich klinisch kon verbreden door het diverse aanbod aan acute casuïstiek. In Australië kreeg zij een indruk van het acute zorgmodel aldaar en raakte zij geïnspireerd door de verschillende inrichtingen van het internationale zorgsysteem.

Na het behalen van haar artsenbul is zij een Promotietraject gestart in 2019 binnen de Traumachirurgie in samenwerking met Netwerk Acute Zorg Noord-Holland Flevoland. Ze verrichte onderzoek naar de optimalisatie van de integrale ketenzorg voor acute trauma patiënten. Eva had de eer om onderzoeksresultaten te presenteren om internationale congressen in Valencia, Praag en Oslo en ontving in 2022 de G.J. Heijmans prijs voor beste voordracht op het nationaal assistentensymposium van de Nederlandse Vereniging voor Traumachirurgie. Tevens was zij bij de start van de COVID-19 pandemie betrokken bij de opzet van de ROAZ crisisorganisatie van regio Noord-Holland Flevoland, waarna zij met veel plezier actief was in het coördineren van patiëntverplaatsingen en binnen de organisatie van het team gedurende de COVID-19 golven.