

Trauma Team Performance

Trauma Team Evaluatie

(met een samenvatting in het Nederlands)

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Part



1

Chapter

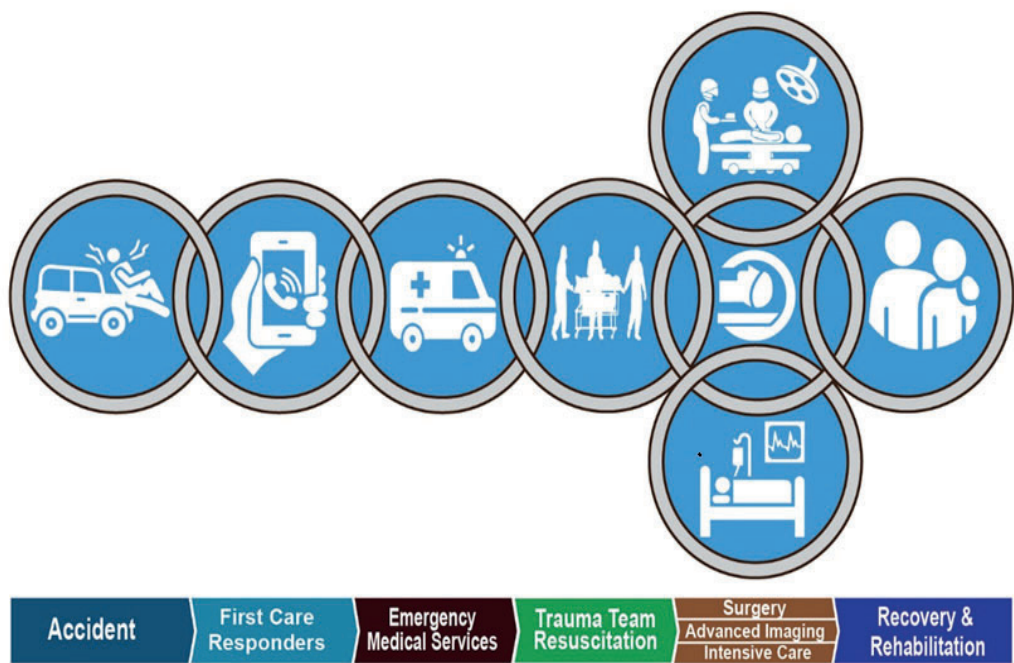
1

Introduction and outline of thesis

Introduction

The initial care for patients suffering severe injuries is one of the most challenging in healthcare, necessitating many (para)medical healthcare professionals working together. The initial management of severely injured patients is a series of sequential of parallel (sub)processes that begins with the first responder at the scene of accident and ends with definitive treatments such as surgery or intensive care (Figure 1). After transportation from the scene of accident, the initial treatment in-hospital by the trauma team is an important step in the management of severely injured patients. A trauma team consists of medical specialists, nurses and paramedical personnel. The team has a 24/7 readiness and is directly available when severely injured trauma patients are admitted the emergency department of a hospital. The aim of the trauma team is to rapidly resuscitate and stabilize a trauma patient, identify and treat first life-threatening injuries, and prevent the aggravation of existing injuries. (1,2)

Figure 1: Chain of trauma care



The emergence of trauma teams

Although in-hospital resuscitation of trauma patients by a trauma team is a common concept in today's trauma care, it still is a relatively new development that has evolved in tandem with the rise of regionalized trauma care. Beginning in the 1960s, there was an increased interest in civilian trauma care and a trend toward regionalization of trauma care, especially in the United States. At the time, more Americans were killed on the nation's highways each year than were slain throughout the entire Vietnam War. (3) In comparison to the current situation, the state of trauma care was appalling. The emergency facilities were frequently staffed by junior or undertrained physicians and having limited equipment to treat trauma patients. (4)

The first civilian trauma centers were established in 1966 at Cook County Hospital in Chicago and at San Francisco General Hospital in California. (5) At the time, concepts of regionalization of trauma care mostly arranged from United States' military experience with organized trauma care. (5) The aim behind regionalization of trauma care was that patients with serious injuries would be admitted to designated hospitals rather than the nearest hospital. These designated hospitals were well-equipped to treat these patients and had more experienced physicians at hand. Within these designated hospitals the concept of trauma teams emerged, resulting in the availability of medical specialist from various disciplines immediately or very shortly after the admission of severely injured trauma patients. (6) Both the concept of regionalization of trauma care and resuscitation of patient with a trauma team have shown to improve trauma care and are increasingly being accepted around the world, with most western counties now having adopted these concepts. (7) In **Chapter 2** the current state of knowledge to achieve adequate trauma team performance is described within a review.

Rationale of this thesis

Although regionalization of trauma care and introduction of trauma teams has served to accumulate knowledge and skills, creating teams of specialist from various disciplines does not necessarily results in specialized teams. Theoretically, optimal performing trauma teams are formed by specialists from various disciplines, nurses, and paramedics working efficiently together using each other's skills, knowledge and embrace modern

technology and therefore achieving optimal care for trauma patients. The central research question of this thesis was: How can we structurally improve the performance of trauma teams?

In our opinion, there are three main pillars to achieve such an improvement: regular reliable evaluation of trauma teams, education of team members, and adequate organization of trauma teams including (technological) support. The focus of this thesis is on improving trauma team evaluation (Part 2) and on achieving improvements and new insights in trauma team organization and support (Part 3).

Evaluating trauma (Part 2)

Trauma team performance could be defined as how well a team managed the trauma patient during resuscitation in the broadest sense of the term. As different types and severities of injuries requires different approaches and goals, measuring performance of trauma teams and its impact on the care of severely injured patients is a complex matter. Thereby, assessing trauma team performance and its impact on trauma patient outcome is particularly difficult, given that trauma resuscitations constitute an isolated component of the trauma pathway. However there are four measurable factors that do provide insights on trauma team performance: Pace, structure, non-technical skills and technical skills. In this thesis pace, structure and non-technical skills have been described and investigated.

The first measurable factor is pace, which can be described as the tempo at which the team performs a resuscitation. This is relevant given previous reviews and studies have linked resuscitation pace to the likelihood of a patient surviving his injuries. Accelerated resuscitation pace, particularly in patients suffering from serious hemorrhage, could mean the difference between life and death. (8,9) The second factor is structure, which we operationalized into adherence to guidelines or protocols (e.g. ATLS adherence) The Advanced Trauma Life Support (ATLS®) Program is accepted globally within trauma care and was developed to teach physicians a safe and reliable method to assess, and initially manage the trauma patient (3).

The ATLS principles reflect a systematic strategy to evaluate and manage severally

injured patients and provide a foundation of common knowledge for all trauma team members. The concept of the ATLS program is simple and based on the mnemonic “ABCDE” and order of which priority takes place in management of the injured patient: A stands for Airway and cervical spine protection; B for Breathing; C for Circulation; D for Disability, and E for Exposure/Environment. The focus of the ATLS is on the critical “first hour” of care, which includes initial assessment, lifesaving intervention, re-evaluation, and stabilization of a trauma patient. (10) The third factor is non-technical skills and are the skills needed for adequate teamwork. Teamwork could be defined as the ability of a group of individuals to work together to achieve a common goal. (11) Teamwork of physicians, nurses and ancillary personnel are key, especially since many of the ATLS-derived tasks are performed parallel by different team members to increase the pace of resuscitations. Thereby decisions during trauma resuscitations are based upon other members’ findings and interpretations of the situation.

Currently, not all trauma centers evaluate trauma team performance as a routine, and if the team performance is evaluated, there is a great variety in evaluation techniques. (12–14) Currently, chart review, live observations and video analyses are used and each of these methods has advantages and disadvantages. Chart review requires the least effort in terms of organization. The charts are available in most trauma centers as documentation of medical diagnoses and treatment it is part of daily practice. However, chart review is not reliable, as a previous study found that 80% of resuscitation errors identified through video review were missed by chart review. (15) Thereby, factors such as the pace, most of the non-technical skills and technical skills are hard not measurable using this chart review.

Assessment of team performance using live observations or video able to review all of these factors. However it is unknown if video review and live observations are equally reliable. Nevertheless, this is crucial to know when intending to improve trauma team performance as these evaluations are the foundation on which quality assessments and education are build. Therefore, in **Chapter 3** live observations and video analysis as methods to analyses trauma teams on ATLS adherence and the pace of the resuscitation were analyzed. Validity and reliability during simulated and real life resuscitations of these two methods were compared. Subsequently, **Chapter 4** describes an observational study

where the reliability of video analysis to assess non-technical skills was evaluated. The T-NOTECHS tool was used to evaluate non-technical skills and stands for Trauma Nontechnical Skills and was developed in previous research (16) to assess non-technical skills of the trauma team during trauma resuscitations.

Team organization and support (Part 3)

To improve team performance, one must first know the context in which trauma teams collaborate. Trauma resuscitations itself are dynamic processes mainly as patients' injuries are unknown at the time of admission, but may be life-threatening. Organization wise, trauma teams can be very dynamic as, the staffing of trauma team composition varies. As team members accomplish more resuscitations together, the more familiar the team members become with each other's duties, behaviors, and interactions. This is important as, intuitively, teamwork could be enhanced by team familiarity. Nevertheless, there is a lack of research and knowledge about nature, extend and impact of staffing variation within trauma teams. Therefore, **Chapter 5** describes and investigates trauma team staffing at the UMC Utrecht trauma center, which is a start to broadening our understanding of team staffing.

Besides team variety, influencing team performance, effective team coordination has been described as critical for the quality and pace of resuscitations and effective leadership can facilitate this coordination. (17) The trauma team leader coordinates the team members' activities and gives direction regarding the clinical and logistical implications during the resuscitation. Currently, the experience of the trauma team leader is mostly not taken into account in organizing trauma teams, while a leader is key in coordination of the trauma team and therefore the performance of the trauma team. As a result, we wondered if the leader's level of experience influences team performance. Therefore, chapter 6 describes a before and after study where the effects of introducing an on-site trauma surgeon and the effect their presence has on resuscitation pace and guidelines was evaluated. An on-site trauma surgeon acting as trauma team leader is more experienced than a senior resident who acted as trauma team leader before the transition. Subsequently, **chapter 7** describes the effects of adding a leader with experience during the initial phase of the management of severely injured patients. The introduction of an in-house attending policy for trauma surgeon replaced the on-call (out-of-hospital) attendance policy. During the on-call

attendance policy, a PGY 5 or older resident in general surgery served as house officer. In this chapter the time on the emergency department, time to imaging and definitive care were compared during the periods before and after the transition of attendance policy. Finally, **chapter 8** describes an observational study that investigates the effects of a more experienced trauma team leader on resuscitation pace, as the resuscitation time between resuscitations led by a fellow trauma surgeon were compared to their more experienced staff trauma surgeon colleagues.

Next to the organization of a trauma team, supporting the trauma team might also improve team performance. Many time-sensitive and critical tasks have to be performed in the complex environment of the management of severely injured patients in the resuscitation room. Even experienced teams can make mistakes in this situation and that makes methods to support the trauma team during the resuscitation valuable for success. Checklists have been used in aviation and other fields of medicine and a checklist could complement the naturally limited human memory, which could be even more impaired by the stress felt during trauma resuscitations. (18–20) Within the field of trauma, the use of a checklist during trauma resuscitations is not standard practice. Therefore in the final chapter, **Chapter 9**, a systematic review is presented of studies investigating the effect of the introduction of a checklist of ATLS related tasks during the trauma resuscitation.

Historical perspective of video usage

In 1988, Hoyt and colleagues reported a new method to obtain new insights in trauma team performance. (21) The authors described how to use the ‘state-of-the-art technique’ to record no less than 2500 resuscitations using a camera that was connected to a video recorder, using a separate video tape for each resuscitation. The camera and recorder were turned on by a nurse as part of their pre-admission duties before patient arrival. When the resuscitation was finished, the camera and recorder were manually turned off. The following decade, similar video recording technology was described in several articles. (22,23) These authors were positive about the use of video to analyse trauma resuscitations. However, there were also several limitations described, such as missing videos, bad technical video quality, technical failures, or staff members who forgot to turn on the recorder. Thereby, large trauma centers had issues with storing the many physical videotapes. But as video technology and accessory software has evolved and the modern

video review equipment has changed drastically since then, most of these problems have been solved.

Current equipment for a video review system at UMC Utrecht

The camera

In resuscitation room at the UMC Utrecht an Axis P5414 HD camera with integrated microphone is used. This is a PTZ (Pan, Tilt and Zoom) IP (Internet Protocol) camera. Unlike a traditional fixed camera, a PTZ camera allows users to adjust the camera's view remotely as necessary. The power supply of the camera is 24-volt DC (Direct Current), and the camera is connected to the hospital Ethernet network by an internet LAN cable. Our camera can also be supplied with an Ethernet (high power) cable only. The camera is mounted on the wall at the foot end of resuscitation table, since this position obtains the best view during trauma resuscitation. Recordings of trauma resuscitations are fully automatic, using integrated motion sensors. The camera activates when movement is registered in the resuscitation room and automatically stops when a certain time no movement is registered anymore. Automatic recording avoids interference during resuscitation (no attention needed to activate the system) so no resuscitations are missed.

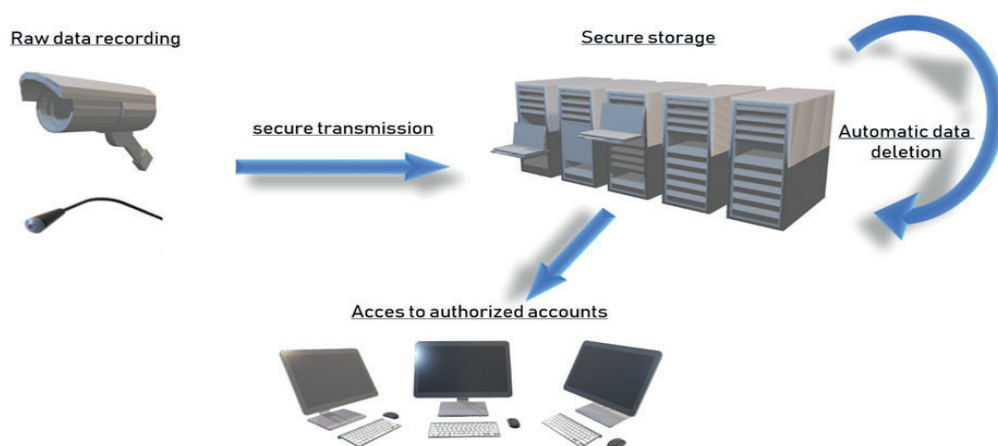
Storage

The camera sends the digital encrypted videos via the hospital Ethernet network to a secured digital server, where the videos are stored. The digital server is physically present in the hospital and managed by the hospital ICT department in physically secured rooms. We use a virtual machine server, which is an emulation of a computer system. To protect the privacy of patients and employees, all captured videos are automatically deleted after two weeks.

Access to camera and video

In the UMC Utrecht AXIS Companion (R) software is used to manage and access the video review system. This AXIS Companion allows for a quick and easy setup of video camera systems. For security and confidentiality reasons, a controlled number of personnel have access to the software. The software allows for watching trauma resuscitations live and also provides remote access to the camera, which enables to change angle if needed.

Figure 2: Overview of data recording, transmission, storage and access



Video Analysis

None of the video analysis in this thesis was automated. One or more researchers analyzed resuscitation in this theses using automatic captured video- and audio recordings based on the research question of each chapter.

Figure 3: Trauma resuscitation room from video perspective



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Chapter

2

Trauma team

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Editor's key points

- The horizontal distribution of tasks between team members reduces the time from injury to critical interventions.
- Organizing the staff caring for seriously injured patients into trauma teams improves outcomes.
- Simulation training of teams improves performance but must be repeated on a regular basis if the effect is to be sustained.
- Videoing and review of real and simulated trauma resuscitations can be used for training and audit.

Abstract

The introduction of trauma teams has improved patient outcome independently. The aim of establishing a trauma team is to ensure the early mobilization and involvement of more experienced medical staff and thereby to improve patient outcome. The team approach allows for distribution of the several tasks in assessment and resuscitation of the patient in a 'horizontal approach', which may lead to a reduction in time from injury to critical interventions and thus have a direct bearing on the patient's ultimate outcome. A trauma team leader or supervisor, who coordinates the resuscitation and ensures adherence to guidelines' should lead the trauma team. There is a major national and international variety in trauma team composition, how ever crucial are a surgeon, an Emergency Medicine physician or both and anesthetist. Advanced Trauma Life Support training, simulation-based training, and video review have all improved patient outcome and trauma team performance. Developments in the radiology, such as the use of computed tomography scanning in the emergency room and the endovascular treatment of bleeding foci, have changed treatment algorithms in selected patients. These developments and new insights in shock management may have a future impact on patient management and trauma team composition.

Keywords

Patient care team; Patient outcome assessment; Resuscitation; Task performance and Analysis; Wounds and injuries.

Trauma is the leading cause of death in the age group up to 44 yrs. in the Western world, (1–3) despite improvements in trauma care over the last four decades.

The current model of civilian trauma systems was first in the USA with the adoption in the American Congress of the Emergency Medical Systems Act, Public Law 93 – 154, on November 1, 1973. The intention was to set up an area-wide emergency medical system. (4) The rationale for this was that failure to provide sufficient specialized care in an early phase of major trauma had been demonstrated to be a major shortcoming in the management of seriously injured patients. (5) One of the improvements in trauma care that resulted from this law was the introduction of multidisciplinary trauma teams. A trauma team aims to rapidly resuscitate and stabilize the patient, and to reduce the time to diagnosis and treatment with the overall objective of improving survival rates. Cowley (6) was among the first to conclude that having different specialties in a trauma Centre is a necessity to reduce mortality. In the next decade, more studies came to this conclusion. (7-10)

Trauma team composition

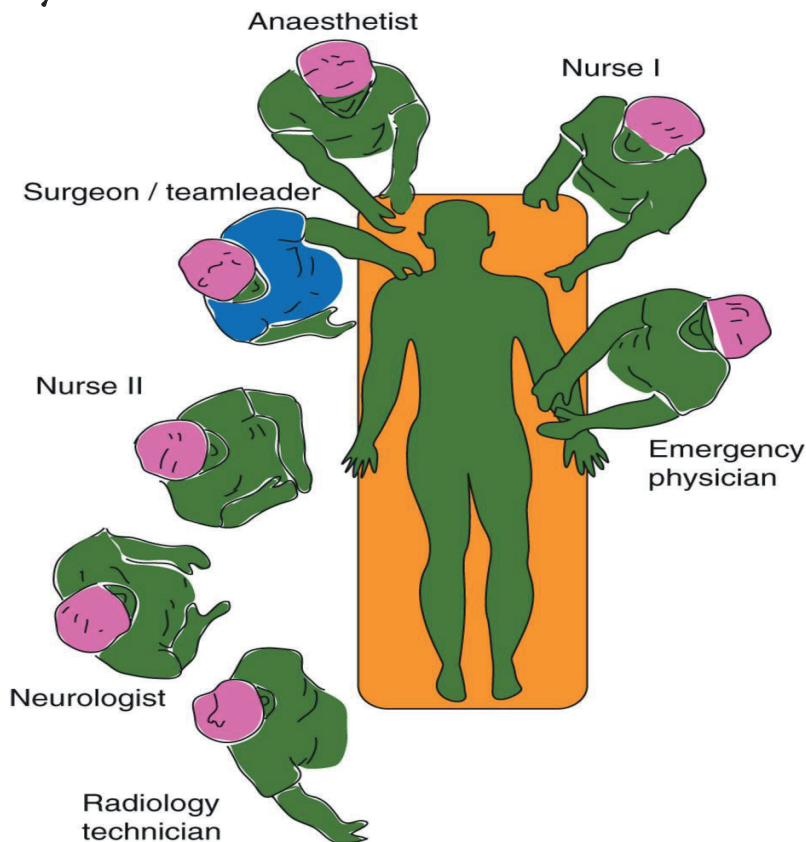
A team approach allows for distribution of the several tasks in assessment and resuscitation of the patient among a number of people. This ‘horizontal approach’ can lead to a reduction in time from injury to critical interventions. Driscoll and Vincent (11) showed that the time to complete the primary survey had a direct bearing on the patient’s ultimate outcome.

Outcomes from the initial assessment and resuscitation of trauma patients are improved by an organized trauma team. (12,13) There is variation, both nationally and internationally, in trauma team composition. However, the different approaches have much in common and an example of a trauma team composition and tasks are summarized in Figure 1 and Table 1.

The treatment of seriously injured patients requires the rapid assessment of injuries and institution of life-preserving therapy. The trauma team leader is often a surgeon who coordinates the resuscitation and ensures adherence to Advanced Trauma Life Support (ATLS) guidelines. Depending on the local situation, the trauma team can be led by an emergency physician as well. In the basic set up, an anaesthetist, one or two emergency department (ED) nurses, and a radiology technician join the team leader. The assessment and treatment of a protected unobstructed airway, which takes priority over management

of all other conditions in the primary survey, is usually carried out by the anaesthtist, but can also be done by an intensivist, surgeon, or Emergency Medicine physician, depending on local agreements. The team leader interprets the results of the assessment of breathing and circulation and procedural treatment of injuries is provided if necessary. The nurses assist the medical staff and perform various tasks such as obtaining vital signs, performing or assisting with activities like i.v. access, drawing of blood, and undertaking urinary and gastric catheter placement. In many institutions, a nurse may also act as scribe, keeping a contemporaneous record of the management of the patient.

Figure 1: Set-up of the multidisciplinary trauma team in the University Medical Centre Utrecht.



In some units, a neurologist or a neurosurgeon can be present for the determination of the Glasgow coma score, pupillary light response, and focal neurological deficit. In other hospitals, the surgeon or emergency physician will perform the primary neurological examination and consult a specialist when necessary. A radiology technician should

Table 1: Tasks of the trauma team members in the University Medical Centre Utrecht

Anaesthetist
<ul style="list-style-type: none"> • Airway management • Intubation • Ventilation • Performs procedures
Surgeon/team leader
<ul style="list-style-type: none"> • Initial assessment and survey • Coordinates team activities • Performs procedures
Primary nurse
<ul style="list-style-type: none"> • Calls alert • Records vital information • Assists with procedures of surgeon
Neurologist
<ul style="list-style-type: none"> • Neurological evaluation
Radiology technician
<ul style="list-style-type: none"> • Films as needed Chest Pelvis
Radiologist
<ul style="list-style-type: none"> • Performs FAST if needed • Reads films • Prepares CT
Secondary nurse
<ul style="list-style-type: none"> • Assists with airway management • Places monitoring devices • Sets up ventilator
Emergency physician/physician assistant
<ul style="list-style-type: none"> • Records vital signs • Venous access/draws blood • Inserts urinary catheter • Assists performed procedures
Circulating nurse
<ul style="list-style-type: none"> • Brings blood • Carries blood samples • Prepares transport

be present to make conventional X-rays of the thorax and pelvis as adjuncts to the primary survey. If a focused assessment sonography in trauma (FAST) is indicated, a radiologist should be present as well. The radiologist can either be a member of the trauma team or can be on site and be paged by the trauma team if necessary.

Usually, additional personnel such as junior surgical residents, emergency physician residents, or respiratory technicians are members of the trauma team as well. It is important not to have excessive numbers of people in the team, since it is more difficult to ensure the overview by the team leader and adherence to ATLS protocol by all team members.(11)Manyhospitalshave developed a tiered trauma team response. Depending on the reported trauma mechanism, expected injuries, and physiological parameters, the appropriate trauma team is requested. (14-16) Information from prehospital medical personnel is important for guiding the appropriate response and for assembly and preparation of the appropriate trauma team.

(17)Depending on a triage system, patients are directed to the adequate level hospital, (18,19) and trauma team activation is requested. The coordinating ED nurse will then activate the appropriate team, according to the activation criteria (Table 2). Evaluation of the current practice has shown that a considerable rate of overtriage is necessary in order to prevent undertriage, and thus a delay in mobilizing the trauma team. (20)

The team leader must check that the resuscitation is proceeding satisfactorily, decide

which additional tests should be done, and formulate a definitive plan. Leadership skills have shown to be of particular importance: in situations where a command physician is clearly identified, there usually is a shorter time to primary and secondary survey and to performing diagnostic investigations. (21–23) A study performed by Lubbert and colleagues in 2009 (24) showed that efficient leadership was associated with a lower total number of deviations from ATLS protocol. Studies comparing surgeons with non-surgeons in the role of trauma team leader show no difference in predicted survival or ED length of stay. (25–27) Several studies have shown that the availability of an attending trauma surgeon on the trauma team 24 h a day reduces resuscitation time and time to incision for emergency operations, but has not demonstrated an impact on mortality. (28–29)

Besides leadership, other human factors such as communication, supervision, and seeking

Table 2: Trauma team activation criteria in the University Medical Centre Utrecht

Mechanism	Motor vehicle accident	<ul style="list-style-type: none"> •Speed over 80 km h⁻¹ •Ejection/roll over/trapped •Unrestrained/fatality
	Motor bicycle	<ul style="list-style-type: none"> •Any with speed >30 km h⁻¹
	Pedestrian/cyclist	<ul style="list-style-type: none"> •Struck by car or motorcycle/any speed
	Fall	<ul style="list-style-type: none"> •Adult >3 m and/or 5 stairs •Elderly on anti-coagulant therapy •Motor bikes/cycle/water ski
	Horse	<ul style="list-style-type: none"> •Any horse-related injury
	Assaults	<ul style="list-style-type: none"> •Shooting •Stabbing •Focal blunt head trauma with GCS <13
	Multiple casualties	<ul style="list-style-type: none"> •With significant injuries
	Other	<ul style="list-style-type: none"> •Explosion •Hanging •Submersion
	Injuries	<ul style="list-style-type: none"> •Potential airway obstruction/respiratory distress •Penetrating injury to the head/neck/chest/abdomen/pelvis/back/limbs •Paralysis (spinal cord injury) •Burns >10% BSA
	Signs	<ul style="list-style-type: none"> •Respiratory rate <10 or >30 •Heart rate <40 or >120 •Arterial pressure <90 systolic at any stage •Capillary return >2 s •GCS <14
	Treatment	<ul style="list-style-type: none"> •Multi-trauma transferred from other hospital within 24 h of injury •Intubation or assisted ventilation •>2 litre of fluid resuscitation

GCS,: Glasgow coma score; BSA: body surface area

help are important. These human factors could influence team structure and collaboration, (30,31) effectiveness during resuscitation, (32) and leadership attributes (33) and they could potentially influence clinical outcome factors. Understanding the role of trauma team members (34) and human factors may impact the clinical outcome of trauma patients. (35)

The effects of the introduction of trauma teams

The aim of establishing a trauma team is to ensure the early mobilization and involvement of more experienced medical staff and thereby to improve patient outcome. Although it is difficult to separate the benefits of a trauma team from the effects of implementation of trauma systems, there is evidence that the introduction of trauma teams has improved patient outcome. Data from Petrie and colleagues (36) showed that patients with an injury severity score (ISS) ≥ 12 had a significantly better outcome when a trauma team was activated than when they were treated on service-by-service basis. Not only was the performance better when the trauma team was involved in the management of moderately to severely injured patients, there were significantly more unexpected survivors as well, even though both groups had access to the same personnel, imaging techniques, operating theatres, and intensive care unit in the same tertiary care center.

The introduction of a trauma team in a level I trauma center led to a significant improvement in triage time for all patients leaving the ED. Furthermore, it resulted in a trend towards lower overall mortality rates and mortality rates among patients with severe head injury. (37) A significant reduction in overall mortality rate, from 6.0% to 4.1%, was seen in another study; in patients who were most severely injured with an ISS of 25 or greater, mortality rates decreased from 30.2% to 22% (8.3% absolute reduction in mortality, 95% confidence interval 2.1 – 14.4%). (38) In patients who meet well-established trauma call criteria who are not treated by a trauma team, a higher mortality has been demonstrated. (39) The horizontal approach of trauma team assessment and resuscitation of patients may lead to a reduction in time from injury to critical interventions. A decrease in time to definitive care, for instance, time to hemorrhage control or neurosurgical interventions, may have an impact in mortality. A well-organized trauma team has been shown to carry out a complete resuscitation in a mean of 56 min rather than 122 min, more than halving the total resuscitation time. A study in our institution demonstrated an even shorter total trauma room time of 33 min. (24)

Trauma training

ATLS course

The first ATLS course was in 1978. The course was adopted by the American College of Surgeons (ACS) Committee on Trauma and incorporated as an educational program 1 year later. In that same time period, area-wide medical emergency systems were implemented and the development of trauma teams gained more attention. A group of local surgeons and physicians, the Lincoln Medical Education Foundation, together with University of Nebraska Medical Center and the Nebraska State Committee on Trauma (COT) of the ACS, founded courses to improve the quality of ATLS skills. (40) Originally, the ATLS course was developed for doctors in rural areas who did not manage trauma patients on a regular base. The ACS expanded the ATLS course nationally in 1980. The first pilot courses seemed to show an improvement of outcome of trauma patients in rural areas. (41,42) ATLS courses are nowadays very common and widely accepted and have resulted in better outcome as was shown in several studies. (43,44) Ali and colleagues showed that an ATLS program for physicians resulted in a statistically significant improvement of in-hospital trauma patient outcome (observed to expected mortality ratio of 3.16 pre-ATLS compared with 1.94 post-ATLS). The same study group also showed a significant decrease in mortality and morbidity after instituting a prehospital Trauma Life Support (PHTLS) programme. (45)

Simulation-based training

Simulation-based training (SBT) is focused on promoting expertise through simulation techniques. It creates a situation where skill development, practice, and feedback are applied and can take place in a replication of the real-world environment. (46) The current review will focus on the teamwork aspect of SBT. Shapiro and colleagues (47) concluded in 2004 that high-fidelity medical simulation training appeared to be a promising didactic teamwork training method. After an intervention study using a pre and post-training design, it was clear that there were significant improvements in different domains using the Trauma Team Performance Observation Tool (TPOT). These included improvements in the domains of leadership ($P=0.003$), situation monitoring ($P=0.009$), mutual support ($P=0.004$), communication ($P=0.001$), and overall ($P=0.001$). The times from arrival to the computed tomography (CT) scanner (26.4 – 22.1 min, $P=0.005$),

and the operating theatre (130.1–94.5 min, $P=0.021$) improved significantly. (48) Another pre- and post-intervention study showed significant improvements in the objective variables of resuscitation time (,0.05), T-NOTECHS scores (,0.05), and frequency of near- perfect task completion (,0.001). (49) The T-NOTECHS score is a modified non-technical skills scale for trauma and is developed to assess teamwork skills of multidisciplinary trauma resuscitation teams. Miller and colleagues (50) concluded that in situ trauma simulation (ISTS) improved performance during the period when the training had taken place, especially teamwork and communication skills compared with the period before the ISTS, but that the effect was not sustained when the ISTS training stopped. The scores measured in the period between 1 and 5 weeks after the last ISTS session were similar to the baseline scores. In conclusion, the effect of stimulation training has positive outcomes on team performance, although it is questionable what the long-term effects are. Consequently, it seems to be important that trauma teams train on a regular basis, if the effects of training are to be sustained.

There are many different modalities available for SBT. The diverse range of medical-simulation modalities enables trainees to acquire and practice an array of tasks and skills. (51) There is little evidence as to which modality has the best outcome. A study by Wisborg and colleagues (52) concluded that there seems to be no difference in outcome in between stimulation using a manikin or standardized patients when the educational goal is training communication, co-operation, and leadership within the team. A critical note, however, is that the outcome is measured in participants' assessment of their educational outcome and the degree of realism instead of a more objective outcome score.

Video review

Studies have been published describing the videotaping and review of both simulated and actual trauma resuscitations. Video recording of trauma resuscitations can serve three goals. First of all, evaluation of trauma resuscitations can be of use for educational purposes. Videotaping real trauma resuscitations with subsequent review creates the opportunity to modify behavior by analysing resuscitation performance in a more controlled format with more experienced physicians. Secondly, video registration can serve as a tool for quality assessment, for instance, to monitor adherence to ATLS guidelines. (53) Finally, the video registration data can be used for research purposes.

Hoyt and colleagues (54) were the first to describe the use of video review of trauma team resuscitations. They evaluated 2500 resuscitations in a 3.5 year period. The resuscitations were reviewed using an audit form and discussed during a conference attended by various members of the trauma team, including prehospital personnel, radiology, respiratory therapy, doctors, nurses, and students. The review process produced an overall 12% reduction in resuscitation time during a 3 month resident rotation. When stratified for injury severity, the group with an ISS \leq 20 had a reduction in resuscitation time of 15%, compared with a 9% reduction in patients with an ISS $>$ 20. A greater benefit for more severely injured individuals was also shown by Townsend and colleagues (55) in a similar study.

In order to pursue quality improvement using video recording of trauma resuscitations, an objective evaluation system is required. Written guidelines must direct reviewers through the tape and remove subjective evaluation of events. (56) Besides evaluation of objective data, such as adherence to ATLS protocols and total resuscitation time, videotape review can be used to assess teamwork and leadership. (53) In order to improve trauma teamwork, a tool to accurately capture and assess the important factors of trauma resuscitation has been developed. (57) This tool was developed on the basis of five behavioral domains, which had been used to evaluate non-technical skills (NOTECHS) in the operating theatre. Inter-rater reliability was evaluated using video review of team training using simulated scenarios and actual resuscitations. Although further work to improve inter-rater reliability is warranted, the clinical relevance of the tool was suggested by improvement of the scores after teamwork training, and correlation with clinical parameters in simulated and actual trauma resuscitations.

Scherer and colleagues (58) showed an improvement in half of the behaviors studied within 1 month of initiating conference-based video review, compared with no improvements after 3 months of verbal feedback. Video data are objective evidence of an individual's performance. Enabling colleagues to understand their performance is the first step in effecting a change in behavior. It can also be helpful in identifying incongruities in perceived self-efficacy, which is the discrepancy between the behavior the participants think they are performing vs the behavior they actually perform.

The future of trauma teams

So far, we have discussed the institution and development of trauma teams and described the current situation. In the latter part of this article, we will discuss the future of trauma care and its impact on the trauma team.

Radiology

The CT has become an important diagnostic tool in trauma care. In many trauma patients, a clear history is not available and physical examination can be misleading (59) or equivocal. (60) Furthermore, it is not possible to exclude abdominal or pelvic organ injury based on clinical examination. (61) Therefore, diagnostic imaging has become a widely accepted standard for management of poly-trauma patients. Sonography is usually readily available in the ED and the FAST is used as initial screening. It has a high positive predictive value for detection of free fluid, but a low sensitivity. CT is the modality of choice in order to detect visceral injuries and determine the extent of blunt abdominal trauma. (62,63) The advantages of the CT are clear: not only does it provide more complete information regarding the abdomen, it also allows for rapid examination of the head, neck, and chest. (64) Several large series have shown the effectiveness of targeted CT in management of hemodynamically stable patient with blunt abdominal or thoracic trauma. (63,65-68) A more recent study demonstrated a significant increase in survival in hemodynamically unstable major trauma patients receiving a whole-body CT scan as well, if performed quickly within a well-structured environment and by a well-organized trauma team. (69) This is a remarkable result, even though it was a non-randomized retrospective study. Furthermore, there were more than 300 patients who did not receive a CT scan due to emergency surgery. Resuscitation should still be physiology-driven and in patients with severe instability, emergency surgery precedes radiological evaluation. However, since CT scanning is generally available in or close to the trauma room; it can be used early in the resuscitation phase and thus may lead to a better survival of trauma patients. CT scanning may have potential in the prehospital phase; indeed, it is currently in use in stroke patients enrolled into a pilot study in Germany. (70,71)

This development in imaging could have an impact on trauma team composition. CT has a high sensitivity for the detection of parenchymal injuries and a good sensitivity

for injuries of the gastrointestinal tract, provided that adequate examination technique and careful diagnostic interpretation is combined. (64) The radiologist should thus be a regular member of the trauma team to aid in quick and thorough interpretation of the CT images. Moreover, in addition to aiding with diagnosis, the interventional radiologist will be increasingly involved in the treatment of trauma patients. A growing number of hospitals are equipped with a hybrid operating theatre facilitating combined surgical and endovascular treatment of trauma patients.

Shock management

Changing insights into coagulation path of physiology have driven the demand for earlier and different diagnostic technologies such as thromboelastograph, and point-of-care testing. Coagulation therapy continues to evolve and may also influence future trauma team composition.

Trauma-induced coagulopathy is well known in severely injured patients and was first recognized during the Vietnam War. (72–74) Coagulopathy after trauma is common and was previously attributed to iatrogenic causes such as dilution from i.v. fluid therapy, massive blood transfusion, and other factors such as progressive hypothermia, and acidosis. (75–77) While these factors should not be neglected, we now know that acute traumatic coagulopathy (ATC) is an independent predictor of mortality. (78,79)

In 56% of trauma patients, abnormal coagulation is present in the first 25 min after injury. (80) In the last decade, we have developed a better pathophysiological understanding of ATC. Key characteristics of ATC are isolated factor V inhibition, dysfibrinogenemia, systemic anticoagulation, impaired platelet function, and hyperfibrinolysis.⁸¹ In addition, activation of protein C due to endothelial disruption is likely to cause coagulation factor consumption and loss of inhibition of fibrinolysis. (82,83) ATC can be exacerbated by hypothermia, acidosis, and resuscitation with hypo-coagulable fluids.

Increasing injury severity is associated with increasing likelihood of an abnormal coagulation test (ISS 9 – 16: 5%; ISS 17– 25: .10%; ISS .45: 43%). Mortality due to severe injury and coagulopathy occurs quickly. The mean time to death for trauma patients who die of uncontrolled hemorrhage is 2 h (84) and more than half of all injured civilians,

in rural areas up to 80%, who die from their injuries die in the prehospital phase. (85,86)

It is increasingly recognized that blood and coagulation management is an important aspect of the early treatment of severely injured trauma patients. Massive hemorrhage requires massive transfusion to maintain adequate circulation and haemostasis. (87) Current data support that trauma patients treated with higher ratios of plasma and platelet to red blood cell transfusions have improved outcomes, but further clinical investigations are needed. (87,88) In cases of massive transfusion, a well-defined protocol helps to delineate how blood products are ordered, prepared, and delivered; determine laboratory algorithms to use as transfusion guidelines; and outline duties and facilitate communication between involved personnel. The development of such a protocol is a joint responsibility of members of the trauma team and a hospital transfusion team.

The improved understanding of ATC and the institution of mass transfusion protocols may have an impact on the operative treatment of trauma patients. Administration of blood products early in the resuscitation could lead to less hemodynamic instability and thus decrease the number of patients requiring damage control surgery, since damage control management is focused on a hemodynamic stable patient before definitive surgical treatment. This could therefore mean that early total care could be possible for more trauma patients and secondary and tertiary surgical treatment can occur sooner, or even in one session.

Conclusions

Trauma patients benefit from resuscitation by a trauma team because of the rapid resuscitation and stabilization and reduction in time to diagnostics and treatment. The team leader must oversee the resuscitation and intervene when necessary. Leadership skills have shown to be of particular importance. Resuscitation should be physiology-driven and the patients' response to resuscitation determines further treatment, which can vary from damage control surgery to observation.

Authors' contributions

D.T.G.-K. and O.M. literatures search and writing up the first draft of the paper; L.L.: concept and outline of the research, revising manuscript critically for important intellectual content, and final approval of the version to be published.

Declaration of interest

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Part



2

Chapter

3

Evaluation of Validity and Reliability of Video Analysis and Live Observations to Assess Trauma Team Performance

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Abstract

Introduction

A trauma resuscitation is dynamic and complex process in which failures could lead to serious adverse events. In several trauma centers, evaluation of trauma resuscitation is part of a hospital's quality assessment program. While video analysis is commonly used, some hospitals use live observations, mainly due to ethical and medicolegal concerns. The aim of this study was to compare the validity and reliability of video analysis and live observations to evaluate trauma resuscitations.

Methods

In this prospective observational study, validity was assessed by comparing the observed adherence to twenty-eight Advanced Trauma Life Support (ATLS) guideline related tasks by video analysis to live observations. Interobserver reliability was assessed by calculating the intra class coefficient of observed ATLS related tasks by live observations and video analysis.

Results

Eleven simulated and thirteen real-life resuscitations were assessed. Overall, the percentage of observed ATLS related tasks performed during simulated resuscitations was 10.4% ($P < 0.001$) higher when the same resuscitations were analysed using video compared to live observations. During real-life resuscitations, 8.7% ($p < 0.001$) more ATLS related tasks were observed using video review compared to live observations. In absolute terms, a mean of 2.9 (during simulated resuscitations) respectively 2.5 (during actual resuscitations) ATLS-related tasks per resuscitation were not identified using live observers, that were observed through video analysis. The interobserver variability for observed ATLS related tasks was significantly higher using video analysis compared to live observations for both simulated (video analysis: ICC 0.97; 95% CI 0.97-0.98 vs. live observation: ICC 0.69; 95% CI 0.57-0.78) and real-life witnessed resuscitations (video analyse 0.99; 95% CI 0.99-1.00 vs live observers 0.86; 95% CI 0.83-0.89).

Conclusion

Video analysis of trauma resuscitations may be more valid and reliable compared to evaluation by live observers. These outcomes may guide the debate to justify video review instead of live observations.

Keywords

Resuscitation, Trauma Team, Live observers, Video review, Quality assessment

Introduction

With the implementation of trauma systems, severe trauma patients are resuscitated with a systematic approach. The initial management of severely injured patients is performed by several (para)medical healthcare professionals and extends over a series of sequential processes that begin with the first responder on the accident site and ends with definitive treatments such as surgery or intensive care at the hospital.

This interdisciplinary response to injuries has resulted in significant improvements in mortality and morbidity of severely injured patients. (1–3) Resuscitation by a trauma team is one of the cornerstones of a structured response to injury, especially for severely injured patients. (4–6) The objective of a trauma team is to assess all life-threatening injuries in patients and offer immediate resuscitation and stabilization if necessary.

A trauma resuscitation is a dynamic process, where several tasks are performed simultaneously or in quick succession. During these resuscitations, the Advanced Trauma Life Support (ATLS) guidelines, which are acknowledged worldwide, provide guidance to the trauma team by prioritizing diagnostic and therapeutic processes. (7) Nevertheless, during this dynamic process, failures in technical or non-technical skills (e.g., communication or leadership) could cause serious adverse events, and even mortality. (8–11) Therefore, there is a continuous effort to optimize healthcare for severely injured patients. To this end, the American College of Surgeons requires quality assessment programs to be certified as a level one trauma center; (12) hence, several trauma centers have incorporated evaluation of trauma team resuscitations within their quality assessment program. (13,14)

The validity and reliability of trauma team evaluations are crucial, as these evaluations are the foundation upon which quality assessments and education are built. Video analysis has been described as an effective approach to assess trauma team performance, as it provides an accurate documentation of resuscitation. For example, the ability to replay a video allows for a detailed analysis of (non-)technical skills and processes during the

resuscitation. (15–21) However, privacy issues and regulations withhold several trauma centres from using video to review trauma resuscitations. (22) Due to these medicolegal issues, some hospitals use live observers instead of video analysis to assess trauma team performance (23,24) A systematic comparison of the validity and reliability of video analysis and live observations as methods to assess trauma team performance is lacking.

The aim of this study was to compare the validity and reliability of video analysis and live observation as methods to evaluate trauma resuscitations on ATLS adherence in simulated and real-life witnessed trauma resuscitations.

Materials and methods

Design

This study was a prospective observational study to compare the validity and reliability of live observations versus video analysis as methods to assess ATLS adherence in simulated and real-life trauma resuscitations. Audio recordings were also included in the video recorded (simulated) resuscitations. First, eleven simulated trauma resuscitations were assessed. Three simulated resuscitations were assessed by two live observers and eight additional simulated resuscitations were assessed by one live observer. Next, all eleven simulated resuscitations were assessed by two observers by using videos (video analysis). Additionally, thirteen real-life resuscitations were assessed. All real-life resuscitations were assessed by two live observers and two video assessors. (Figure 1) Throughout the study period, the video assessors were the same investigators as the live observers and blinded for each other's findings. The investigators were not familiar with the trauma team members. Team members' roles are identified by the color of their lead apron. All resuscitations were assessed using a predefined list of twenty-eight ATLS related tasks (table 1). The same list was used during both simulated and real-life resuscitations by live observers and by the video assessors.

Setting and sample

The study was performed at the University Medical Center of Utrecht, a level one trauma center and a Joint Commission International (JCI) accredited tertiary care facility in the Netherlands. The trauma team training took place in the same resuscitation room where patients were resuscitated, while the simulated trauma resuscitations were weekly

yielded using the SimMan®. During each training session, a scenario of a severely injured patient was simulated. The trauma team composition during simulation was comparable to the composition during real-life resuscitations, only without a neurologist and radiology technician; a review by Kreb et al. (19) contains a detailed description of the trauma team's composition and the trauma team activation criteria. Thirteen consecutive real-life resuscitations of adult injured patients resuscitated with a trauma team were assessed.

Outcomes

Validity

Validity is defined as the extent to which a measurement method or test measures what it is supposed to measure. An assumption of the study was that only false negative observations would occur and there would be no false positive observations, meaning that tasks would be missed by the live observers or by using video analysis, but no tasks would be observed that did not occur. Therefore, the total number of observed ATLS tasks was our primary outcome measure to assess validity. The total observed ATLS tasks was defined as observed tasks divided by the total number of listed ATLS related tasks which should be performed (28 tasks).(7) The total observed tasks were represented in percentages. The second validity assessment was to compare the observed separate ATLS related tasks between live observers and video assessors.

Reliability

Reliability is defined as the extent to which a repeated measurement method provides the same results. Our primary outcome to assess reliability was interobserver variability of live observations and video analysis for the observation of ATLS-related tasks during simulated and real-life resuscitations. Interobserver variability is defined as the degree of agreement among observers.

Sample size calculation

G-power was used to calculate the needed sample size for the real life resuscitations. (24) The results of the video analysis and live observations of simulated resuscitations were used to estimate the sample size for the real-life resuscitations. As the assessment of simulated and real-life resuscitations are likely to differ in practice, a 50% deviation from the effect size found during simulated resuscitations was used to calculate the needed

sample size of real-life resuscitation. Within G-power, in the family of t-tests, a 2-tailed test was used to calculate the total sample size. The calculated sample size was thirteen, which was based on the α error of 0.05, the power ($1-\beta$ error) of 0.95, and the effect size of 1.1.

Statistical analysis

Validity

Differences in overall observed ATLS adherence during real life resuscitations between live observers and video analysis were compared using the Student's t-test using SPSS (IBM Corp. Released 2012. IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY: IBM Corp). Differences in overall observed ATLS adherence between live observers and video analysis during simulated resuscitations were compared using the partially overlapping t-test as described by Derrick et al. (25) using R-studio, whereas there are within both groups paired and unpaired observations. A p-value of less than 0.05 was deemed statistically significant.

Reliability

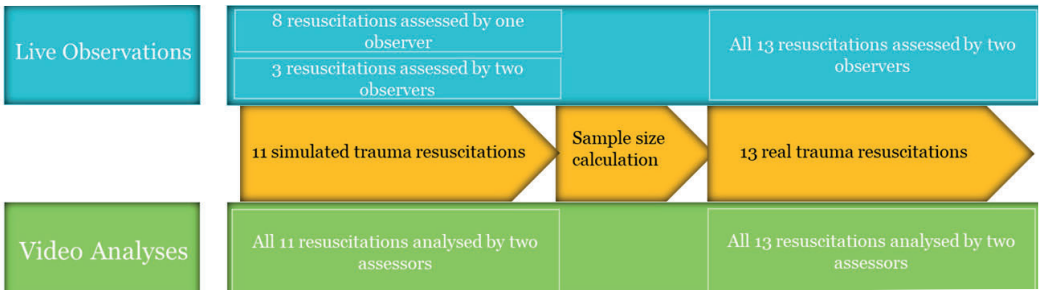
Interobserver variability was calculated using the intra-class correlation coefficient (ICC) using SPSS (IBM Corp. Released 2012. IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY: IBM Corp.). A higher ICC value indicates a higher level of agreement among the ratings . Perfect agreement is shown by an ICC value of 1.0, while random agreement is indicated by a value of zero, and a pattern of systematic disagreement is shown by negative ICC values. The cut-off points for qualitative ratings of agreement based on ICC values were based on the article by Cicchetti et al. (27) where interobserver reliability is considered low for ICC values less than 0.40, fair for ICC values between 0.40 and 0.59, good for ICC values between 0.60 and 0.74, and excellent for ICC values between 0.75 and 1.0. Differences in ICC were deemed significant in case 95 percent confidence interval (CI) did not overlap.

Standards ethical statement

The Medical Ethical Committee of the University Medical Center Utrecht approved conduction of this study and have therefore been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments Thereby as agreed with the hospital's legal department, no informed consent from patients or

workers was required because the institution uses video registration as part of local quality assessments. Videos of resuscitation were stored on a server, separately from patient record databases. To protect the privacy of patients and employees, all captured videos were analysed within and automatically deleted after thirty days. No patient related data was gathered for this study. Finally, the authors have nothing to declare and have no conflict of interest.

Figure 1: Overview of study design



Results

Eleven simulated resuscitations and thirteen real life resuscitations were live observed and reviewed on video.

Validity

Table 1 shows the total observed ATLS-related tasks using video analysis and live observations of simulated and real-life resuscitations. Overall, the percentage of observed ATLS tasks was 10.4% ($p<0.01$) higher when resuscitations were assessed using video analysis compared live observations in simulated resuscitations, and 8.7% ($p<0.01$) higher when resuscitations were assessed using video analysis compared to live observations in real-life resuscitations. In absolute terms, 2.9 (during simulated resuscitations) respectively 2.5 (during actual resuscitations) ATLS-related tasks per resuscitation were not identified using live observers, that were observed through video analysis. During simulated resus citations, twenty-one of the twenty-eight ATLS related tasks were more often observed using video analysis compared to live observations. Of these eight tasks were significantly more observed using video review compared to live observation: pulse oximeter (100% vs 77.3%; $p=0.035$), fluid administration (100% vs 77.3%; $p=0.035$), announcing results of arterial blood gas (100% vs 68.2%; $p=0.005$), EKG monitoring (90.9% vs 68.2%; $p=0.020$).

Tabele 1: ATLS adherence

ATLS related tasks	Simulated resuscitations ¹				Real life resuscitations ²			
	Observers	Video	difference	P-Value	Observers	Video	difference	P-Value
Total observed ATLS tasks	63.0%	73.4%	10.4%	<0.001*	55.4%	64.1%	8.7%	<0.001*
Airway Assessment	90.9%	100%	9.1%	0.090	92.3%	92.3%	0.0%	-
Intubation	54.5%	63.7%	9.2%	0.069	23.1%	23.1%	0.0%	-
Rigid collar	90.9%	90.9%	0.0%	0.560	61.5%	61.5%	0.0%	-
Headblocks	100%	100%	0.0%	-	69.2%	69.2%	0.0%	-
Breathing assessment	100%	100%	0.0%	-	88.5%	100%	11.5%	0.083
Chest Tube	68.2%	72.7%	4.5%	0.946	0.0%	0.0%	0.0%	-
Needle Thoracentesis	13.7%	18.2%	4.5%	0.816	0.0%	0.0%	0.0%	-
Oxygen administration	100%	100%	0.0%	-	50.0%	53.8%	3.8%	0.327
Pulse oximeter	77.3%	100%	22.7%	0.035*	88.5%	100%	11.5%	0.083
First IV line	100%	100%	0.0%	-	80.8%	100%	19.2%	0.022*
Second IV line	81.9%	100%	18.1%	0.090	26.9%	53.8%	18.9%	0.006
Fluid administration	77.3%	100%	22.7%	0.035*	76.9%	100%	23.1%	0.011*
Withdrawal of blood samples	100%	100%	0.0%	-	95.2%	100%	4.8%	0.327
Results of arterial blood gas	68.2%	100%	31.8%	0.005*	61.5%	69.2%	7.7%	0.161
EKG monitor	68.2%	90.9%	22.7%	0.020*	69.2%	100%	30.8%	0.003*
Order of blood products	59.1%	86.6%	27.5%	0.031*	0.0%	7.7%	7.7%	0.161
Arrival of blood products	31.9%	59.1%	28.0%	0.014*	0.0%	0.0%	0.0%	-
Blood pressure and heart rate	81.9%	100%	18.1%	0.090	100%	100%	0.0%	-
Pelvic examination	81.9%	81.9%	0.0%	-	84.6%	92.3%	7.7%	0.077
Abdominal examination	90.9%	100%	9.1%	0.239	92.3%	100%	7.7%	0.077
Long bone examination	45.5%	77.3%	31.8%	0.023*	76.9%	84.6%	7.7%	0.077
Pupil examination	9.1%	18.2%	9.1%	0.390	42.3%	88.5%	46.2%	0.077
Neurological examination	9.1%	18.2%	9.1%	0.354	88.5%	92.3%	3.8%	0.038
Log Roll	9.1%	18.2%	9.1%	0.534	46.2%	46.2%	0.0%	-
Temperature measurement	9.1%	18.2%	9.1%	0.584	3.8%	23.1%	16.3%	0.192
Introduction of catheter	0%	9.1%	9.1%	0.249	30.8%	30.8%	0.0%	-
Warm Blankets	86.4%	100%	13.6%	0.090	100%	100%	0.0%	-
Rectal exam	0.0 %	0.0%	0.0%	-	0.0%	7.9%	7.9%	0.077

Reliability

Interobserver variability for assessing adherence to ATLS related tasks was significantly higher when assessed using video analysis versus live observations for both simulated resuscitations (ICC 0.97 (0.97-0.98) vs 0.69 (0.57-0.78)) and (0.99(0.99-1.00) vs 0.86 (0.83-0.89)). (Table 2)

Tabele 2: inter class reliability

	ICC Live observations (95%CI)	ICC Video review (95%CI)
Simulated resuscitations		
ATLS tasks	0.69 (0.57-0.78)	0.97 (0.97-0.98)
Real resuscitations		
ATLS tasks	0.86 (0.83-0.89)	0.99 (0.99-1.00)

Discussion

This is the first study to compare validity and reliability of live observations and video analysis to evaluate trauma resuscitations on ATLS adherence. From our study results, video analysis appears to be more valid compared to live observations, as significantly more ATLS related tasks were observed. Furthermore, the degree of agreement using

video analysis was significantly higher compared to live observers. Superiority of video analysis over live observations of real-life resuscitations have been seen in previous studies for the evaluation of non-technical skills. Reliability of the T-NOTECHS, a tool to assess non-technical skills, was measured using video analysis. (22) In that study, we found an ICC of 0.94 and 0.84, respectively, when reliability during real life resuscitation was measured as the mean of three assessors or a single assessor. 22) In the study by Steinemann et al., (22) the interobserver variability of non-technical skills assessment during simulated resuscitations was higher using video analysis (ICC 0.71) compared to assessment of live observers (ICC 0.44). Furthermore, in the study by House et al., (27) the performance of emergency medicine residents during pediatric rapid sequence induction of anesthesia and intubation were assessed by live assessors and video analysis. In their study, overall interrater agreement for video analysis was higher compared to live observations. (ICC 0.79 vs ICC 0.75)

A key implication of the results is that video analysis might be more appropriate for ongoing quality assurance programs in level one trauma centers compared to live observations. In a recent nationwide survey across United States’ level one and two trauma centers, 65% of respondents reported that video analysis resulted in performance improvement initiatives, (23) and 41% stated that video analysis has led to changes in institutional guidelines. (23) However, medicolegal and patient privacy concerns were

expressed as main barrier to implement video review of trauma resuscitation. (23) Interestingly, only 2.8% of trauma centers had first-hand experience with a video analysis-related medical-legal problem. Moreso, video review may even reduce medicolegal cases, as Yang et al. (28) found a significant relation between patient safety and the risk of medicolegal involvement of physician in Canadian hospitals. In other words, video review may enhance patient safety, which may result in less medicolegal issues of physicians. Thereby, live observations should not be assumed to be less incriminating compared to video reviews. One should seek legal counsel before implementing a quality assessment program of trauma team resuscitation.

To mitigate privacy threats, proper informing, security, and anonymization methods should be adopted while performing video analysis. Quality improvements through video assessment should be secure and anonymized, and personnel should be informed being video using a clear sign at the entrance of the emergency and updated using local hospital information platforms. Data should be stored securely and must comply with local regulations, and access to the videos should be restricted to only a few key personnel. All of these actions should be well-documented and regularly evaluated. Finally, there are some recently described advanced methods available that could significantly anonymize patients and personnel in the trauma room. In the study by Silas et al. et al., (29) videos of operating rooms during surgery were processed into point clouds. Recognition of staff by their colleagues was rated using a Likert scale, where the score of 1 was anonymous, (unable to identify) and a score of 10 was not anonymous, (easy to identify) The mean scores for unaltered and point cloud videos were 7.05 and 1.41, respectively. ($P < 0.001$). Thereby, the authors noted that evaluation of surgical activity was still possible using this method.

Strengths and limitations

Our study methodology included a sample size calculation, and was able to sufficiently demonstrate differences in reliability and validity between video analysis and live observations to assess the adherence of ATLS related tasks. Another strength of this study is that both real life trauma resuscitation and simulated resuscitation were evaluated. However, there are limitations to our research that should be considered. First, recall bias may have been introduced, as the life observers were the same persons as the video assessors. Therefore video assessors may have remembered some parts of the resuscitation

as they also have witnessed the same resuscitation in real life. This effects is tried to minimize as, the videos are assessed 5 till 30 days after the resuscitation occurred. A longer period between the actual resuscitation and is not possible as videos were removed within thirty days due to local hospital security and privacy policies. Second, this study assumed only false negative observations and no false positive observations, implying that live observers or video analysis would miss tasks, but no tasks would be observed that did not occur. However, false positive observations are theoretically possible and are more likely to occur during live observations compared to video review. An assessor could reviewed parts of the resuscitation multiple times during video analysis in case the assessor has reservations about a specific activities, which is not possible during live observation. By assumption no false positive observations would occur, the assessment of this study was limited to whether the task was performed or not, and did not evaluate whether it was performed well or not. However, in this study, no ATLS-related tasks were identified by live observers that were not found using video analysis, indicating that the chance of false positive observations appears low. Third, the interrater variability of live observers for simulated resuscitations should be interpreted with caution. Only three of the eleven simulated resuscitations were assessed by two live observers, which means that analysis of interobserver variability for live observers in simulated setting included only three cases. Therefore, values found for interobserver variability of live observers in simulated resuscitations are more uncertain than interobserver variability of video analysis or live observations during real life resuscitations, which are reflected in the confidence intervals. Finally, no patient related data was gathered; therefore, we were not able to take severity of injury into account. Resuscitations of severely injured patients are more dynamic, and may therefore be challenging to observe for live observers, while in contrast, video assessment creates the opportunity to replay a video which may even increase reliability of the assessment in these resuscitations. Therefore, we strongly advise to use video analysis to assess trauma resuscitations.

Conclusion

Video analysis of trauma resuscitations may be more valid and reliable compared to evaluation by live observers. These important outcomes may guide the debate to justify video review instead of live observations, albeit with possible ethical concerns. The ethical issues in order to provide a more efficient way of analyzing and retaining trauma resuscitation procedures.

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Chapter

4

Reliability of the assessment of non-technical skills by using video-recorded trauma resuscitations

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Abstract

Purpose

Non-technical skills have gained attention, since enhancement of these skills is presumed to improve the process of trauma resuscitation. However, the reliability of assessing non-technical skills is underexposed, especially when using video analysis. Therefore, our primary aim was to assess the reliability of the Trauma Non-Technical Skills (T-NOTECHS) tool by video analysis. Secondly, we investigated to what extent reliability increased when the T-NOTECHS was assessed by three assessors (average intra-class correlation (ICC)) instead of one (individual ICC).

Methods

As calculated by a pre-study power analysis, 18 videos were reviewed by three research assistants using the T-NOTECHS tool. Average and individual degree of agreement of the assessors was calculated using a two-way mixed model ICC.

Results

Average ICC was 'excellent' for the overall score and all five domains. Individual ICC was classified as 'excellent' for the overall score. Of the five domains, only one was classified as 'excellent', two as 'good' and two were even only 'fair'.

Conclusions Assessment of non-technical skills using the T-NOTECHS is reliable using video analysis and has an excellent reliability for the overall T-NOTECHS score. Assessment by three raters further improve the reliability, resulting in an excellent reliability for all individual domains.

Keywords

Non-technical skills · T-NOTECHS · Video analysis · Trauma team · Assessment

Introduction

The introduction of trauma teams has led to improved management and outcomes of severely injured patients (1–3). A trauma team is a multidisciplinary group of healthcare workers who collectively work together on the initial assessment and treatment of

severely injured patients. (4) In this context, optimal technical performances of interventions is emphasized in resuscitation guidelines. (4) However, coordinated performance of such interventions within trauma teams requires more than mastering technical skill. Non-technical skills such as task management, leadership, situational awareness, communication and decision-making could be defined as cognitive, behavioral and social skills that contribute to safe and efficient team performance. (6-10)

As the added value of non-technical skill training on patient safety, process efficiency and medical errors is shown by a growing number of studies, (6-17) the issue of assessment becomes increasingly relevant. Therefore, there is a demand for a simple, validated and reliable assessment tool to lower the threshold for trauma centers to incorporate such assessments in their quality audits.

The T-NOTECHS is a tool developed to assess non-technical skills of the trauma team during trauma resuscitation. (18) The T-NOTECHS, stands for Trauma Nontechnical Skills and is based on the NOTECHS, which was initially used to assess non-technical skills in aviation (19) and later on adapted and applied to assess non-technical skill performance of surgical teams. (20) As described by Steinemann et al., (20) the T-NOTECHS was developed by a panel of trauma practitioners composed of two trauma surgeons, one trauma/medical intensivist, and two critical care nurses. The T-NOTECHS consists of five behavioral domains: leadership, cooperation and resource management, communication and interaction, assessment and decision making, and situation awareness/coping with stress. (18)

The T-NOTECHS is, to our opinion, a simple and validated instrument, but the reliability as found by Steinemann et al. (18) was low (ICC 0.48). An ICC of 0.48 means that 48% of the observed variance in T-NOTECHS scores is due to systematic differences compared to the total variance in achievement scores. (21) These values are especially low when aiming to assess the impact of training on non-technical skills over time.

To our knowledge, the reliability of the T-NOTECHS has only been tested during actual resuscitations by real-time observers and not by video analysis. (18) Video recordings particularly provide an indisputable, unbiased and accurate documentation of complex

events and could therefore improve the reliability of the T-NOTECHS. Furthermore, video allows to assess the same resuscitation by multiple assessors, without interfering with the resuscitation process. In this study, the primary aim was to assess the reliability of the T-NOTECHS tool by assessing non-technical skills of trauma team with video analysis during actual trauma resuscitation. Secondly, we investigated to what extent reliability increased in case T-NOTECHS was assessed by three assessors (average ICC) instead of one (individual ICC).

Methods

Design and sample

We retrospectively analyzed videos of consecutive trauma resuscitations. The trauma team was assessed on non-technical skills using the T-NOTECHS tool. To measure the inter observer reliability (a fully crossed design was used), all included videos were reviewed by all three assessors independently.

Setting

This study took place in a level one trauma center in the Netherlands. Conform institution's protocol, the trauma team is activated in case of (potentially) severely injured patient, which is predefined by physiological or anatomical criteria or mechanism of trauma was applicable. The trauma team, at our institution, consists basically of a trauma team leader, a surgical resident under direct supervision of a trauma surgeon, an anesthetist, one or two emergency department (ED) nurses, and a radiology technician. There are no differences in trauma team composition during the night or day. The tasks of each team member are in described in detail by Kreb et al. (22)

Data collection

As part of our standard quality audit, all trauma resuscitations by a trauma team are recorded on video prospectively. Eighteen recorded videos of trauma resuscitations were used to analyze non-technical skills of the trauma team. The baseline characteristics of resuscitated patients were collected. Three trained research assistants analyzed the recorded videos, who were respectively fourth (two of the three) and sixth (one of the three) year medical students. Before the analysis of the recorded videos using T-NOTECHS, the research assistants had 1 year experience with analyzing trauma resuscitations, while

they had already been trained and gained experience in video analysis of Advanced Trauma Life Support (ATLS) adherence during resuscitation of trauma patients. Furthermore, prior to the assessment of the 18 videos, training sessions were yielded to align assessments of non-technical skills of the research assistants. The training consisted of reading the article of Steinemann et al. (18) and a 2 h training session where assessment of resuscitations using the T-NOTECHS tool was discussed. The research assistants were blinded to each other's results. Videos were assessed on a computer inside the hospital building using a standardized score sheet in Microsoft Excel (Microsoft Corp. Released 2007. Microsoft Office Excel 2007, Version 12.0. Redmond, WA: Microsoft Corp.). All five behavioral domains of the T-NOTECHS were scored on a five-point Likert scale following the guidelines as described by Steinemann et al. (18) (Fig. 1). Five points indicate perfect behavior in a behavioral domain and one point indicates the team did not demonstrate this behavior. The sum of the scores of each behavioral domain ranged from 5 to 24, and a total of 25 points indicates perfect teamwork and a total of 5 points indicates ineffective teamwork.

Sample size calculation

We performed a pre-study power analysis by using the formula proposed by Walter et al. (23). The ICC we expected (ρ_1) was 0.85 and the lowest ICC we would accept (ρ_0) was 0.6. We had three raters (n) to assess all videos. In our sample size calculation, the alpha (α) level and $(1 - \beta)$ was set at 0.05 and 0.80, respectively. Finally, we used a dropout rate of 15%, in case technical issues would appear. We used Microsoft Excel (Microsoft Corp. Released 2007. Microsoft Office Excel 2007, Version 12.0. Redmond, WA: Microsoft Corp.) to calculate the needed sample size. According to our sample size analysis, we needed to assess 18 videos of trauma resuscitations.

Statistical analysis

Reliability is defined as the extent to which measurements can be replicated. In other words, it reflects not only the degree of correlation, but also agreement between measurements. (24) To assess inter observer reliability, the intra-class correlation (ICC) and corresponding 95% confidence interval (CI) were calculated using SPSS (IBM Corp. Released 2012. IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY: IBM Corp.). Higher ICC values indicate a greater degree of agreement between raters. An ICC estimate

of 1 indicates perfect agreement and 0 indicates only random agreement. Negative ICC estimates indicate systematic disagreement. (25) In this study, we used cutoffs according to Cicchetti et al. (26) for qualitative ratings of agreement based on ICC values, with inter observer reliability being poor for ICC values less than 0.40, fair for values between 0.40 and 0.59, good for values between 0.60 and 0.74, and excellent for values between 0.75 and 1.0.

There are several ICC forms that could be used that are slightly different from each other. In brief, the different forms of ICC are based on the “Model”, “Type” and “Definition” of the relationship. The “Model” could be a one-way random effects, two-way random effects, or two-way fixed effects or a two-way mixed effects (1-way fixed and 1-way random). The “Type” could be a single rater or the mean of raters and the “Definition” of relationship could be an absolute agreement or consistency. (27) As in our study all included videos (random sample) were analyzed by all three involved research assistants (fixed assessors), a “two-way mixed effect” was used to calculate the ICC. We studied both the reliability in case the T-NOTECHS would be used by a single rater and three raters. Therefore, both “types” of ICCs were calculated. Finally, we calculated both the absolute agreement and consistency ICC (aICC and cICC). Absolute agreement concerns if different raters assign the same score to the same subject. Conversely, relative agreement concerns if different raters assign the same rank ordering of subjects.

Ethical consideration

The Medical Ethical Committee of the University Medical Center Utrecht has approved the study (reference number WAG/mb/18/022906). Thereby, as agreed with the hospital’s legal department, no informed consent from patient nor personnel needs to be obtained, as our institution makes use of video registration as part of local quality audits. Besides the non-technical skills, no other data of hospital personnel was gathered. Videos of resuscitation were stored on a secured server and all captured videos were analyzed and automatically deleted after 14 days. Thereby T-NOTECHS scores were anonymously stored, which means that a T-NOTECHS score is not traceable to a specific trauma team member or patient.

Results

Baseline and assessment scores

Eighteen videos of 18 consecutive trauma team resuscitations were included and assessed by three observers. No resuscitations were missed. The total mean score of the T-NOTECHS was 19 out of 25 graded by all three assessors (Table 1). The domain ‘situation awareness and coping with stress’ had the highest mean score (4.1/5) and the domain ‘leadership’ the lowest mean score (3.6/5) (Table 1). What stands out of Table 2 is that all patients were injured following blunt trauma.

Table 1: Mean T-NOTECHS scores

	Rater 1	Rater 2	Rater 3	Mean of raters
Leadership	3.5 (1.0)	3.8 (1.2)	3.3 (0.9)	3.5 (0.9)
Cooperation and resource management	3.8 (0.8)	3.7 (0.8)	3.7 (0.8)	3.7 (0.8)
Communication and interaction	3.6 (1.1)	3.7 (1.0)	3.6 (1.2)	3.6 (1.0)
Assessment and decision making	3.6 (0.9)	3.9 (0.8)	3.7 (0.9)	3.8 (0.8)
Situation awareness and coping with stress	4.4 (0.4)	4.2 (1.0)	4.2 (1.0)	4.1 (0.7)
Overall T-NOTECHS	19 (3.6)	19 (4.5)	19 (4.3)	19 (3.9)

Table 2: Baseline characteristics

ISS (median, P25–P75)	9.5 (2–14)
Multitrauma patients	33%
Male gender	39%
Median age (P25–P75)	47 (16–66)
Trauma mechanism	
Blunt	100%
Penetrating/other	0.0%
Multitrauma patients	33%
Severe TBU patients (GCS ≤ 8)	17%
Deaths	5.6%

Observed group (n=18); Baseline characteristics of resuscitated population (P25–P75: 25 and 75th percentile); ISS: Injury Severity Score; GCS: Glasgow Coma Scale)

Reliability

The difference for absolute ICC (aICC) and consistency ICC (cICC) for the T-NOTECHS overall score and each domain was small (maximal 0.01). The calculated reliability of the T-NOTECHS was different when the resuscitation was assessed by a single or three raters. When reliability was calculated for the mean of three assessors, the overall score and each domain were ‘excellent’, as the calculated ICC values were between 0.95 and

0.76. The highest reliability was found in the domain ‘Cooperation and resource management’ (aICC = 0.95, 95% CI 0.89–0.98) and the lowest reliability ability was found in the domain ‘Leadership’ (aICC = 0.76, 95% 0.49–0.90) (Table 3). When reliability was calculated for a single assessor, the reliability was less compared to mean of three assessors (Table3). Single assessor reliability was ‘good’ for scoring the domains ‘Communication and interaction’ (aICC = 0.73, 95% CI) and ‘Assessment and decision making’ (aICC = 0.59) The scoring domains ‘Leadership’ (aICC = 0.52) and ‘Situation awareness and coping with stress’ (aICC = 0.59) had a only a ‘fair’ single assessor reliability. The aICC was also lower for the over- all T-NOTECHS score and the domain ‘Cooperation and resource management’ compared to the reliability when reliability was calculated as a mean of three assessors; how- ever, the score was still ‘excellent’ (aICC = 0.86 resp. 0.84) (Table 3).

Table Reliability and performance scores of T-NOTECHS

	Absolute	Consistency	Score	Absolute	Consistency	Score
	ICC (95% CI)	ICC (95% CI)		ICC (95% CI)	ICC (95% CI)	
Leadership	0.76 (0.49–0.90)	0.77 (0.50–0.91)	Excellent	0.52 (0.25–0.76)	0.53 (0.25–.77)	Fair
Cooperation and resource management	0.95 (0.88–0.98)	0.95 (0.89–0.98)	Excellent	0.86 (0.72–0.94)	0.86 (0.73–.91)	Excellent
Communication and interaction	0.89 (0.76–0.96)	0.88 (0.75–0.95)	Excellent	0.73 (0.51–0.88)	0.72 (0.50–.87)	Good
Assessment and decision making	0.90 (0.76–0.96)	0.90 (0.77–0.96)	Excellent	0.73 (0.51–0.87)	0.74 (0.54–.89)	Good
Situation awareness and coping with stress	0.81 (0.58–0.92)	0.81 (0.57–0.92)	Excellent	0.59 (0.32–0.80)	0.58 (0.31–.80)	Fair
Overall T-NOTECHS	0.94 (0.87–0.98)	0.94 (0.87–0.98)	Excellent	0.84 (0.70–0.93)	0.84 (0.69–.93)	Excellent

Discussion

Our most important finding is that assessment of non- technical skills of the trauma team in real trauma resuscitation using the T-NOTECHS is reliable using video analysis. We found an excellent reliability for the overall T-NOTECHS score. Our second most important finding is that the T-NOTECHS is even more reliable when scores are demonstrated as the mean of three assessors, while all five individual domains instead of two of the T-NOTECHS achieved the highest reliability score. We hope that our research will be helpful in solving the difficulty of measuring non-technical skills during trauma resuscitation. The most important implication of the excellent reliability of the T-NOTECHS tool using video analysis is the possibility to assess the development of non-technical skills over time.

We found a much higher ICC for T-NOTECHS scores than reported by Steinemann et al. (18). We found an ICC of 0.94 and 0.84, respectively, when measured as the mean of three assessors or a single assessor using video analysis, while in their study an ICC

of 0.48 was found for assessment of actual resuscitations by live observers. A possible explanation could be that video analysis instead of live observation may have a positive influence on the reliability of the T-NOTECHS. This suggestion is further supported by results of T-NOTECHS reliability for simulated resuscitation in their study. They found higher T-NOTECHS values using video analysis compared to assessment by live observers (ICC 0.44 vs ICC 0.71). In their study, in contrast to this study, no video analysis was used for actual trauma resuscitations, because of hospital policies. Another explanation that our ICC was higher than the study of Steinmann et al. (18) could be a result of our training and experience in trauma resuscitation assessment of the assessors prior to the start of the study. Overall, other variants of the NOTECHS measuring teamwork during surgery have shown to be reliable. Nevertheless, the results of previous studies investigating the reliability of the NOTECHS are not comparable to our study in exact terms, while different study designs, populations and statistics were used. (18,28,29) In the study of Sevdalis et al., (20) the NOTECHS was used by a psychiatrist who observed and assessed non-technical skills among surgical teams in a simulated setting. In this study, the reliability was calculated using Cronbach's alpha (α) internal consistency coefficients, which provide the same values as a two-way consistency ICC of average measurements (in our study a two-way mixed ICC was used) and, therefore, not completely, but most comparable to our mean ICC results. (20, 30) The NOTECHS tool used in their study had also five domains, which are comparable to T-NOTECHS, but adjusted for surgical team performance. Like the T-NOTECHS, the NOTECHS in their study had a five-point Likert-scale for each five individual domain. The most reliable domain had a Cronbach's α of 0.87 and the least reliable domain had a score of 0.77. In the study of Mishra et al., (28) a single observer assessed non-technical skills of individual team members, sub teams and the team as a whole using the Oxford NOTECHS. The Oxford NOTECHS is comparable to T-NOTECHS in number and sort domains, but adjusted for surgical team assessment. Thereby, domains were scored on a four-point Likert-scale for each member and points were summed up for each sub team (4–16 points) and overall team score (12–48 points). Reliability was tested using inter-rater agreement (Rwg). The overall NOTECHS Rwg for the team was 0.99. and the lowest domain for the team had an overall score of Rwg 0.93. These high scores indicate that the tool is very reliable; however, using Rwg to assess reliability in their study design may have introduced analytical bias. Analyses by Rwg uses a null hypothesis of complete lack of agreement among raters, which is in their

study means that all of the 37 options for overall team score (all possible outcomes when individual scores are summed up) had an equal chance (i.e., 1/37 or 2,7%) of being scored by the assessor. Such a distribution is very unlikely, which was more or less confirmed by the statement in the article of Robertson et al. (29) presenting the successor of the Oxford NOTECHS, the Oxford NOTECHS II. The authors wrote that the successor intended to provide greater discrimination, as teams scored within a narrow middle range in the first Oxford NOTECHS version. The Oxford NOTECHS II had the same fundamentals compared to the Oxford NOTECHS, but the scale was altered. Reliability of the Oxford NOTECHS II was measured using ICC, without description of what kind of ICC model, type or definition was used and therefore no proper comparison to our results could be made. The ICC for the individual domains was between 0.68 and 0.88.

Although our sample size was intuitively small, our study design included a sample size calculation and our study was able to adequately indicate the reliability of T-NOTECHS for a single and multiple assessor by video analyses. Another strength of this study is that real trauma resuscitation was analyzed (instead of simulations). However, our study has also several limitations that should be considered. First, we were not able to properly assess intra-observer variability. Videos of trauma resuscitations are automatically deleted from the server after 30 days, because of local hospital's security and privacy policies. Assessing the same video within 2 weeks would have introduced recall bias. Second, in this study we assessed non-technical skills of the trauma team during resuscitations. The trauma team is activated for potentially severely injured patients, which is predefined by anatomical, physiological criteria or mechanism of trauma; however, the mean ISS of resuscitated patients in this study was relatively low. (9) Therefore, our results may be less representative for resuscitations of more severely injured patients. Third, we used a two-way mixed-effects, as only three research assistants were used to assess non-technical skills. We have chosen to assess non-technical skills by adequately trained personnel with the intention to improve the validity and reliability of our measurements. The downside of choosing a limited number of trained personnel is, in exact terms, that we tested the reliability of non-technical skills assessment of our trained research assistants. Therefore, caution should be exercised when generalizing our results, while our results might overestimate the reliability of T-NOTECHS. Finally, our assessors were trained medical students, which intuitively might be inferior to assessment by experienced clinical

experts. However, these students had already had training and gained experience in the assessment of trauma resuscitation and had extensive training in the assessment of non-technical skills. To our knowledge, for trauma resuscitations specifically, no study has investigated the effect of raters' education on the reliability of non-technical skills assessment of trauma teams. Nevertheless, a considerable amount of literature has been published on the use of objective structured clinical examinations (OSCEs), which have become widely used in medical education. (31) Medical schools have invested significant resources in designing and implementing OSCE in assessment programs, with the rigor of the process highly dependent on whether OSCEs provide reliable and valid indicators of student competence (32) Research suggests that untrained raters may be less consistent than trained raters. (33,34) In addition, raters with more clinical experience are not naturally better assessors of non-technical skills. A recently published study of Pradarelli et al. (35) showed that clinical experience of raters, in their study surgeons, had no effect on reliability of non-technical skill assessment of other surgeons. Furthermore, from a practical viewpoint, routine assessment of resuscitation is very time consuming and, in our opinion, not feasible to be performed in the precious time of experienced clinicians. Overall, assessment by other personnel than experienced clinicians is more likely to be incorporated in daily practice. Therefore, we believe that the reliability we found is appropriate for the purpose of T-NOTECHS. As evidence supporting the importance of non-technical skill for trauma team resuscitation is growing rapidly (6–17), training of non-technical skills becomes more important. For instance, closed loop communication has shown to reduce overall resuscitation time (36). Furthermore, enhanced leadership is positively associated with improvement of processes during resuscitation. (37) The T-NOTECHS might be a useful, and to our knowledge, best available tool to assess non-technical skills of the trauma team. For daily practice, one rater to assess non-technical skills using the T-NOTECHS seems legitimate as part of quality assessment, while the overall score is a reliable value. For research or quality improvement, it might be interesting to secondarily assess non-technical skills with three raters. For example, when (relatively) low overall T-NOTECHS scores are correlated to a certain factor (e.g., trauma mechanism, severity of injury, experience of trauma team), an analysis with three raters would be useful.

Conclusion

Assessment of non-technical skills using the T-NOTECHS is reliable using video analysis

and has an excellent reliability for the overall T-NOTECHS score. Assessment by three raters (score as a mean) further improves the reliability, resulting in an excellent reliability for all individual domains.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest. **Open Access** This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons license and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons license, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons license and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this license, visit <http://creativecommons.org/licenses/by/4.0/>.

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Part

3

Chapter

5

Variation of in-Hospital trauma team staffing: new resuscitation, new team

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Abstract

Background

Non-technical errors, such as insufficient communication or leadership, are a major cause of medical failures during trauma resuscitation. Research on staffing variation among trauma teams on teamwork is still in their infancy. In this study, the extent of variation in trauma team staffing was assessed. Our hypothesis was that there would be a high variation in trauma team staffing.

Methods

Trauma team composition of consecutive resuscitations of injured patients were evaluated using videos. All trauma team members that were part of a trauma team during a trauma resuscitation were identified and classified during a one-week period. Other outcomes were number of unique team members, number of new team members following the previous resuscitation and new team members following the previous resuscitation in the same shift (Day, Evening, Night).

Results

All thirty-two analyzed resuscitations had a unique trauma team composition and 101 unique members were involved. A mean of 5.71 (SD 2.57) new members in teams of consecutive trauma resuscitations was found, which was two-third of the trauma team. Mean team members present during trauma resuscitation was 8.38 (SD 1.43). Most variation in staffing was among nurses (32 unique members), radiology technicians (22 unique members) and anesthesiologists (19 unique members). The least variation was among trauma surgeons (3 unique members) and ER physicians (3 unique members).

Conclusion

We found an extremely high variation in trauma team staffing during thirty-two consecutive resuscitations at our level one trauma center which is incorporated in an academic teaching hospital. Further research is required to explore and prevent potential negative effects of staffing variation in trauma teams on teamwork, processes and patient related outcomes.

Keywords

Resuscitation, Trauma team, Composition, Staffing, Variation.

Background

The implementation of trauma systems, in conjunction with a systematic approach to trauma resuscitation, has considerably improved the outcome of critically injured patients.

(1) One of the pillars of these advances is a coordinated early resuscitation, for which the establishment of in-hospital trauma teams is critical. (2–4) A trauma team's goal is to diagnose life-threatening injuries and provide immediate resuscitation and stabilization.

Previous studies already found that beside technical failures, non-technical errors, such as insufficient communication or leadership, may hinder these goals and could lead to severe adverse effects, including increased mortality rates. (5–9) Therefore, acquiring non-technical skills is of utmost importance for effective teamwork between physicians, nurses and ancillary personnel in order to accomplish a coordinated resuscitation. Establishing a shared mental model of the patient's circumstance allows team members from various backgrounds to comprehend both the clinical and logistical implications of individual trauma patients. (10,11) In short, a shared mental model could be defined as representation of team members' shared knowledge about the team and its environment, such as the team's goals, processes, communication, available information and adaptations to situations and members' roles, behaviors and interactions. (12) The establishment of a shared model is especially important, but also more difficult to achieve, when physicians and nurses from various disciplines converge to resuscitate a critical injured patient under time pressure.

However, little is known about the nature, extent and impact of staffing variation within trauma teams. Intuitively, the more resuscitations performed with the same team members, the more familiar the team members get with each other's roles, behaviors, and interactions, which facilitates the establishment of a shared mental model. However, based on our own clinical experience, human resources vary considerably and change frequently. Therefore, during resuscitations members of the trauma team sometimes may not even know each other by name. In this study, we aimed to assess the extent of trauma team staffing variability in daily and day-to-day trauma teams. Our hypothesis was that there would be a high variation in trauma team staffing.

Methods

Design, Sample and Outcomes

This study was a retrospective observational study of prospectively gathered videos of actual trauma resuscitations. During the a one-week period in May 2018, all successive resuscitations of injured patients were retrospectively examined on trauma team composition utilizing video records. Two experts with significant experience in evaluating video records of trauma resuscitation evaluated all available video recordings. The main outcome of this study was number of unique compositions of trauma teams in terms of personal staffing. Other outcomes were number of unique team members, number of new team members compared to the previous resuscitation and new team members compared to the previous resuscitation in a comparable shift (Day, Evening, Night).

Setting

Trauma center

This study was performed at the University Medical Center Utrecht (UMC Utrecht), an academic teaching hospital and a level one trauma center in the Netherlands. The coordinating emergency department nurse activated the trauma team if one of the preset criteria for admitted trauma patients was met. These criteria are based on the trauma mechanism or certain patient's psychological or anatomical conditions as reported by ambulance staff prior to the patients' admittance. These criteria can be found in Table 1.

Trauma team composition and activation

The trauma team in the UMC Utrecht has generally the following composition: a trauma surgeon or fellow, a surgical resident, an anesthesiologist's resident, an emergency physician, a neurologist, two emergency department nurses, and a radiology technician. The article of Kreb et al. (13) provide a more thorough explanation of trauma team composition and task assignment. The trauma surgical resident is the team leader, while the trauma surgeon or resident is directly available, supervise the surgical resident and is ultimately responsible. The emergency physician performs documentation of the resuscitation, contacts the radiologist when a CT scan is required. At the UMC Utrecht, we have a one-tier trauma team activation strategy, which means that the trauma team composition is theoretically the same for each trauma resuscitation. Only the trauma surgeon could decide to consult additional medical doctors or extend the team with an

additional nurse. The trauma team is activated in case one of the predefined activation criteria is met. At the time of the study, ten staff trauma surgeons, three trauma surgeons fellows, eleven surgical residents, five ED physicians, roughly 45 nurses could potentially be part of the formation of a trauma team. Yearly there are roughly 1200 trauma admission of which nearly 400 are severely injured.

Schedule system

During working days (Monday-Friday) there is a 3-shift system (day, evening, night), for residents and nurses and a 2-shift system for trauma surgeons or fellows. During the weekend there is also a 2-shift system for residents.

Table 1: Trauma team activation criteria in the University Medical Centre Utrecht

Mechanism	Motor vehicle accident	<ul style="list-style-type: none"> •Speed over 80 km h⁻¹ •Ejection/roll over/trapped •Unrestrained/fatality
	Motor bicycle	<ul style="list-style-type: none"> •Any with speed >30 km h⁻¹
	Pedestrian/cyclist	<ul style="list-style-type: none"> •Struck by car or motorcycle/any speed
	Fall	<ul style="list-style-type: none"> •Adult >3 m and/or 5 stairs •Elderly on anti-coagulant therapy •Motor bikes/cycle/water ski
	Horse	<ul style="list-style-type: none"> •Any horse-related injury
	Assaults	<ul style="list-style-type: none"> •Shooting •Stabbing •Focal blunt head trauma with GCS <13
	Multiple casualties	<ul style="list-style-type: none"> •With significant injuries
	Other	<ul style="list-style-type: none"> •Explosion •Hanging •Submersion
	Injuries	<ul style="list-style-type: none"> •Potential airway obstruction/respiratory distress •Penetrating injury to the head/neck/chest/abdomen/pelvis/back/limbs •Paralysis (spinal cord injury) •Burns >10% BSA
	Signs	<ul style="list-style-type: none"> •Respiratory rate <10 or >30 •Heart rate <40 or >120 •Arterial pressure <90 systolic at any stage •Capillary return >2 s •GCS <14
	Treatment	<ul style="list-style-type: none"> •Multi-trauma transferred from other hospital within 24 h of injury •Intubation or assisted ventilation •>2 litre of fluid resuscitation

Data collection

First, among all included videos, unique trauma team members were identified and categorized in one of the following groups: trauma surgeon or fellow, surgical resident,

emergency physician, anesthesiologist, neurologist, emergency nurse, radiology technician or other. Each video was analyzed to identify attending team members per resuscitation. Resuscitations were categorized in shifts (Day 8.00-16.00; Evening 16.00 -24.00 and Night 24.00-8.00). Data was collected using a score sheet in Microsoft Excel (Microsoft Corp. Released 2010. Microsoft Office Excel 2010, Version 14.0. Redmond, WA: Microsoft Corp.). Finally, resuscitated patient's baseline characteristics were gathered (age, ISS,).

Statistical analysis

For this study and SPSS (IBM Corp. Released 2012. IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY: IBM Corp) and Microsoft Excel (Microsoft Corp. Released 2010. Microsoft Office Excel 2010, Version 14.0. Redmond, WA: Microsoft Corp) were used for descriptive analysis. Data was considered nonparametric in case Shapiro-Wilk test's p-values were 0.05 or lower. Baseline characteristics were reported as means and standard deviations (SDs), whilst non-normally distributed data were provided as medians with interquartile ranges (IQRs). Percent deviation (PD) was computed for results reported in percentages.

Privacy and Ethics

This study was authorized by the institutional research board. In accordance with the legal department of our hospital, no inform consent of patients nor personnel was needed, as the records of videos are part of our quality assessment program. Video recordings were stored on a secure server inside the hospital building. Video records were automatically removed from the server after fourteen days and data was anonymized within fourteen days.

Results

Baseline characteristics

In total, 32 videos of trauma resuscitations were included and analyzed. All provided data were normally distributed (Shapiro-Wilk test $p > 0.05$), except for the ISS. (Shapiro-Wilk test $p = 0.04$). The median ISS was twelve (IQR 5-21). (Table 2)

Table 2: Baseline characteristics

Age, mean	50 (SD 18)
Gender, percentage male	72
ISS, median	12 (IQR 5-21)

Team staffing variation

All 32 resuscitations had a unique trauma team composition (100%) and a total of 101 unique trauma members were identified (Table 3). Mean number of team members

present during trauma resuscitation was 8.38 (SD 1.43). Most variation in staffing was among nurses (32 unique team members), radiology technicians (22 unique team members) and anesthesiologists (19 unique team members). The least variation was among trauma surgeons (3 unique team members), ER (emergency room) physicians (3 unique team members) and trauma fellows (2 unique team members). The mean number of new members in teams of consecutive trauma resuscitations was 5.71 (SD 2.57), which was 67.4% (Percent Deviation (PD) 45.0) of the average total team size. (Table 3). Percentage of consecutive resuscitations' new team members were 64.9% (PD 51.0), 65.5% (PD 38.46), 71.4 % (PD N/A) for day, evening and night shift respectively.

Table 3: Team composition

Category	Unique members (SD)	Resuscitations present (%)
Total trauma resuscitations	32	N/A
Unique trauma teams	32	N/A
Team members core team		
Trauma surgeon	3	17 (53.1%)
Trauma Fellow	2	11 (29.1%)
Surgical resident	7	32 (100%)
Emergency Physician	3	13 (40.6%)
Anesthesiologist	19	32 (100%)
Radiology technician	22	32 (100%)
Nurse	32	32 (100%)
Neurologist	11	29 (90.6%)
Additional team members		
Radiologist	2	2 (6.3%)
Overall		
Total unique trauma team members	101	
Average number of members per resuscitation	8.375 (1.43)	

Table 4: Team variation

	Trauma resuscitations (n)	Mean new team members compared to previous resuscitation	
		N (Standard Deviation)	% (Percent Deviation)
Total	32	5.7 (SD 2.6)	67.4 (PD 45.0)
Day shift (08:00-16:00)	15	6.0 (SD 3.1)	64.9 (PD 51.0)
Evening shift (16:00-24:00)	15	5.3 (SD 2.1)	65.5 (PD 38.5)
Night shift (00:00-08:00)	2	5.0 (SD N/A)	71.43 (PD N/A)

Discussion

This is the first study to describe the extent of staffing variety of trauma teams. We found a very high variation in trauma team staffing at our level one trauma center, which is incorporated in an academic teaching hospital. All 32 trauma teams demonstrated an

unique composition and 101 unique members were identified of a trauma team. Thereby, we found that on average, two-thirds of the trauma team staffing rotated during the successive resuscitation. Within most academic hospitals, education of (para) medic personnel is common and rotation of residents, fellows and nurses is routine and occurs frequently. As many level one trauma centers are incorporated within academic teaching hospitals variation in trauma teams is likely to be common within trauma resuscitation in the emergency department. In the United States, approximately 75 percent of all level one trauma centers are incorporated in academic teaching hospitals.(14)

Some recent studies found positive effects of familiarity of team members on teamwork, processes or patient care, which supports the reasoning that less variation in trauma team staffing may improve trauma care. First of all, Joshi et al. (15) investigated familiarity of team members on teamwork and clinical effectiveness during three simulated trauma scenarios. Teams whose staffing remained constant across the scenarios (stable teams) were compared to team whose staffing fluctuated with each scenario(dynamic teams). 46 trainees (23 General Surgery; 23 Emergency Medicine) were allocated into stable- or dynamic teams. The teamwork in both groups enhanced significantly, but the teamwork was more enhanced in the stable teams (stable: 9%, $p < 0.04$; dynamic = 4.9%, $p < 0.03$). Thereby, significant increased improvements in clinical effectiveness was only seen in the stable team. (stable: 15.2%; $p = 0.03$; dynamic 8.7% $p = 0.19$). A study of Powezka et al.(16) performed a retrospective analysis of 326 vascular procedures. They introduced the Familiarity Score, which yields the total of numbers of times each team member (vascular consultant, vascular registrar, scrub nurse, anesthetic consultant) had worked together, in the previous six months, divided by the number of possible combinations of pairs in the team. They found that the Familiarity Score was significantly associated with the length of the procedure (Bayes Factor= 37).

Moreover, Krumann et al, (17) performed a retrospectively analysis on the effect of familiarity among team members on complication rates after elective open abdominal surgery. During a 6- month period a senior and junior surgeon performed all surgical interventions. The first and last month of this period where compared. A significant higher percentage of complications were found during the first period compared to the last period (54.2% vs. 34.5 %; $P = 0.04$), demonstrating familiarity may improve

team performance and patient safety. Finally, Obermair and colleagues (18) evaluated impact of team familiarity in elective gynecological surgery on complications among 6,707 medical records. After surgery, the lead surgeon scored familiarity of the team using a five-point Likert scale which was documented at the operation report. In their analyses, after adjustment for ASA score and BMI, the likelihood of an adverse event was doubled in non-familiar teams compared to familiar teams (OR 2.06, 95%CI 1.20 to 3.55 $p < 0.01$). Moreover, in contrast to predictable circumstances during elective surgery or simulated environments, the circumstances during the resuscitations of severely injured patients are more stressful and less predictable, requiring highly adaptive teams. Therefore, extrapolating the findings of the discussed recent studies to actual trauma resuscitations, familiarity may enhance teamwork and team performance even more.

Although this study did not investigate the direct effects of familiarity within trauma teams on patient's outcome, our findings emphasize the importance of non-technical abilities among team members and clear role assignments of the team members. Nontechnical skills such as communication, leadership, and teamwork are examples of nontechnical skills that are increasingly being recognized as key components of emergency resource management. (19) Thereby, a clear task delineation is required as it is hard to collaborating together without fully understanding each other necessitates. Trauma team simulation training has been proven to increase nontechnical skill development. (20) Furthermore, during simulation training, understanding of role assignment within trauma teams might be a trainable aspect. Therefore, regular trauma team training might reduce the negative effects of unfamiliarity of team members.

Further research

More research is required to gain insights into the nature and extend of trauma team staffing variations and the impact on patient care and patient outcomes. First of all, to obtain a general overview and to increase generalizability of our study results, our study should be replicated in multiple trauma centers. Second, there is evidence of previous studies that teamwork leads to improved performance. (21) Therefore, we suggest investigating the impact of high variance in team staffing on teamwork. Future research projects, should an may further improve our understanding of the impact of the trauma team variation including clinical outcomes The overall theory is that considerable

variance in trauma team staffing leads to impaired teamwork, which in turn is thought to lead to deteriorated performance. In simplest form, the impact of team variance on teamwork could be assessed during simulation sessions to compare teams with no or little variance to high variance. There are reliable and validated tools available to assess the teamwork, such as the T-NOTECHS tool. (22-24) Third, interventions to effectively reduce team variation could be developed, tested and implemented into practice. We suggest two types of interventions to be investigated. First interventions that reduce team staffing variance and second, interventions that reduce negative effects of team staffing variance. An example how team variance could be reduced is by advanced scheduling systems. Coordination of having the similar staff occupation within teams is extremely challenging, as multiple (para)medical specialties are involved in the trauma team. A possible approach could be scheduling using advanced methods, such as deep learning techniques, as described by Rosemarin. (25) Their supposed deep-learning scheduling system was able to schedule based on hospital's data and specific goals, which among other goals, could be the reduction of trauma team staffing variance.

Strengths and limitations

The strength of this study was the use of video recordings of trauma resuscitations to analyze trauma team composition, which provides an unbiased, indisputable and accurate documentation of the trauma resuscitation. However, our study also has limitations that should be considered. This was a single-site study in a level one trauma center in an academic institution. The practices and policies at our institution may differ from other academic medical centers and even more from smaller non-academic hospitals. As such, the generalizability of our findings may be limited. Furthermore, we analyzed 32 trauma team activations, within a relative short time. Thereby, most of the trauma resuscitations were during day and evening time, and very few during the night. Therefore, our study populations was too small to perform additional analysis. Therefore, our results should be considered as a rough estimation of the extent of staffing variation of trauma teams at our hospital. Nevertheless, we believe that our key finding, that there is a high variance team staffing, will not change with an larger study population. Thereby,theoretically, there shall even be more variations over longer periods, because of rotations of residents, vacations and new personnel during the year.

Conclusion

We found an extremely high variation in trauma team staffing at our level one trauma center which is incorporated in an academic teaching hospital. Further research is required to explore the nature and impact of high variation in trauma team staffing on teamwork, processes and patient related outcomes.

Abbreviations

ASA Score - American Society of Anesthesiologists Score

BMI – Body Mass Index

ER physicians – Emergency Room physicians

IQR – Inter Quartile Range

GCS – Glasgow Coma Scale

PD – Percent Deviation

SD – Standard deviation

T-NOTECHS – Trauma Non-Technical Skills

UMC Utrecht - University Medical Center Utrecht

Declarations

Ethics approval and consent to participate

This study was authorized by the institutional research board. In accordance with the legal department of our hospital, no inform consent of patients nor personnel was needed, as the records of videos are part of our quality assessment program. Video recordings were stored on a secure server inside the hospital building. Video records were automatically removed from the server after fourteen days and data was anonymized within fourteen days.

Consent for publication

Not applicable

Availability of data and materials

The datasets generated and/or analyzed during the current study are not publicly available due to privacy regulations, but are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests

Funding

Not applicable

Authors' contributions

O.M. and R.H. designed and performed the experiments in consultation with L.L. and W.B.. O.M. analyzed the data. O.M. wrote the manuscript in consultation with L.L. and W.B.

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Chapter

6

The Effect of an On-Site Trauma Surgeon During Resuscitations of Severely Injured Patients

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Submitted

Abstract

Background

Although the timely involvement of trauma surgeons is widely accepted as standard care in a trauma center, there is an ongoing debate regarding the value of an on-site attending trauma surgeon compared to an on-call trauma surgeon. The aim of this study was to evaluate the effect of introducing an on-site trauma surgeons and the effect of their presence on the adherence to Advanced Trauma Life Support (ATLS) related tasks and resuscitation pace in the trauma bay.

Methods

The resuscitations of severely injured (ISS >15) trauma patients one month before and one month after the introduction of an on-site trauma surgeon were assessed using video analysis. The primary outcome was total resuscitation time. Second, time from trauma bay admission until tasks were performed, and ATLS adherence were assessed.

Results

58 videos of resuscitations have been analyzed. After the introduction of an on-site trauma surgeon, the mean total resuscitation time was 259 seconds shorter ($p=0.03$) and seven ATLS related tasks (breathing assessment, first and second IV access, EKG monitoring and abdominal, pelvic, and long bone examination; were performed significantly earlier during trauma resuscitation ($p \leq 0.05$). Further, we found a significant enhancement to the adherence of six ATLS related tasks (Airway assessment, application of a rigid collar, IV access; EKG monitoring, log roll, and pronouncing results of arterial blood gas analysis; $p\text{-value} \leq 0.05$).

Conclusion

Having a trauma surgeon on-site during trauma resuscitations of severely injured patients resulted in improved processes in the trauma bay. This demonstrates the need of direct involvement of trauma surgeons in institutions treating severely injured patients.

Keywords

Resuscitation, Trauma team, Composition, Leadership, Experience

Background

High quality trauma care delivery necessitates a strategy that combines a systematic approach, with clinical judgment and effective coordination. The introduction of trauma systems, including a well-structured resuscitation, has significantly improved the outcome of patients who have suffered severe injuries. (1) One of the pillars of a coordinated early resuscitation strategy has been the formation of in-hospital trauma teams. (2–4) A trauma team consists of multiple (para)medical members of various disciplines and the aim of the trauma team is to identify life-threatening injuries and administer prompt resuscitations and stabilization.

The trauma team leader is responsible for well-coordinated resuscitation and decision making during the resuscitation. (5–7) The value of a trauma surgeon during the resuscitation of severely injured patients has been well established and the timely involvement of trauma surgeons is recommended in the American College of Surgeons' trauma guidelines. (8) However, the concept of 'timely' is ambiguous, and as such, there is an ongoing debate regarding the value an in on-site trauma surgeon during trauma resuscitations. Several studies have found that the introduction on-site attending trauma surgeons, compared to on-call trauma surgeons, enhance efficiency of the trauma resuscitation, such as faster decisions, fewer errors, shorter time to disposition, and shorter hospital stays. (9–12) This demonstrates that the early involvement of experienced trauma team leaders will enhance the quality of initial trauma care.

However, studies that use video analysis to evaluate processes in the trauma bay after the introduction of an in-hospital attending trauma surgeons are lacking. Previous mentioned studies evaluated process efficiency by retrospectively analyzing available data, such as data on emergency department or in-hospital lead times. This study aims to evaluate the direct effect of the introduction of a physical attendance of a trauma surgeon (on-site) during the initial trauma resuscitation of severely injured patients on process efficiency (resuscitation time) and quality in the trauma bay.

Method

Design, sample and outcomes

This study utilized a 'before and after' study design using video analysis to evaluate the effects of introducing an attending trauma surgeon. All videos of severely injured patients resuscitated by a trauma team between the period of June 1st, 2013 and July 31st, 2013 were assessed. Severely injured patients were defined as having trauma injuries that resulted in an Injury Severity Score (ISS) of >15 . The primary outcome was (A) total resuscitation time which was defined as time from the patient's arrival in the trauma bay until patient left the resuscitation bay. Secondary outcomes were (B) the time to perform tasks related to the Advanced Trauma Life Support (ATLS) guidelines – which was defined as the time between patient arrival and the completion of ATLS task assessment – as well as (C) the adherence which was defined as the completion of the 26 tasks as prescribed in the ATLS guidelines. Resuscitations were assessed on twenty-six tasks predefined ATLS related tasks. (table 1). The Dutch National Trauma Database (DNTD) regional data was used to describe patient demographics (age, gender) and explanatory variables (ISS, trauma mechanism).

Location

The University Medical Center of Utrecht is a 1000-bed tertiary care center accredited by the Joint Commission International (JCI). Our hospital meets all the American College of Surgeons' Committee on Trauma's (ACS-COT) requirements for a level-1 trauma center, with the exception of an onsite CT scan, which is located outside the emergency department instead of in the resuscitation bay.

Intervention

On 1 July 2013, attending trauma surgeons transitioned from an out-of-hospital (OH) on-call schedule to an in-house (IH) schedule. Prior to this transition, trauma surgeons were available for on-call consultation and a senior resident in general surgery served as house officer. After the transition, there was a continuous presence of a trauma surgeon and a resident in general surgery (varying from junior to senior). As a result, instead of only a surgical resident prior to the transition, both a trauma surgeon and a surgical resident were present from the start of every trauma resuscitation after the transition, irrespective of the (expected) injury severity of the trauma patient. There were no other

differences in trauma team composition and detailed description of the trauma team composition could be found in the article of Kreb et al.(13)

Statistics

The continuous data with a normal distribution are expressed as means and SDs (total resuscitation time), whereas the non-normally distributed data are presented as medians with IQRs (ISS, Age, time from admission to ATLS related task performed). Student t-tests were used to compare parametric continuous data from before and after the transition and Mann-Whitney U tests were used for non-parametric continuous data. The χ^2 test and Fisher's exact test were used to compare categorical variables (patient characteristics: sex, type of trauma; ATLS adherence). All statistical analyses were performed using SPSS (IBM Corp. Released 2011. IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY: IBM Corp.) A p-value of less than 0.05 was deemed statistically significant.

Results
Population

During the period of the study, fifty-eight videos of resuscitations of severely injured patients were captured and analyzed, and of the fifty-eight videos, twenty-six resuscitations were captured before the transition and thirty resuscitations after the transition. The demographics and baseline clinical characteristics before and after the transition was comparable, except for the median ISS (before transition 25 [IQR 20-34] vs after transition 20 [IQR 17-25] ($p = 0.01$) (Table 1).

Table 1: Baseline characteristics and total resuscitation time

	Before transition (n=28)	After transition (n=30)	p-value
Gender; male (%)	17 (61)	15 (50%)	0.290
ISS median (IQR)	25 (20-34)	20 (17-25)	0.01*
Age median (IQR)	47 (24-52)	48 (25-67)	0.98
Trauma mechanism; blunt (%)	28 (100)	30 (100%)	N.A.
Total resuscitation time; seconds (SD)	1404 (264)	1145 (357)	0.03*

Time management

The total resuscitation time was significantly shorter after the transition with a time of 1404 seconds [SD 264] vs 1145 seconds [SD 357], $p=0.03$ (Table 1). The median time of seven of the twenty-six ATLS related tasks were significantly lower after the transition

(Breathing assessment 285 seconds [IQR 225-365] vs 192 seconds [171-245], $p<0.01$; First IV access 566 seconds [546-870] vs 296 seconds [247-348], $p=0.02$; Second IV access 820 seconds [485-994] vs 404 seconds [338-480], $p<0.01$; EKG monitoring 232 seconds [212-324] vs 200 seconds [180-218], $p=0.02$; Pelvic examination 310 seconds [259-393] vs 213 seconds [194-358], $p<0.01$; Abdominal examination 307 seconds [242-387] vs 212 seconds [191-368], $p=0.01$ and Long Bone examination 321 seconds [251-403] vs 221 seconds [207-379], $p=0.01$). None of the ATLS related tasks were performed faster before the transition. (Table 2)

Table 2: ATLS adherence and time management

	ATLS adherence			Time management		
	Adherence (percentage)			Time in seconds (IQR)		
	Before transition	After transition	p-value	Before transition	After transition	p-value
Handover information	28/28 (100%)	30/30 (100%)	-	122 (109-168)	122 (108-142)	0.55
Airway Assessment	19/28 (68%)	25/30 (83%)	0.03*	186 (123-255)	172 (149-200)	0.97
Breathing assessment	28/28 (100%)	30/30 (100%)	-	285 (225-362)	192 (171-245)	<0.01*
Oxygen administration	23/28 (82%)	27/30 (90%)	0.47	220 (113-266)*	193(143-606)*	1.00
Pulse oximeter	28/28 (100%)	30/30 (100%)	-	227 (152-289)	174 (150-251)	0.07
IV access 1	28/28 (100%)	30/30 (100%)	-	566 (546-870)*	296 (247-348)	0.02*
IV access 2	13/28 (68%)	23/30 (77%)	0.03*	820 (485-994)	404 (338-480)	<0.01*
Withdrawal of blood samples	28/28 (100%)	30/30 (100%)	-	484 (411-599)	507 (380-562)	0.62
pronouncing results of arterial blood gas analysis	15/28 (54%)	24/30 (80%)	<0.01*	793 (732-1025)	867 (756-984)	0.62
EKG monitor	16/28 (57%)	25/30 (83%)	0.04*	232 (212-324)	200 (180 -218)	0.02*
Order of blood products	3/28 (11%)	0/30 (0%)	0.11	361 (81-511)*	-	NA
arrival of blood products	0/28 (0%)	0/30 (0%)	-	-	-	NA
Blood pressure and heart rate	28/28 (100%)	30/30 (100%)	-	279 (204-339)	217 (184-298)	0.13
Pelvic examination	28/28 (100%)	30/30 (100%)	-	310 (259-393)	213 (194-358)	<0.01*
Abdominal examination	22/28 (79%)	27/30 (90%)	0.29	307 (242-387)	212 (191 -368)	0.01*
Long bone examination	24/28 (86%)	26/30 (87%)	1.0	321 (251-403)	221 (207-379)	0.01*
Pupil examination	18/28 (62%)	26/30 (87%)	0.07	317 (265-420)	338 (278-450)	0.58
Neurological examination	12/28 (43%)	20/30 (67%)	0.11	537 (496-658)	422 (364-627)	0.28
Log Roll	3/28 (11%)	12/30 (40%)	0.02*	697 (572-721)	460 (369 -598)	0.09
rectal examination	2/28 (7%)	6/28 (21%)	0.26	785 (408 -948)*	461 (389 - 711)	0.18
Temperature measurement	0/28 (0%)	1/30 (3%)	1.0	-	1851**	NA
Warm Blankets	27/28 (96%)	30/30 (100%)	0.48	286 (201-332)	253-213-295)	0.62
Intubation	12/28 (43%)	9/30 (30%)	0.41	528 (413-765)*	434 (382-538)	0.08
Spine Control	22/28 (79%)	29/30 (97%)	0.05*	-	178 (128 -252)*	NA
Chest Tube	3/28 (11%)	3/30 (10%)	1.0	1377 (639 -1800)	859 (764 -1472)*	0.827
Urinary catheter	14/28 (50%)	22/30 (73%)	0.10	894 (737-1201)	980 (664-1345)	0.893

ATLS Adherence

Six of the twenty-six ATLS related tasks regarding the primary survey were performed significantly more often after the transition when compared to before the transition (second IV access 68% vs 77%, $p=0.03$; EKG monitoring 57% vs 83%, $p=0.04$, pronouncing results of arterial blood gas analysis 54% vs 80%, $p<0.01$; Log Roll 11% vs 40%, $p=0.02$,

Airway assessment 68% vs 83%, $p=0.02$) and spine control 79% vs 97%, $p=0.05$). None of the assessment tasks or interventions were performed more frequently after the transition (Table 2).

Discussion

We found a significant acceleration of the resuscitation process in the trauma bay for severely injured patients directly after the introduction of trauma surgeons physically attending the trauma resuscitations. Total resuscitation time was significantly shorter and seven ATLS related tasks (breathing assessment, first and second IV access, EKG monitoring and abdominal, pelvic and long bone examination) were performed significantly earlier during trauma resuscitation. Furthermore, we found a significant enhancement of ATLS adherence of six tasks (airway assessment, application of a rigid collar, IV access; EKG monitoring, log roll and pronouncing results of arterial blood gas analysis).

These findings are consistent with those of a prior study in which we assessed the impact of introducing a 24-hour in-house attending trauma surgeon. In-hospital lead times of severely injured patients ($ISS > 24$) of patients before ($n=214$) and after ($n=392$) were compared and there was a significant decrease in the length of stay in the emergency department. (median 2.7 h (IQR 1.6-4.0) vs 2.1 h (1.5-3.7) $p<0.01$) There was also a significant decrease in time from the ED (Emergency Department) to the intensive care unit (ICU) for patients directly transferred to the ICU (median time of 1.4 h (IQR 1.1–2.5) vs 1.2 h (IQR 1.0–1.6) ($p<0.01$) and almost doubling of the percentage of patients who reached the operation room within 30 minutes (4.8 % vs 8.0%) .(14) Moreover, a recent systematic of de la Mar et al., (15) revealed that ten out of sixteen included studies found at least one process related outcome to be improved after the implementing an in-house trauma surgeon attendance strategy. Furthermore, 7490 severely injured patients were included in a meta-analysis from eight different studies and severely injured patients treated by on-site surgeons had a significantly lower mortality rate when compared to trauma surgeons on call (risk ratio 0.86, 95% confidence interval 0.78 to 0.95; $P<0.01$).

The improved time management and ATLS adherence are most likely a direct result of the addition of experience. It is debatable what effect a four-minute reduction in resuscitation time (as roughly found in our study) would have on clinical outcomes of the

patient. The impact of such a time reduction will largely depend on the population being studied. Till date there is still limited objective data to support time targets from injury to definitive care and four minute reduction won't significantly improve the outcome for those who don't have acute life-threatening injuries. However, there is almost no doubt that earlier interventions save lives in a subset of severely injured casualties. Among these injuries, acute hemorrhage remains the leading cause of preventable deaths. (16) Aside from reasoning the shorter resuscitation time as a result of an on-site trauma surgeon, the shorter resuscitation time and improved adherence to ATLS guidelines reflect improved management of severely injured patients. Management of severely injured patients entails more than just time management and protocol adherence. We believe that an attending (experienced) surgeon can adapt to the complex nature of resuscitation of severely injured patients better than surgical residents. Moreover, in the context of resuscitation of severely injured trauma patients, non-technical abilities such as leadership, decision-making, and situation awareness have been described as critical (7,17), and given that non-technical abilities often increase with practice, it is reasonable to think that the presence of an attending surgeon during the trauma resuscitation of severely injured patients is required for optimal trauma care. This reasoning is also supported by research of other institutes such as Cole et al. (18) who found that diagnostic imaging and hemorrhage control were significantly more likely achieved during resuscitation led by a trauma surgeon compared to a resident. Moreover, even additional experience for trauma surgeons during their career may improve resuscitation outcomes. In the study of McKenney et al. (19) a correlation between time as faculty surgeon at a level one trauma center and mortality in the most severely injured patients (ISS>35) was found. In addition, Hong et al. (20), found that patients suffering severe neurotrauma (GCS ≤8) had a higher chance to survive when resuscitated by an experienced trauma team leader when compared to a less experienced trauma team leader (odds ratio (OR): 14.5, 95% CI 1.7–125.5, p=0.015).

Strengths and limitations

The risk for information bias was minimized by the fact that solely one trained person assessed video recordings. This risk was further minimized by the actual use of video recordings itself as video analysis of trauma resuscitations are a reliable and valid method to assess processes during trauma resuscitation. However, this study has also several lim-

itations that should be considered. First, the Injury Severity Score (ISS) was higher before the transition. In another recent study performed at our institution, we found a negative correlation between resuscitation time and patient severity of injury, implying that more severely injured patients were resuscitated faster than less severely injured patients.(20) Moreover, a previous study of Spanjersberg and colleagues (21) discovered comparable results, with, resuscitation times of severely injured patients (Revised Trauma Score (RTS) of 12) being shorter (35 minutes) than less severely injured patients (RTS < 12; 46 minutes). This may imply that the influence of an on-site trauma surgeon during trauma resuscitation on resuscitation time may even be underestimated. However, introduction of a trauma surgeon on-site did even shorten the time needed to complete the resuscitations by more than 4 minutes. The study's second limitation is the small number of reviewed cases, which increases the likelihood of randomness and prevents more advanced (statistical) analysis. However, this study contributes to the existing literature because it is the first to evaluate the introduction of an on-site trauma surgeon and through video analysis. However, this study contributes to the existing literature because it is the first to evaluate the introduction of an on-site trauma surgeon and through video analysis. As a result, the findings of this study indicate that an on-site trauma surgeon is very likely to improve the pace and ATLS adherence of trauma resuscitations. Larger studies evaluating the effect of an on-site trauma surgeon during trauma resuscitation on are unlikely until automatic computer analysis will become available. Such automated video analysis is already being used in professional sports. (21) A third limitation of this study was that ATLS adherence was measured based on a predefined list of ATLS related tasks. Strictly, not all tasks are always indicated for every case. For example, a second IV line for patient hemodynamically stable patient may be overtreatment. This may imply that the ATLS adherence is undervalued, as not all tasks are indicated during the individual cases. However, the videos of patients that are analyzed, are patient that are relatively severe injured (ISS>15) and therefore, we believe that most of the predefined ATLS related tasks are mostly indicated.

Conclusion

In conclusion, the addition of a trauma surgeon's physical presence during trauma resuscitations of severely injured patients resulted in improved processes in the trauma bay and this demonstrates the need of direct involvement of trauma surgeons in institutions treating severely injured patients.

Abbreviations

ACS-COT - the American College of Surgeons' Committee on Trauma's

ATLS – Advanced Trauma Life Support

CT – Computed Tomography

DNTD - The Dutch National Trauma Database

EKG- Electrocardiogram

GCS – Glasgow Coma Score

ICU – Intensive Care Unit

IH – In-Hospital

IQR – Inter Quartile Range

ISS – Injury Severity score

IV – Intravenous

JCI – Joint Commission international

OH- Out-of-Hospital

OR – Odds Ratio

RTS - Revised Trauma score

Ethics approval and consent to participate

This study was performed according to the Helsinki Declaration. The Medical Research Ethics Committee (MREC) Utrecht (METC Utrecht) approved this study. Furthermore this study was also approved by our hospital's legal department. Furthermore this study was also approved by our hospital's legal department. In For this study, informed consent has been waived, and it was waived by The Medical Research Ethics Committee (MREC) Utrecht (METC Utrecht) as retrospective nature, thus no informed consent of patients or personnel was required, because video analysis of trauma resuscitations are part of our quality assessment program. Video recordings were stored on a local secured server. At the time of data was gathered, video records were automatically removed from the server after thirty days and data gathered from the videos were directly anonymized.

Consent for publication

Not applicable

Availability of data and materials

The datasets generated and/or analysed during the current study are not publicly available due to privacy regulations, but are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests

Funding

Not applicable

Authors' contributions

O.M. designed and performed the experiments in consultation with W.H. L.L. O.M. analysed the data. O.M. wrote the manuscript in consultation with W.h. L.L.

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Chapter

7

The pace of a trauma resuscitation: Experience matters

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Abstract

Purpose

Resuscitation quality and pace depend on effective team coordination, which can be facilitated by adequate leadership. Our primary aim was to assess the influence of trauma team leader experience on resuscitation pace. Second, we investigated the influence of injury severity on resuscitation pace.

Methods

The trauma team leaders were identified (Staff trauma surgeon vs Fellow trauma surgeon) and classified from video analysis during a one-week period. Resuscitations were assessed for time to the treatment plan, total resuscitation time, and procedure time. Furthermore, patient and resuscitation characteristics were assessed and compared: age, gender, Injury Severity Score, Glasgow Coma Scale <9, and the number (and duration) of surgical procedures during initial resuscitation. Correlations between total resuscitation time, Injury Severity Score, and time to treatment plan were calculated.

Results

After adjustment for the time needed for procedures, the time to treatment plan and total resuscitation time was significantly shorter in resuscitations led by a Staff trauma surgeon compared to a Fellow trauma surgeon (median 648 s (IQR 472-813) vs 852 s (IQR 694-1256); $p < 0.01$ resp. median 1280 s (IQR 979-1494) vs 1535 s (IQR 1247-1864), $p = 0.04$). Surgical procedures were only performed during resuscitations led by Staff trauma surgeons (4 thorax drains, 1 endotracheal intubation, 1 closed fracture reduction). Moreover, a significant negative correlation ($r = -0.698$, $p < 0.01$) between Injury Severity Score and resuscitation time was found.

Conclusion

Experienced trauma team leaders may positively influence the pace of the resuscitation. Moreover, we found that the resuscitation pace increases when the patient is more severely injured.

Keywords

Resuscitation, Trauma Team, Resuscitation Time, leadership

Introduction

The implementation of trauma systems and a coordinated resuscitation strategy have substantially improved the outcomes of seriously injured patients. (1) Trauma teams are one of the cornerstones of a coordinated resuscitation strategy. (2–4) The aim of a trauma team is to identify all life-threatening injuries and to provide rapid resuscitation and stabilization.

Effective team coordination is critical for the quality and pace of resuscitations and leadership can facilitate this coordination. (5) Resuscitation pace represents the speed of consecutive performed tasks and decision-making during the resuscitations. The trauma leader supervises and coordinates the team members' activities. (6–8) The coordination of activities is of vital importance, when critically injured patients are resuscitated in a team approach. During the resuscitation, multiple concurrent diagnostic and therapeutic efforts occur simultaneously.

Adequate leadership within a trauma team during a resuscitation asks for more than the correct application of the resuscitation guidelines only. Even though resuscitation guidelines provide a rational and sequential algorithmic approach, they largely focus on the technical tasks performed by individual physicians and do not address the adaptation of the complicated character of most actual resuscitations. On one hand, the complexity of resuscitation is related to the injury severity or patient characteristics, and on the other hand, this is related to the fact that in a healthcare environment, trauma resuscitations are performed by teams and not by isolated physicians. Teamwork is a complex phenomenon with many elements at play. During trauma resuscitations, for example, team members' behaviors, cognitions, and attitudes are some of the elements that interact. (9) Previous studies have shown that non-technical skill training improves patient safety, process efficiency, and reduces medical errors by improving teamwork, including the quality of leadership of the team leader within trauma teams. (10–13) These studies, however, have evaluated resuscitation processes, such as guideline adherence and resuscitation time, primarily in a simulation setting, and did not evaluate the impact of the experience of the involved team leader. The primary aim of this study is to investigate whether the experience of a trauma team leader enhances resuscitation's pace in real-life resuscitations.

Secondary, the influence of the severity of patients' injury on the pace of the resuscitation was investigated. Our hypothesis was that the pace of resuscitations led by a staff trauma surgeon would be faster than resuscitations led by a fellow trauma surgeon and that the pace of resuscitations would be faster when patients were more severely injured.

Methods

Design, Data collection, and Outcomes

This study is a retrospective observational study of prospectively gathered videos and data. All consecutive resuscitations of injured patients performed by a trauma team were retrospectively analyzed using videos recordings during the first week of May 2018. All included video recordings were analyzed by two researchers, with extensive experience in analyzing video recordings of trauma resuscitations. The first step in data collection was to identify trauma team leaders and categorization them into one of the following groups: trauma surgeon staff or Fellow trauma surgeons. In the Netherlands, a fellowship is the direct post-graduate period of medical specialty training as a trauma surgeon, which usually comprises 1-2 years of follow-up training. Trauma surgeon staff, however, have at least 5 years of experience as trauma surgeons. All resuscitations were assessed regarding: A) time to treatment plan: time to the announcement of an initial treatment plan after assessment of the injured patients (T1); B) the total resuscitation time: from patient arrival in the trauma room until patient left the resuscitation room (T2); and C) procedural times (T3): the time from the start till the end of a surgical procedure performed during the resuscitation in the trauma room. These times were compared between the group of Fellow trauma surgeons and Staff trauma surgeons. Furthermore, patient characteristics were assessed: age, gender, Injury Severity Score (ISS), and Glasgow Coma Scale (GCS) <9. Finally, team extension which was defined as the addition of an extra nurse or anesthesiologist supervisor and administrative delay was assessed.

Setting

This study was performed at the University Medical Center Utrecht (UMC Utrecht), a level one trauma center in the Netherlands, which is incorporated in an academic teaching hospital. At the UMC Utrecht, we have a one-tier trauma team activation protocol, and the trauma team is activated when one of the predefined sets of trauma mechanisms, physiological, or anatomical criteria applies to admitted patients following injury. (Table 1)

In accordance with our institutional protocol, the trauma team in UMC Utrecht consists of a supervising trauma leader, (a Staff trauma surgeon or Fellow trauma surgeon), a surgical resident, an anesthesiologist’s resident, an emergency care physician, two emergency department nurses, a neurologist, and a radiology technician; eight team members. In the case of severely injured patients, the nursing team may be extended to three and the anesthesiologist may be accompanied by a supervisor. The decision to extend the team is based on suspected injuries and interventions during resuscitation. The allocation of trauma surgeons (Staff or Fellow) is based on a duty schedule made by forehand, thus not based on the expected severity of the injury. A detailed description of trauma team composition and task allocation is described by Kreb et al. (14)

Table 1: Criteria for activation of the trauma Team

Physiological	Endotracheal intubation or endangered airway
	Respiratory distress
	Reduced level of consciousness
	Any episode of hypotension
Anatomical	Penetrating wounds proximal of the knee
	Amputation or degloving injuries
	Spinal injury
	Flail chest
	Pelvis fracture
Trauma mechanism	Two or more long bone fractures
	Fall of a height >3m
	Large deformity of motor vehicle
	Intrusion of passenger’s compartment
	Death of passenger in same vehicle
	Overturned car
	Pedestrian hit with >25km/h
	Ejected from the car
Other	Extrication time >20 min
	Activation of trauma helicopter
	On request of ambulance personnel

Statistical analysis

For this study, we used descriptive analysis, using Microsoft Excel (Microsoft Corp. Released 2010. Microsoft Office Excel 2010, Version 14.0. Redmond, WA: Microsoft Corp.) and SPSS IBM Corp. Released 2012. IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY: IBM Corp.) and SPSS IBM Corp. Released 2012. IBM SPSS Statistics for Windows, Version 21.0. Armonk, NY: IBM Corp.) The skewness of data was

determined using a Shapiro-Wilk test; if p-values were 0.05 or higher, data were considered normally distributed. For outcomes described in percentages, percent deviation was calculated. Because of the relative small sample size both parametric and non-parametric data (time to the treatment plan (T1), total resuscitation time (T2), procedure time (T3), age, ISS GCS) were presented as medians with Inter Quartile Range (IQRs) and Mann-Witney U test were used to compare the data of the two groups. We used the χ^2 test to compare categorical variables (gender, administrative delay and team extended). Spearman's correlation coefficient is often recommended for non-normally distributed data. However, several studies show that Pearson's correlation coefficient may offer substantial advantages in terms of statistical power for continuous non-normal data. (15,16) Therefore, both, Pearson's and Spearman's rho correlation were used to determine whether statistical evidence for a relationship between Injury Severity Score (ISS) and total resuscitation time (T2) existed. A scatterplot including a trend line was made using Excel (Microsoft Corp. Released 2010. Microsoft Office Excel 2010, Version 14.0. Redmond, WA: Microsoft Corp.) The trendline was intended to visualize a general pattern of resuscitation time over ISS rather than creating a prediction model. The type of trend line with the highest R-squared value is displayed. R-squared has a value ranging from 0 to 1, with higher values indicating better prediction ability. In this study, we used cutoffs according to Chin et al. (17) for a qualitative value for the goodness-of-fit based on R-squared values. Values above 0.67 were considered substantial, values between 0.67 and 0.33 were considered moderate, values between 0.33 and 0.19 were considered weak, and values lower than 0.19 were considered very weak. A p-value of less than 0.05 was deemed statistically significant.

Privacy and Ethics

After a waiver for approval by our institutional review board was achieved, recorded videos were analyzed, and regional data from the Dutch National Trauma Database (DNTD) were used. Trauma team members were informed of video analysis of the trauma resuscitation. Thereby, in agreement with the hospital's legal department, informed consent from patient and personnel was not required as our institution uses video registration as part of local quality audits. For security and privacy reasons, video recordings are stored on a secured server inside the hospital building and are automatically deleted after fourteen days.

Results

Baseline characteristics

Thirty-two videos of trauma resuscitations were included and analyzed. All provide data were normally distributed ($p > 0.05$), except for the ISS. ($p < 0.05$) (Table 2). Of the thirty-two analyzed resuscitations, fourteen resuscitations were led by a Fellow trauma surgeon, and eighteen were led by a Staff trauma surgeon. Significantly more procedures (4 thorax drains, 1 endotracheal intubation, and 1 closed fracture reduction) were performed when the trauma team was led by Staff trauma surgeons compared to Fellow trauma surgeons (Staff trauma surgeons 6 procedures vs Fellow trauma surgeon 0; $p=0.02$). No significant difference was found between ISS and GCS between the groups. (Table 2) In both groups, the teams were not extended by additional members.

Table 2: Baseline characteristics and resuscitation times

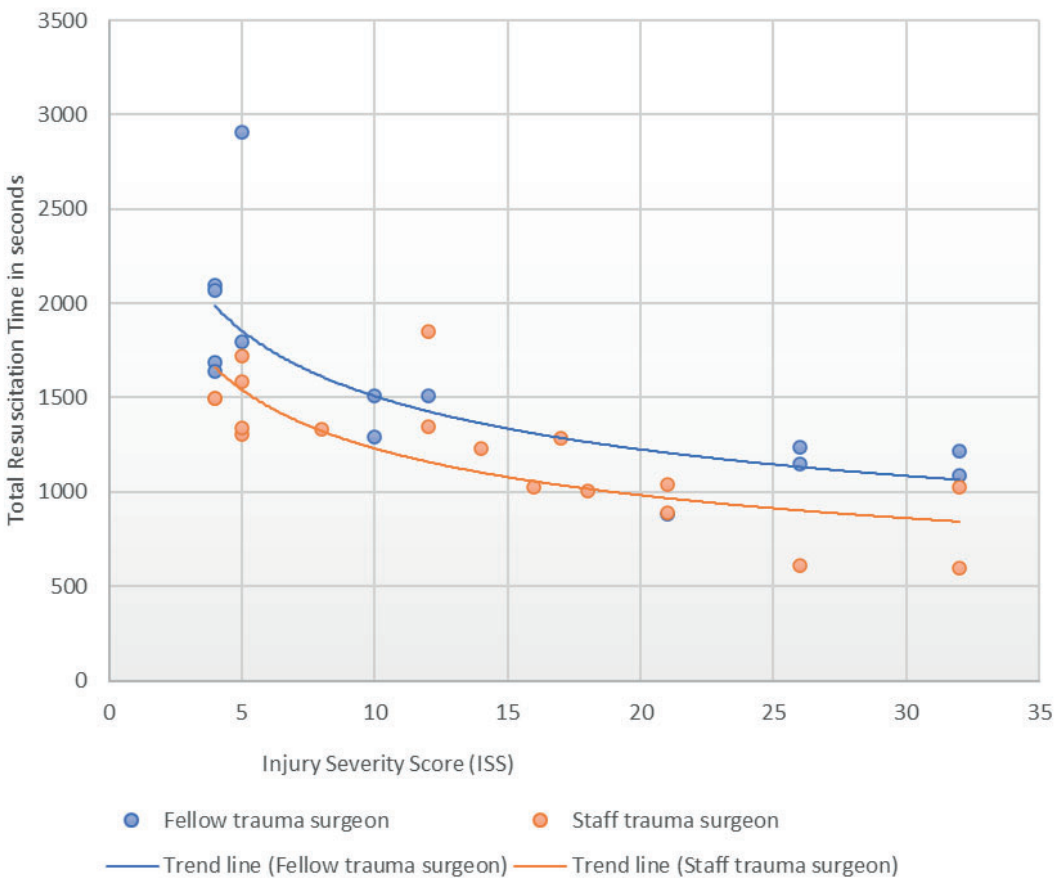
	Fellows	Trauma surgeons	p-value
Resuscitations, cases	14	18	NA
Number of team leaders	2	3	
Age, mean (SD)	47 (15)	53 (19)	0.41
Gender, percentage male	64	78	0.45
ISS, median, (IQR)	10 (4-26)	13 (5-21)	0.43
GCS<9, percentage	14	6	0.40
Team extension, cases	0	0	NA
Procedures, amount	0	6	0.02*
Time to plan in seconds, median (IQR)	852 (694-1256)	719 (489-393)	0.04*
Time to plan minus procedure time in seconds, median (IQR)	852 (694-1256)	648 (472-313)	0.01*
Total resuscitation time in seconds, median (IQR)	1535 (1247-1864)	1363 (1039-1611)	0.22
Total resuscitation time minus procedure time in seconds, median (IQR)	1535 (1247-1864)	1280 (979-1494)	0.04*
Administrative delay, cases	1	1	0.92

The influence of experience on resuscitation' pace

The pace of resuscitations led by a trauma surgeon was significantly faster than resuscitations led by a Fellow trauma surgeon. (Table 2) The time to initial treatment plan (T1) was significantly shorter in staff trauma surgeons (Staff trauma surgeons median 719 seconds vs Fellow trauma surgeon 852 seconds; $p=0.04$). The total resuscitation time was shorter, however it did not reach statistical significance (Staff trauma surgeon median 1363 vs Fellow trauma surgeon 1535, $p=0.22$). After adjustment for procedures (procedures were only during resuscitations led by Staff trauma surgeons), the total

resuscitation time for Staff trauma surgeons was significantly shorter compared to Fellow trauma surgeons. (Staff trauma surgeons median 1280 vs Fellow trauma surgeon 1535 seconds; $p=0.04$).

Figure 1: Scatterplot and trend line between Injury Severity Score and total resuscitation time (of Trauma fellow surgeons and Staff trauma surgeons).



The R-squared value trend line Staff trauma surgeon (0.59) resp. Fellow trauma surgeon (0.68)

The influence of severity of injury on resuscitation’ pace

Overall, the total resuscitation time was negatively correlated with the ISS score. ($r -0.698$; $p<0.01$) This was also the case for resuscitations led by both, Staff trauma surgeons and Fellows. (Pearson’s correlation: Staff trauma surgeons: $r -0.808$, $p<0.01$; Fellow trauma

surgeon: $r = -0.712$, $p = 0.02$ spearman's correlation: Fellow trauma surgeon: -0.844 , $p < 0.01$; staff trauma surgeons: -0.842 , $p < 0.01$). A scatterplot with an indicative trend line is shown in Figure 1. The goodness-of-fit of the trend lines of Staff trauma surgeons and Fellow trauma surgeons were moderate (R^2 value: 0.59) and substantial (R^2 value: 0.68), respectively.

Discussion

We found a higher pace of trauma resuscitations in resuscitations that were led by experienced supervising Staff trauma team leaders compared to less experienced team leaders (Fellow trauma surgeons). On average, the time until the treatment plan was declared, was six minutes shorter and the total resuscitation time six minutes shorter when trauma teams were led by a Staff trauma surgeon. This difference in resuscitation pace is of clinical relevance for critically ill trauma patients requiring immediate care. Especially for patients suffering severe hemorrhage, the enhanced resuscitation pace could be the difference between life and death. (18,19) Secondly, we found a strong correlation between the severity of injury and resuscitation pace, whereas patients suffering more severe injuries were resuscitated faster. This strong correlation could be a result of situational awareness of the team (patients needing treatment fast) which leads to an expedited resuscitation. Our results are in line with the results of the study of Spanjersberg et al. (20) In their study, the total resuscitation time was shorter in severely injured (Revised Trauma Score of 12) patients compared to less severely injured patients (Revised Trauma Score lower than 12). (34.8 versus 45.9 minutes). However, their results need to be interpreted with caution, as severely injured patients were resuscitated with a larger and more experienced trauma team compared to less severely injured patients.

Consistent with a previous study, (21–23) we found that more experienced trauma team leader enhances the pace of trauma resuscitations. In a before-and-after observational study performed at our hospital, we found that the introduction of a 24-hour in-house attending trauma surgeon (instead of an on-call attending trauma surgeon) availability of extra experience was created within the trauma team and during initial trauma care. This resulted in a significant decrease of length of stay in the emergency department, more patients reached the ICU within an hour, and a doubling of the percentage of patients

arrived in the OR within 30 minutes.(21) Cole et al.(22) found that in trauma resuscitations led by an experienced team leader (consultants), targets such as diagnostic imaging and hemorrhage control were significantly more likely achieved compared to trauma resuscitations that were led by less experienced trauma team leaders (residents). Furthermore, the study of Hong et al. (23), showed that patients had a higher chance to survive when resuscitated by a team with an experienced trauma team leader. Their multivariate logistic regression analysis among 284 resuscitations revealed that a less experienced trauma team leader (trauma surgeons with less than two years' experience) was an important risk factor for mortality among patients with a GCS ≤ 8 (odds ratio (OR): 14.5, 95% CI 1.7–125.5, $p=0.015$).

Although leadership can be trained, experience is still essential. In a recent randomized controlled trial regarding leadership training by Fernandez et al.(24), overall leadership scores of trauma team leaders who had received simulation leadership training were significantly higher compared to their untrained colleagues (trained leaders: mean score 10.97 SD 3.67; untrained leaders: mean score 7.27 SD 2.52; $p=0.02$). Despite these findings, the experience remains an important cornerstone, as was demonstrated by Sarcevic et al.(25) In their study, they distinguished a directive leadership style and an empowering leadership style. A directive leadership style is preferred in resuscitations of severely injured patients with inexperienced team members. Inexperienced team members may not possess the confidence or knowledge necessary to make quick decisions. Directive leaders can help inexperienced team members by taking control of the situation. The empowering leadership style was found to be better suited during resuscitations of less severely injured patients with more experienced team members. (25) By empowering, members with more experience can make their own decisions. Therefore, the trauma team leader could focus more on decision-making and the overall plan. In the case of resuscitations of less severely injured patients, the empowering leadership style provides an educational value. Trauma leader has more time for decision making and can discuss the situation more thoroughly with team members.

The factors that explain why resuscitation pace is faster in trauma resuscitations that are led by more experienced trauma team leaders are, to our knowledge, not studied yet. However, one could imagine that experienced trauma leaders can make decisions based

on extensive experience that incorporates not only the resuscitation itself but all aspects within the complete care trajectory of trauma patients. This extensive experience enhances the pace and quality of the decision-making process during trauma resuscitation. Klein et al. (26) describe this phenomenon in detail and call it ‘recognition primed decision making. Non-technical abilities, such as effective communication, have been shown to be critical during trauma patient resuscitation and influence resuscitation pace.(5,27) As those non-technical skills typically develop with experience, it is reasonable to expect that resuscitations led by more experienced trauma surgeons will have a positive impact on the resuscitation pace. Furthermore, experience leads to confidence which may lead to a better overview of the process and could redirect the resuscitation process on time when needed. Finally, based on personal experience in practice, team members express higher trust in a more experienced team leader, leading to less debate during resuscitation, which is time saving.

Strengths and limitations

The strength of this study was the use of video recordings of trauma resuscitations to analyze the pace of the resuscitation, which provides accurate documentation of the trauma resuscitation. Using video recordings allowed us to re-wind if needed, which increased the accuracy of the data collection. Our study also has some limitations. First, our study was a single-site study that enrolled a relatively small sample of thirty-two trauma team activations in a level one trauma center in an academic institution. The practices and policies at our institution may differ from other academic medical centers throughout and considerably vary from community-based practices. Therefore, the generalizability of our findings may be limited. Thereby, the small sample size could have introduced bias, as cofounders might be underpowered and might be overseen. There are many factors at play during trauma resuscitations, including but not limited to patient, team leader, and team member factors, not to mention interpersonal behaviors and interactions. In this explorative study, not all factors have been addressed in this study. Nevertheless, based on our results, we found that ISS could be an important cofounder when assessing the influence of the experience of the leader on resuscitation pace, as the severity of the injury of the patient seems to have an influence on resuscitation pace as well. Furthermore, the overall severity of the injury of the resuscitated patients was medium (median 10 (IQR4-26) for Fellow trauma surgeons and 13 (IQR5-21) for Staff

Trauma Surgeon; $p = 0.43$). The resuscitation pace is especially important for patients suffering more severe injuries. The sample size of this study was too small to compare a group of the most injured patients only. However, as Figure 1 indicates, the pace of the resuscitation led by a Fellow trauma surgeon seems, in general, to be less across all ISS scores. Therefore it is more likely that, despite the small sample size, the results found that the experience of the trauma team leader improves resuscitation pace which is also valid for more severely injured patients. Second, patient-related outcomes were not evaluated in this explorative study. Further research is needed to investigate resuscitation pace's effect on patient-related outcomes, such as length of stay, in-hospital complication, and mortality. Third, the outcome values, T1 (time to initial treatment plan) and T2 (the total resuscitation time), and T3 (procedural time), might have some limitations. For the outcome time to initial treatment plan (T1) minus the procedural time (T3), bias could have potentially have been introduced, as the group who has performed most procedures (Staff trauma surgeons) may be delaying a plan to perform a procedure. However, in this study, all procedures took place after the announcement of a treatment plan and therefore have not influenced T1 minus the procedural time (T3). For the outcome total resuscitation time (T2), administrative factors might have biased the outcome. In practice, there might be some delay when the patient is leaving the trauma room when waiting for the availability of the CT scan. However, in this study only in two cases, there was a delay in transferring the patient to the CT scan. Furthermore, delays are not driven by other administrative factors (for example, bed availability, speed of transport services, etc.) while patients that do not need direct treatment are transported to another room at the ED, to prepare the shock room for new trauma resuscitations. The total resuscitation time (T1) minus procedural time, might also be biased by the fact as during procedures, plans could have been discussed and prepared for simultaneously, perhaps accounting for a seemingly quicker overall resuscitation time by the Trauma surgeon group. Fifth, the exact experience of the trauma team leader was not measured. However, the Fellows had no or only one year experience as trauma surgeon before the resuscitation, while staff members included in this study had at least five years of experience. Finally, we calculated an R-square value to assess the goodness of fit; however, some articles debate whether R-squared values are appropriate. (28,29) Nevertheless, the trendline was intended to visualize a general pattern, rather than creating a prediction model. Thereby, the sample size and the fact that this is a single site would diminish the generability of such a prediction model.

Implications for daily practice

Some considerations for daily practice, can be made. First, hospitals should consider activating a trauma team with the addition of an experienced trauma team leader in cases where it is expected that rapid resuscitation is necessary, which is typically the resuscitation of more critically injured patients. Thereby, we prefer 'scale-down when possible' above 'scale-up when necessary.' The AMC Amsterdam, a level one trauma center in the Netherlands, developed an in-hospital triage tool to downgrade the trauma team when possible to reduce over triage. The tool reduced over triage from (70% to 27%), while no under triage was found, (30) while under triage proportions of 42 percent are reported for two-tiered trauma call systems. (31) Furthermore, we suggest that the experienced trauma surgeon should be available from the beginning of the resuscitation, as already demonstrated in an earlier study (21). Scaling up teams could result in undesired effects. Instead of accelerating the pace of the resuscitations as desired, the addition of a new (senior) trauma leader or other team members may interfere with the existing dynamics of the team, which could be confusing and therefore work counterproductive. Tschan et al. (32) investigated this phenomenon among cardiopulmonary resuscitations and described that the team dynamic underwent important changes each time a new team member of higher status joined the team and did not necessarily improve the performance during resuscitation. Moreover, they found that the shared responsibility of leaders leads to confusion within the team. (32) Translated to trauma resuscitations, this could be the case when experienced trauma team leader integrates during the resuscitation. Our second suggestion is to explore opportunities to improve team members' experience; as is shown in this study, experience is an important factor for rapid resuscitation. Previous studies have shown that simulation training and video review education of actual resuscitations improved resuscitation quality and pace. (33–35). This may imply that experience of team members, at least partly, could be based on educational and/or simulated situations and not solely on actual resuscitation-related situations. Finally, the pace of the resuscitation, might be a valuable quality indicator of trauma resuscitations. For example, resuscitations could be stratified based on severity of injury and relatively slow resuscitations may be chosen for routinely evaluation during case conferences or individual educational feedback initiatives.

Implications for Research

Further research is needed to increase our understanding of leadership, experience, teamwork, and their relation to patients' outcomes. First, consensus should be reached what leadership and experience for trauma resuscitation mean. Winston et al. (36) illustrate the complex nature of leadership. The auteurs investigated the term leadership from a sociological perspective and uncovered over 90 variables that may comprise the whole of leadership. To understand what leadership should mean during trauma resuscitation, explorative studies should analyze what factors discriminate an experienced trauma team leader discriminates from inexperienced trauma team leaders and which of these factors influences the quality and pace of trauma resuscitations. Second, research should focus on how these discriminating factors could be used to improve trauma care. For example, if some of these factors are highly trainable, such as communication skills, this should be the primary focus on training members of the trauma team. Another example could be that these factors are not trainable, but only be gained due to the experience of actual cases. In that case, it should be further defined when experienced trauma team leaders should be deployed.

Conclusion

Experienced trauma team leaders may positively influence the pace of the resuscitation. Second, we found that the resuscitation pace increases when the patient is more severely injured.

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Chapter

8

Severely injured patients benefit from in-house attending trauma surgeons

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Abstract

Introduction

There is continuous drive to optimize healthcare for the most severely injured patients. Although still under debate, a possible measure is to provide 24/7 in-house (IH) coverage by trauma surgeons. The aim of this study was to compare process-related outcomes for severely injured patients before and after transition of attendance policy from an out-of-hospital (OH) on-call attending trauma surgeon to an in-house attending trauma surgeon.

Methods

Retrospective before-and-after study using prospectively gathered data in a Level 1 Trauma Center in the Netherlands. All trauma patients with an Injury Severity Score (ISS) >24 presenting to the emergency department for trauma before (2011–2012) and after (2014–2016) introduction of IH attending's were included. Primary outcome measures were the process-related outcomes Emergency Department length of stay (ED-LOS) and time to first intervention.

Results

After implementation of IH trauma surgeons, ED-LOS decreased ($p = 0.009$). Time from the ED to the intensive care unit (ICU) for patients directly transferred to the ICU was significantly shorter with more than doubling of the percentage of patients that reached the ICU within an hour. The percentage of patients undergoing emergency surgery within 30 min nearly doubled as well, with a larger amount of patients undergoing CT imaging before emergency surgery.

Conclusions

Introduction of a 24/7 in-house attending trauma surgeon led to improved process-related outcomes for the most severely injured patients. There is clear benefit of continuous presence of physicians with sufficient experience in trauma care in hospitals treating large numbers of severely injured patients.

Keywords

In-house attendance, Efficiency of care, Trauma surgeon, Resuscitation, Severely injured.

Introduction

Improved outcomes for severely injured patients treated at designated trauma centers within an inclusive trauma system are well established. (1–3) One of the cornerstones of designated trauma centers has been timely involvement of trauma surgeons in the management of severely injured patients. With ongoing centralization of patients and further differentiation of hospitals, the question arises if trauma surgeons should be in house at all times in centers treating severely injured patients. However, there is ongoing debate regarding the value of such an in-house (IH) attending trauma surgeon. (4–6)

In several Level 1 Trauma Centers, an IH attending trauma surgeon is available 24/7, whereas other institutions maintain an out-of-hospital (OH) on-call attending schedule with a reasonable response time. (7,8) In practice, OH on-call attending schedule means that a (senior) resident may serve as an in-house surgeon, while the attending surgeon participates in all major therapeutic decision-making and attends surgical procedures when needed.

Several studies have examined the effects of IH attending surgeons on process- and patient-related outcomes. On one side there are studies that provide arguments that an IH attending improves efficiency of processes, such as faster decision-making, fewer errors, decrease of time to disposition and reduction in preventable deaths. (6,9–11) On the other side, there is no true consensus on the added value of 24/7 presence of an attending trauma surgeon in terms of overall mortality or hospital length of stay. (22,13) These latter outcomes are subject to the efficiency of the complete trauma care chain. Thus, when attempting to optimize the resuscitation process by introducing IH trauma surgeons, focus should be on process-related outcomes for this specific part of the chain. As stated by Durham et al, aggregate statistics and the use of surrogate markers to determine outcomes may not accurately portray the impact of attending surgeons on the quality of care. (6)

Recently, an IH attending schedule with two experienced trauma surgeons available 24/7 has been introduced in our hospital. The aim of the present study was to compare process-related outcomes before and after the introduction of an institutional IH attending

trauma surgeon schedule in a single large volume Level 1 Trauma Center in the Netherlands.

Methods

The University Medical Center of Utrecht is a Joint Commission International (JCI) accredited tertiary care facility with 1000 beds. Our hospital complies with all requirements as defined by the American College of Surgeons' Committee on Trauma (ACS-COT) for a Level 1 Trauma Center with the CT scan located nearby the Emergency Department (ED), thus not in the resuscitation bay. (7) Trauma team composition and tasks in our institution are described in detail by Kreb et al. (14) In July 2013, a shift from an out-of-hospital (OH) on-call to an in-house (IH) schedule for attending trauma surgeons took place. Before this change, trauma surgeons were available for consultation on-call with a senior resident in general surgery acting as house officer. Trauma surgeons were present during daytime trauma team activations and a selected amount of 'off hours' presentations. After July 2013, there was continuous presence of an IH trauma surgeon together with a resident of no specified level of experience (varying from junior to senior residents in general surgery). In case of a trauma team activation, this IH trauma surgeon was present at the bedside upon presentation of the patient. In addition, a second trauma surgeon was available on-call to perform or assist in surgical procedures or lead resuscitation at the ED if multiple victims arrived simultaneously. Hence, two trauma surgeons were present during surgery if needed. In the Dutch trauma model, trauma surgeons perform surgical procedures for both truncal (i.e. visceral) and extremity (i.e. osseous, including pelvic) injuries, but do not perform vascular reconstructions. (15) There were no other major changes after implementation of the in-house schedule (especially the location of the CT scan and operating room (OR) remained similar) except for 24/7 availability of an ICU bed for trauma patients, even in case of severe bed shortage, from the second year in the IH period onwards.

Study design and participants

After a waiver for approval by our institutional review board was achieved, we conducted a retrospective before-and-after study using prospectively gathered data from the Dutch National Trauma Database (DNTD) and the local emergency department, radiology, operating theatre and hospital logistics databases. Data embedded in these databases were

prospectively gathered as required for national and local quality improvement programs. All severely injured patients presented to the ED with pre-notification of trauma between August 2011 (introduction of new electronic patient documentation system) and December 2012 and from January 2014 through December 2016 were included in the study. Patients presenting six months prior to or six months after the transition to the IH schedule (June 2013) were excluded to minimize possible effects of anticipation on and first implementation of the new schedule. Severely injured patients were defined as patients presenting with trauma resulting in Injury Severity Scores (ISS) >24 only, as we hypothesized that this group would benefit most from the new management model. (16) Children were enrolled in this cohort as well, since the same surgical trauma team performed the initial assessment of both adult and pediatric patients. Eligible patients were divided into two groups based on their dates of presentation; one group of patients who presented before the introduction of the IH system (2011–2012) and one group who suffered trauma in the time period after the introduction of the IH system (2014–2016).

Outcome measures and explanatory variables

The process-related outcomes were duration of emergency department length of stay (ED-LOS) and time to first intervention. ED-LOS was calculated utilizing ED arrival- and departure times as registered by ED staff members, which included finishing administration. Time to first intervention was based on emergency department disposition and categorized into the time between arrival at the ED and arrival at the CT scan, the operating room (OR) or the ICU. Secondly, we assessed in-hospital mortality, hospital length of stay (H-LOS), ED disposition, ICU admission and time to surgical procedures performed within 24 h. Demographic and explanatory variables were extracted from the databases. Stability of trauma was defined according to triage by ED nurses. Triage color was scored based on the Emergency Severity Index and ranges from red to green, with red demanding immediate intervention and green indicating a low level of emergency. (17) Emergency surgeries, defined as any surgical procedure performed directly after ED departure, were categorized into anatomical region and level of emergency. Surgical emergency procedures included laparotomies, thoracotomies, pelvic packing and emergent vascular procedures, neurosurgical emergency procedures comprised all types of neurosurgical interventions (e.g. trepanation), orthopedic emergency procedures included fasciotomies and stabilization of the vertebral column, major pelvic and long-

bone fractures, non-emergent orthopedic procedures consisted of stabilization of minor fractures and other non-emergent procedures encompassed all other procedures for non-life threatening conditions (e.g. wound treatments, oral and maxillofacial procedures).

Statistical analyses

Categorical and dichotomous variables were reported as numbers with percentages, continuous variables as medians with interquartile ranges (IQR). Bivariate analyses using chi-squared with continuity correction according to Yates’ correction and Mann-Whitney U tests, as appropriate, were carried out in order to compare demographic, explanatory, and outcome variables between groups. All statistical analyses were performed using STATA1 13.1 (StataCorp LP, TX, USA). A p-value of <0.05 was considered statistically significant.

Results

Population

A total of 7780 patients presented for 7935 unique traumas during the study period. An overview of the patients presenting and their dispositions are shown in Fig.1. In supplementary Table 1, triage characteristics for all patients admitted for trauma are provided.

Figure 1: flowchart of cohort

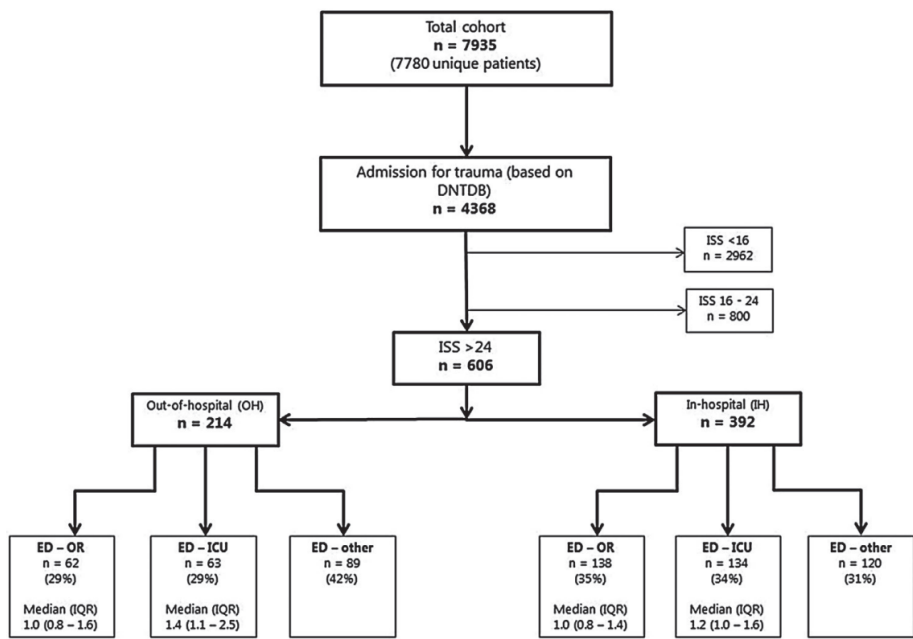


Table 1: Baseline characteristics for patients with ISS > 24 (n = 606)

	Out-of-hospital period (n = 214)	In-hospital period (n = 392)	
	Median (IQR)	Median (IQR)	p-value
Age at presentation (years)	47 (26 - 66)	50 (26 – 69)	0.53
Injury Severity Score	29 (26 - 34)	29 (26 – 35)	0.46
Glasgow Coma Scale ^a	14 (11 - 15)	14 (10 - 15)	0.46
	n (%)	n (%)	p-value
Male gender	150 (70)	254 (65)	0.22
Unstable trauma	137 (64)	254 (65)	0.92
Triage color ^b			
Red	131 (61)	270 (69)	0.26
Orange	77 (36)	118 (30)	
Yellow	2 (1)	4 (1)	
Green	0 (0)	0 (0)	
Missing	4 (2)	0 (0)	
Blunt trauma	206 (96)	385 (98)	0.23

n = number; IQR = interquartile range.; a Glasgow Coma Scale available for 123 patients (57%) pre in house surgeon and 225 (57%) after; b Triage color ranges from most emergent (red) to least emergent (green).

The population of patients presenting with ISS > 24 consisted of 606 patients presenting for 606 unique traumas. Baseline characteristics of these patients are presented in Table 1. There were no significant differences between patients presenting before and after the IH schedule with respect to baseline characteristics. In both groups, the majority of patients were male and nearly all patients suffered blunt trauma.

Process-related outcomes

Outcome variables are presented in Table 2. ED-LOS was significantly shorter after implementation of the IH schedule (2.7 versus 2.1 h; $p=0.009$). There was no difference with respect to time to CT imaging, with a larger percentage of patients undergoing CT scanning after the introduction of in-hospital attending (95% versus 90%; $p=0.018$) (Fig. 2). After introduction of the IH surgeon, time from the ED to the intensive care unit (ICU) for patients directly transferred to the ICU was significantly shorter, with a decrease from a median time of 1.4 h (IQR 1.1–2.5) to a median time of 1.2 h (IQR 1.0–1.6) ($p=0.004$). In addition, the percentage of patients who reached the ICU within 60 min increased from 15% to 33%. Fig. 3 shows time to the intensive- care unit graphically.

Overall time from presentation at the ED to emergent surgical intervention (surgical intervention directly from the ED) did not change significantly (1.0 versus 1.0 h, $p=0.92$).

However, the percentage of patients who had emergency surgery within 30 min of presentation increased from 4.8% to 8.0%. Of all patients demanding surgery within the initial 24 h, a significantly larger.

Table 2: Outcome variables for patients with ISS>24 (n = 606)

	Out-of-hospital period (n = 214)	In-hospital period (n = 392)	
	Median (IQR)	Median (IQR)	p-value
ED length of stay (hours)	2.7 (1.6 – 4.0)	2.1 (1.5 – 3.7)	0.009
Time to CT	0.4 (0.3 – 0.8)	0.5 (0.3 – 0.6)	0.59
Time to immediate ICU admission (hours) (n = 196)*	1.4 (1.1 – 2.5)	1.2 (1.0 – 1.6)	0.004
Time to emergency surgery (hours) (n = 200)	1.0 (0.8 – 1.6)	1.0 (0.8 – 1.4)	0.90
<i>Without pre-operative CT (hours) (n = 38)</i>	0.7 (0.6 – 0.9)	0.5 (0.4 – 0.7)	0.016
Duration of emergency surgery (hours) (n = 199) ^a	1.5 (1.0 – 2.2)	1.7 (1.2 – 2.2)	0.37
<i>With emergent surgical procedure (hours) (n = 62)</i>	1.4 (1.0 – 1.9)	1.5 (1.0 – 2.3)	0.96
Hospital length of stay for admitted patients (days) (n = 579)	14 (6 – 25)	13 (5 – 26)	0.33
	n (%)	n (%)	p-value
ED disposition			
Operating room	62 (29)	138 (35)	0.25
Death in operating room	4 (6)	1 (1)	
intensive care unit	63 (29)	134 (34)	
Medium care unit	48 (22)	66 (17)	
Ward	32 (15)	41 (10)	
Deceased at emergency department	4 (2)	7 (2)	
Death on arrival	3 (1)	3 (1)	
Transfer	2 (1)	3 (1)	
Intensive care unit admission	133 (62)	266 (68)	0.18
Emergency surgery (OR from ED)	62 (29)	138 (35)	0.14
Emergency surgery without pre-operative CT	18 (29)	20 (14)	0.026
Emergent surgical procedure	25 (40)	38 (28)	0.10
Emergent neurosurgical procedure	26 (42)	66 (48)	0.54
Emergent orthopedic procedure	6 (10)	16 (12)	0.88
Non-emergent orthopedic procedure	16 (26)	36 (26)	0.89
Non-emergent other procedure	3 (5)	10 (7)	0.74
Combined surgical types	13 (21)	21 (15)	0.43
Operation <48 hours of presentation	115 (54)	209 (53)	0.53
Operation during night/weekend shift	69 (60)	119 (57)	0.53
In-hospital mortality	52 (24)	107 (27)	0.48

Patient-related outcomes

In-hospital mortality was comparable between both groups (24% versus 27%; p = 0.48). Median hospital length of stay did not differ between the two periods (14 versus 13 days; p = 0.33).

Figure 2: Time to CT<24 h for patients with ISS>24 (n = 565)

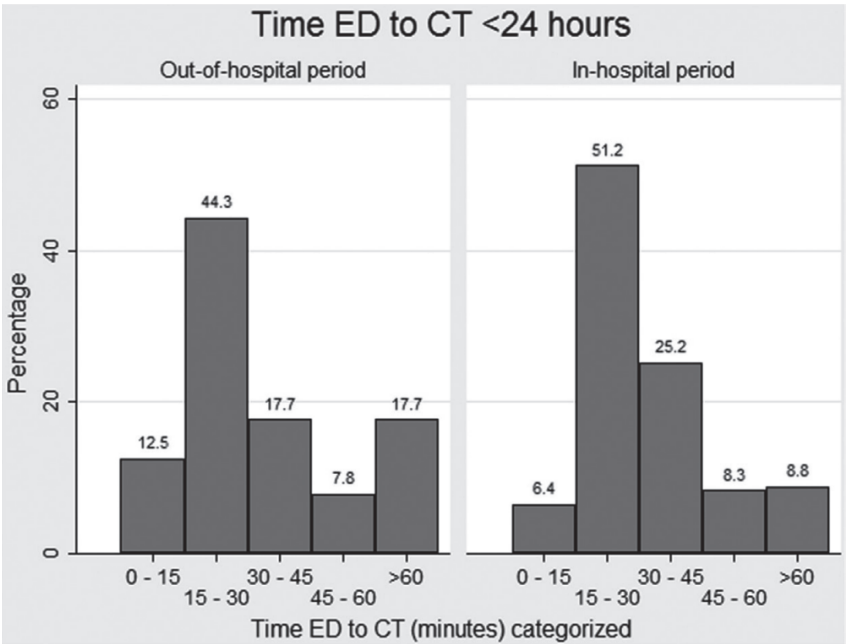


Figure 3: Time to ICU for patients with ISS>24 (directly from ED) (n = 196)

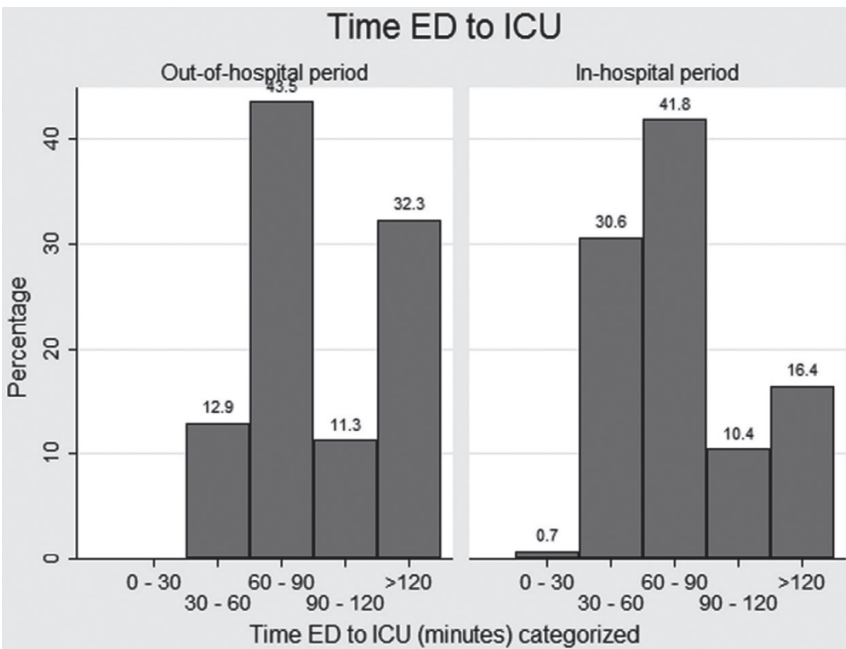
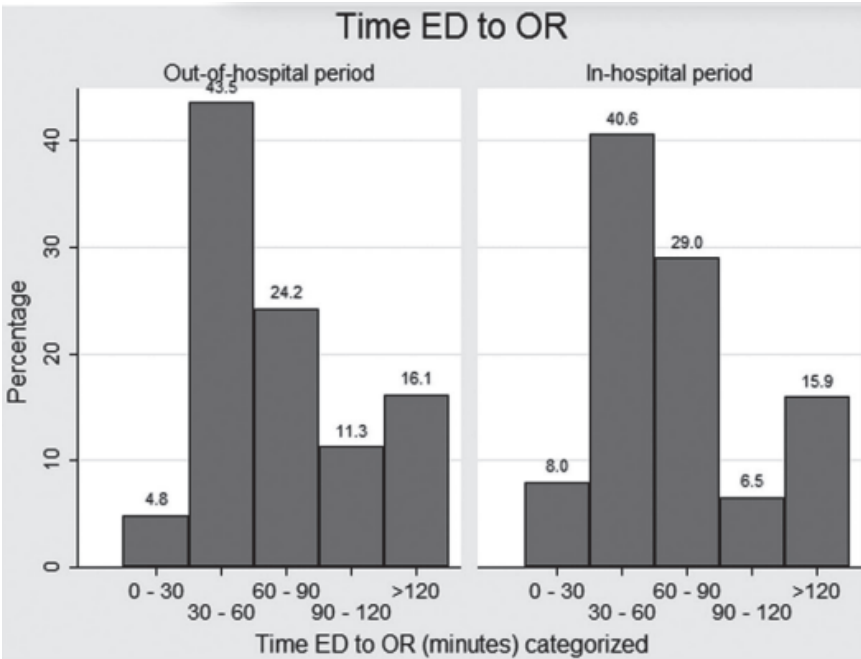
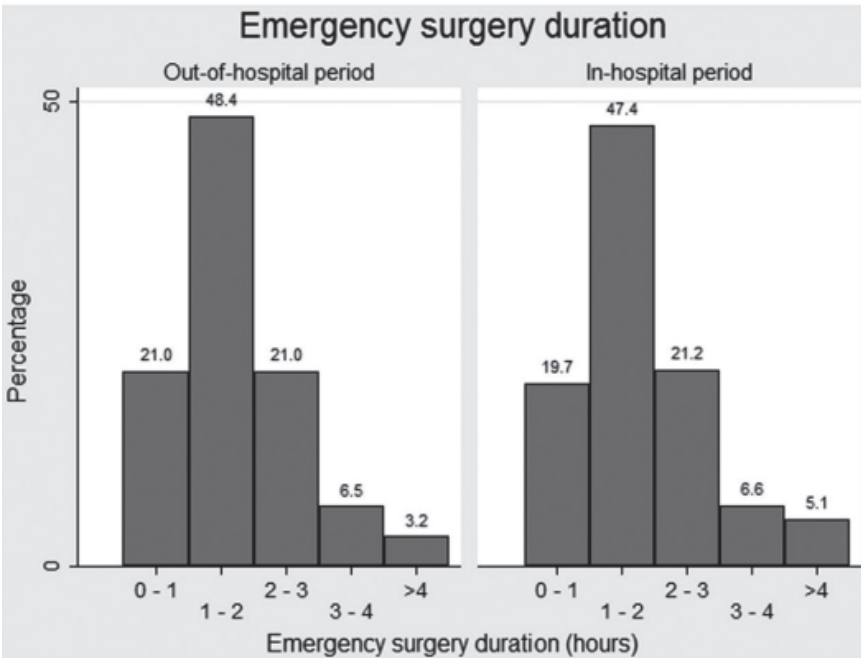


Figure 4: a) Time to OR for patients with ISS>24 (directly from ED) (n=200). b) OR duration for emergency surgeries (directly from ED) (n=199).



a



Discussion

After introduction of an in-house (IH) attending trauma surgeon schedule at our institution, there was significant acceleration of care-processes for severely injured patients, with a significant decrease in emergency department length of stay, a doubling in the percentage of patients that reached the ICU within an hour and a doubling in percentage of patients that arrived at the OR within 30 min.

At our institution, improving care for the most severely injured patients has always been of high priority. For example, video registration has been used to improve functioning of trauma teams. (18) With the recent introduction of an IH attending, process-related quality of care, based on disposition times, improved. It may very well be that the decreased ED-LOS and times to first disposition are the result of improved decision-making and leadership. Although residents may become proficient in the initial evaluation and treatment of trauma patients, the “big picture” and accompanying treatment necessities may be visible for attending surgeons more quickly. Non-technical skills such as leadership, decision-making and situation awareness have been reported to be of utmost importance in the context of resuscitation in trauma patients.(19,20) As those non-technical skills typically develop with experience, one can imagine that presence of an experienced surgeon (attending) is necessary for optimal care of the injured. Positive effects of in-house trauma surgeons on resuscitation times and times to intervention have been described previously. (8–10,21) Interestingly, emergency disposition length of stay increased for patients with less severe trauma after introduction of IH surgeons. This reflects less efficient overall processes at the ED, such as prolonged administrative times and fewer availability of hospital beds. In the light of this, the shorter ED-LOS for severely injured patients emphasizes the contribution of trauma surgeons to the acute care of this vulnerable population even more.

With implementation of the in-house schedule, time to the OR for patients without pre-operative CT imaging (most often due to severe instability) as well as the percentage of patients undergoing emergency surgery without prior CT scan, significantly decreased. This may be a reflection of faster decision-making as caused by presence of experienced surgeons, but is also likely to be the result of improved resuscitation processes in the last

years. When a patient appears unresponsive, but becomes a transient responder, a CT-scan is deemed feasible in our institution. We expect the lower percentage of emergency procedures without previous imaging to be beneficial in terms of operative planning, higher amount of non-operative management and more accurate interventions, potentially leading to improved outcomes.

When comparing the IH and OH period, no changes in clinical decision making for interventions that require attending staff, such as nighttime surgeries, could be identified. This is due to the fact that the patient population (as apparent from our baseline characteristics) and the composition of the medical team as well as treatment strategies did not change over the study period. Therefore, the decision making itself did not differ and patients were treated similarly in both periods. For example, nighttime and weekend surgeries were performed in the OH period as well in order to meet our standards of care. Even though decision making remained similar, our results clearly show that the time to interventions that require decision-making was significantly shorter after introduction of IH attending trauma surgeons.

Based on the triage characteristics in our cohort as well as existing literature, a relatively high percentage of severely injured and polytrauma patients is under triaged. (22) It was shown previously that under triaging and not activating a full trauma team increase the odds of mortality. (22,23) When taking this into account, presence of an IH experienced surgeon for all trauma team activations is even more important as one cannot completely rely on triage characteristics. In addition, injuries in patients who appear to be more severely injured than expected may be diagnosed and treated sooner with their presence.

As expected, it was not possible to show any effects of the IH attendings on mortality in this study. Our patient population consists almost solely of blunt trauma patients (where patients with penetrating injuries are suspected to benefit most from early presence of an experienced surgeon), the mortality rate is relatively low and the majority of trauma deaths in our institution is due to brain injuries. (24) Furthermore, the mandatory OH on-call response time was twenty minutes and with a senior surgical resident in house, resuscitation processes were already at a high standard for most patients. Unfortunately, we were not able to assess preventable deaths, functional recovery and quality of life, as

that was beyond the scope of this study. As debated previously, in our pursuit to optimize trauma care, we aim to improve all individual elements in the chain of care in our hospital and thus focused on the process-related outcomes of the in-house schedule.

The volume of a trauma center might have impact on the efficiency analysis of IH attendings, as in-house staff is supposedly most beneficial for patients with poor baseline status (thus, a relatively small part of the total number of patients). (25) Therefore, the findings of our study are not generalizable to every institution delivering care to trauma patients. For low-volume trauma centers not dealing with severely injured patients frequently, having an IH attending may be less favorable due to the number of surgeons needed on the schedule, with increased costs and only little effects on outcomes and process-related factors expected. However, for larger volume hospitals treating multiple injured patients, an IH schedule is feasible and likely beneficial. The presence of IH attendings resulted in improved utilization of resources and reduced ED transit time, thereby increasing the availability of the resuscitation bays and nurses at the ED.

Our study has several strengths. First, as we excluded all patients presenting six months prior or after the transition to the IH schedule, we reduced possible effects of anticipation on and first implementation of the new call schedule on our outcomes. Second, our retrospective before-and-after study was based on prospectively gathered data continuously monitored by trained data managers and a trauma surgeon. Third, we present a large series with a large time span providing a complete overview of processes potentially influenced by trauma surgeons. This study also has its limitations. To our knowledge, there were no major transitions during our study period except for the attendance policy and 24/7 availability of ICU beds in the second half of the IH period. The availability of this latter resource will have influenced the shorter time to ICU admission in the in-house period. Therefore, this finding should not be attributed to continuous presence of IH attending surgeons alone. However, the availability of an ICU bed will not have affected the time to emergency surgery. As the time to this intervention also decreased in the second period, we do believe that part of the faster ICU admission also reflects the change in personnel structure (for example due to attending-to-attending communication with the ICU staff). The historical control design poses its limitations. We were not able to account for the precise difference in surgeon response time, as we

did not have data on the arrival time of the out of hospital calls (mandatory response time was twenty minutes) and nor were we able to retrieve the number of cases in the OH period where an attending surgeon was present at the bedside on arrival. As trauma surgeons will have been present at presentation of severely injured patients during the out-of-hospital period as well, especially during daytime but also 'off hours', the results of the present study may even underestimate the true effects of continuous presence of experienced surgeons. During the IH period, AIS coding has been updated, which is known to reduce ISS scores. (26) This may have caused presence of more severely injured patients in the IH group, potentially causing another underestimation of the effects of IH trauma surgeons.

Conclusions

In conclusion, introduction of a 24/7 in-house attending trauma surgeon in a large volume Level 1 Trauma Center led to improved process-related outcomes, especially for the most severely injured patients. There is a clear benefit of the continuous presence of physicians with sufficient experience in trauma care in hospitals treating a large number of severely injured patients.

Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi: <https://doi.org/10.1016/j.injury.2018.08.006>.

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Chapter

9

Effects of the application of a checklist during trauma resuscitations on ATLS adherence, team performance, and patient-related outcomes: a systematic review

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Abstract

Purpose

In this systematic literature review, the effects of the application of a checklist during in hospital resuscitation of trauma patients on adherence to the ATLS guidelines, trauma team performance, and patient-related outcomes were integrated.

Methods

A systematic review was performed following the Preferred Reporting Items for Systematic Reviews and Meta-analyses checklist. The search was performed in Pubmed, Embase, CINAHL, and Cochrane inception till January 2019. Randomized controlled- or controlled before-and-after study design were included. All other forms of observational study designs, reviews, case series or case reports, animal studies, and simulation studies were excluded. The Effective Public Health Practice Project Quality Assessment Tool was applied to assess the methodological quality of the included studies.

Results

Three of the 625 identified articles were included, which all used a before-and-after study design. Two studies showed that Advanced Trauma Life Support (ATLS)-related tasks are significantly more frequently performed when a checklist was applied during resuscitation. [14 of 30 tasks ($p < 0.05$), respectively, 18 of 19 tasks ($p < 0.05$)]. One study showed that time to task completion (-9 s, 95% CI = -13.8 to -4.8 s) and workflow improved, which was analyzed as model fitness (0.90 vs 0.96; $p < 0.001$); conformance frequency (26.1% vs 77.6%; $p < 0.001$); and frequency of unique workflow traces (31.7% vs 19.1%; $p = 0.005$). One study showed that the incidence of pneumonia was higher in the group where a checklist was applied [adjusted odds ratio (aOR) 1.69, 95% Confidence Interval (CI) 1.03–2.80]. No difference was found for nine other assessed complications or missed injuries. Reduced mortality rates were found in the most severely injured patient group (Injury Severity score > 25 , aOR 0.51, 95% CI 0.30–0.89).

Conclusions

The application of a checklist may improve ATLS adherence and workflow during trauma resuscitation. Current literature is insufficient to truly define the effect of the application

of a checklist during trauma resuscitation on patient- related outcomes, although one study showed promising results as an improved chance of survival for the most severely injured patients was found.

Keywords

Trauma resuscitation · Checklist · Adherence · Process- and patient related outcome.

Background

A specialized trauma team should resuscitate severely injured trauma patients. The goal was to identify and treat life-threatening injuries at an early stage. Previous studies have shown that severely injured patients resuscitated by a trauma team have a higher chance of survival compared to trauma patients resuscitated without a trauma team. (1-4) Specialized trauma teams are composed of a variable number of medical specialists and paramedical workers and typically consist of a trauma surgeon or an emergency physician, an anesthetist, a radiologist, in some cases a neurologist emergency nurses, and a diagnostic radiographer. To reduce the time from injury to critical interventions, a predefined set of consecutive tasks is performed by the trauma team members. (5)

In most cases, available information about the health status of severely injured patients during resuscitation is limited, while there are potentially many different injuries that could be life-threatening. To adequately identify and treat potentially life-threatening injuries, a full-scale and structured assessment is required. The Advanced Trauma Life Support™ (ATLS™) guidelines are accepted worldwide and are the structural standard for the systematic resuscitation of trauma patients. (6)

The ATLS™ guidelines provide guidance to the trauma team during trauma resuscitation by prioritizing diagnostic and treatment procedures. Previous studies reported that tasks recommended by the ATLS™ guidelines are not always performed during trauma resuscitation, whereas adherence to ATLS™ guidelines varied between 42 and 82%. (7-11) Although procedures within the ATLS™ guidelines are constructed in a chronological and coherent manner, human factors may challenge the natural limitations of our memory. (12,13) A previous study at our institute illustrates that 35 tasks should be performed during the first 7 min, as recommended by the ATLS™. (14) Since there are many tasks

to fulfill in limited time, tasks could easily be overlooked. Thereby, common situations during trauma resuscitation such as stressful circumstances, sudden interruptions and lack of experience of trauma team members affect the capacity of memory and, therefore, may contribute to suboptimal adherence of ATLS™ guidelines. (15–18)

A checklist could complement the naturally limited human memory, which could be even more impaired by the stress felt during initial resuscitation. In general, a checklist could be used as a reminder, in order to completely and adequately fulfill a single complex procedure or a sequence of procedures. For example, safety checklists have been shown to improve medical care and have been used in medicine for several years. Thomassen et al. (10) performed a systematic review in 2014 and summarized medical literature to show the effects of safety checklist. Thirty-four studies were included, of which some had investigated well known-safety.

checklists such as the Surgical Patient Safety System (SURPASS) or the World Health Organization (WHO) surgical safety checklist. The auteurs concluded that the use of safety checklist had reduced mortality and morbidity in targeted patients groups. (19) In addition, safety checklists have strengthened compliance with guidelines, improved human factors, and reduced the incidence of adverse events. (19) Comparable positive effects were found by a more recent studies, of Ramsay et al. (20) who investigated the introduction of the SURPASS in Scotland and of de Jagger et al. (21) who performed a single center observational study, investigating the effect of the introduction of the surgical safety checklist with a follow-up time of 5 years.

The capability of checklists to complement human memory may also improve trauma resuscitation. Therefore, we aimed to systematically review the literature to determine the effects of the application of a checklist during trauma resuscitation of a trauma patient by a trauma team on adherence to the ATLS™ guidelines, trauma team performance, and patient-related outcomes.

Methods

The systematic review adhered to the preferred reporting items for systematic reviews and meta-analyses (PRISMA). (22)

Search strategy

A systematic search of studies listed in the electronic data- bases of Pubmed, Embase, CINAHL, and Cochrane was per- formed from their inception till January 2019. We combined the search terms derived from our research aim in separate search strings for each database (Table 1). Our search terms covered the intended population (Trauma resuscitation, including accessory search terms) and intervention (the application of a checklist, including accessory search terms). By purpose, we did not use search terms for outcomes, in order to avoid the introduction selection bias, as we intended to research all possible outcomes. In addition, all reference lists of included articles were screened for relevant additional citations.

Table 1: Each database-specific search term used to identify articles concerning subject matter

Database	Search terms
Pubmed	(“Checklist”[Mesh] OR checklist*[tiab] OR check list*[tiab]) AND (“Wounds and Injuries”[Mesh] OR Trauma[tiab]) AND (Primary Survey[tiab] OR Secondary Survey[tiab] OR resuscitation*[tiab] OR “Resuscitation”[Mesh] OR team*[tiab])
Embase	‘checklist’/exp OR checklist*:ab,ti OR (check NEXT/1 list*):ab,ti AND (‘injury’/exp OR trauma:ab,ti) AND (‘primary survey’:ab,ti OR ‘secondary survey’:ab,ti OR resuscitation*:ab, ti OR ‘resuscitation’/exp OR team*:ab,ti)
CINAHL	((MH “Checklists”) OR checklist* OR check list*) AND ((MH “Trauma”) OR (MH “Wounds and Injuries”) OR trauma) AND (Primary Survey OR Secondary Survey OR resuscitation* OR (MH “Resuscitation”) OR team*)
Cochrane	(checklist* OR check list*) AND (Trauma) AND (Primary Survey OR Secondary Survey OR resuscitation* OR team*) Limited on; Title, abstract, keywords

Eligibility criteria

Studies were included if the effect of the application of a checklist during resuscitation of trauma patients by a trauma team in an in-hospital setting was evaluated. We included studies with a randomized controlled—or controlled before- and-after study design. All other forms of observational study designs, reviews, case series or case reports, animal studies, and simulation studies were excluded. Solely English and Dutch publications from peer-review journals were reviewed. There were no restrictions on the year of publication, on the age of patients or on composition or method of application of a checklist during trauma resuscitation.

Study selection

First, all eligible studies were selected by screening the title and abstract. Second, all selected papers were screened full-text. During these two phases, two investigators independently selected articles according to the predefined eligibility criteria and discussed their results. In case of any unresolved disagreements, a third reviewer made the final decision using the same eligibility criteria. The resultant articles after the two phases of screening were included in our systematic review.

Data collection and critical appraisal

Two reviewers independently extracted and inserted the following data into tables: Authors, year of publication, study design, research population, checklist's items, composition, form, and application during trauma resuscitation and all identified effects reported by the included articles. To assess the methodological quality of the included studies, the Effective Public Health Practice Project Quality Assessment Tool (EPHPP tool) was applied. (23) This tool has been judged suitable to be used in systematic reviews of effectiveness (24) and has been reported to have content and construct validity. (25,26) Furthermore, this tool is a reliable instrument to assess the quality of randomized controlled trials and before-and-after studies, whereas the overall inter-observer coefficient was found to be 0.77 (95% CI 0.51–0.90). (27) This inter-observer coefficient value is considered as an excellent agreement. (28)

Results

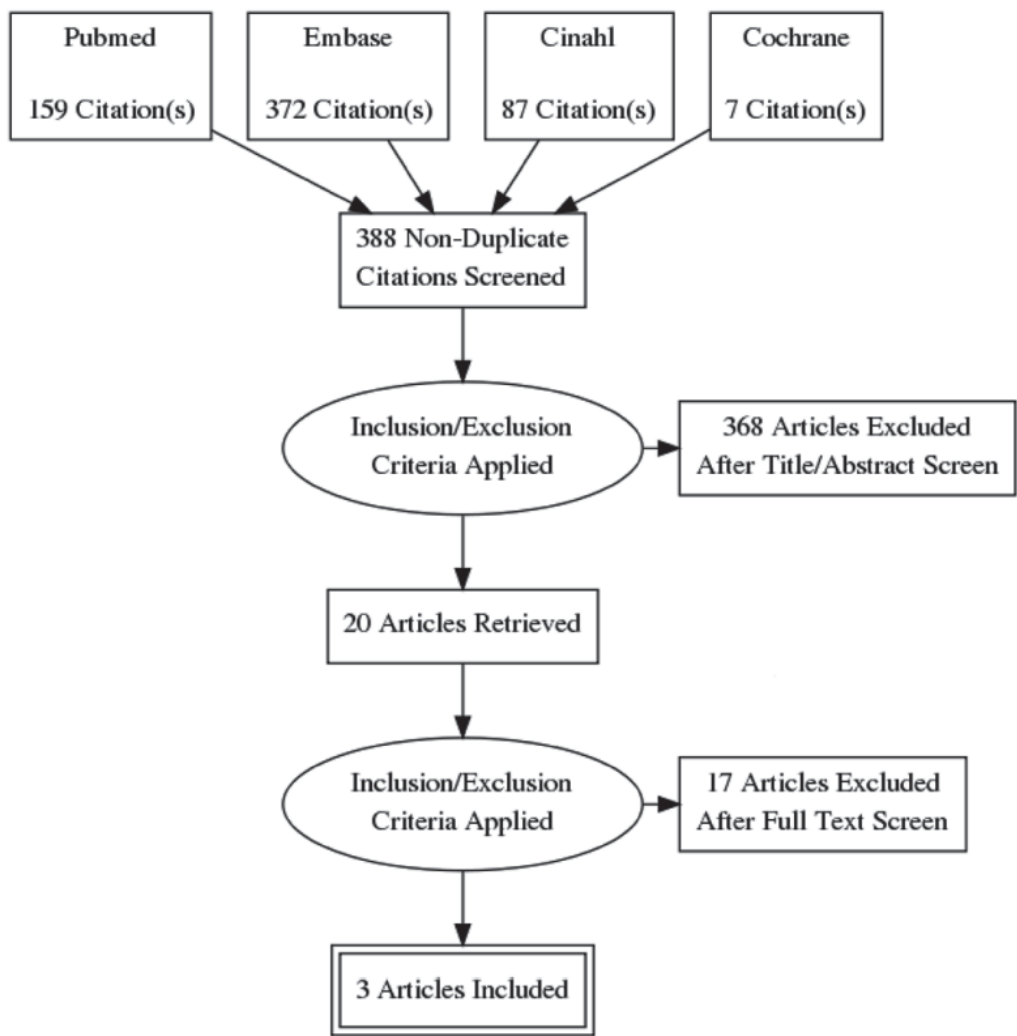
Selection

The search strategy yielded 625 potentially relevant titles and abstract. After screening title and abstract, 20 articles remained for full-text screening (Fig. 1). After screening the full texts of remaining articles, three studies were included in our systematic review. No additional studies were found by assessing the reference lists of included studies.

Study characteristics

All three included studies had a before-and-after study design to investigate the effect of the application of a checklist during trauma resuscitation. Two included studies of Kelleher et al. (29, 30) originated from the same pediatric trauma center and had the

Figure 1: Study attrition diagram



same sample. Two separate analyses and corresponding results were published in two different articles. (30) In their studies all trauma resuscitations had been captured on video during two 4-month periods and were analyzed retrospectively. They included 435 and 437 cases in their analyses, respectively. The third included study, of Lashoher et al., (31) was a multicenter study, including 11 hospitals in eight different countries. A random sample of 20% of all trauma resuscitations was assessed by live observant. Data collection duration varied among the different hospitals and ranged from 3 to 8 months pre- and 3–11 months post-implementation. In total, 3422 resuscitations had been assessed and the results were analyzed.

Critical appraisal

Using the EPHPP quality assessment tool, the quality of the two studies of Kelleher et al. (29, 30) and Lashoher et al. (31) were found to be moderate and weak, respectively (Table 3). Most concerning point that affected the quality of all three studies was the awareness of the participants (trauma team members) of being studied. This effect, also known as the Hawthorne effect, (32) could have influenced behavior during trauma resuscitations. Two other points of concern were found in the study of Lashoher et al.,(31) whereas no description of the randomization, withdrawal, and dropout of trauma resuscitations was provided.

Table 3: Critical appraisal following the Effective Public Health Practice Project Quality Assessment Tool

Authors	Selection bias	Study design	Confounders	Blinding	Data collection	Withdrawals and dropouts	Global rating
Kelleher et al. (29)	Moderate	Moderate	Strong	Weak	Moderate	Not applicable	Moderate
Kelleher et al. (30)	Moderate	Moderate	Strong	Weak	Moderate	Not applicable	Moderate
Lashoher et al. (31)	Weak	Moderate	Strong	Weak	Moderate	Weak	Weak

The checklists

Two different checklists were applied in the three included studies. A paper checklist was used in the two studies of Kelleher et al. (28, 29) The checklist was applied by the surgical team leader (surgical senior resident, fellow, or attending) or a member of the emergency medicine leader- ship team (emergency medicine fellow or attending) during junior resident or trauma nurse practitioner) and other team members.

In the study of Lashoher et al.,(31) the application of the World Health Organization Trauma Care Checklist was investigated. The WHO trauma care Checklist is based on a literature review of medical errors during initial resuscitation of severely injured patients (33) and contains 19 core items, of which 11 items are tasks also described in the ATLS™ guidelines. Hospital staff of all 11 hospitals participating in the study received checklist- and patient safety training. Furthermore, hospital staff of each participating hospital were

Table 2: Overview of included studies: used checklist, effect measured, main results and study quality

Study design/sites/ population/method	Checklist items/composition/ form/application	Effect measured	Main results	Global EHPPH rating
Kelleher et al. (29)				
Controlled before- and-after study	30 ATLS items	Adherence	Fourteen of the 30 ATLS tasks were completed more often after checklist introduction (for all $p \leq 0.01$)	Moderate
Monocenter	Local Delphi procedure		After adjustment the odds were 2.66 (95% CI 2.07–3.42) and 2.46 (95% CI 2.04–2.98) times higher for completing primary survey tasks, respectively, secondary survey after the introduction of a checklist	
435 pediatric trauma patients	Paper checklist	Time to task completion	Vital sign measurements were obtained faster ($p \leq 0.01$ for all) after the checklist was implemented	
Retrospective analysis of videotaped trauma resuscitations	Surgical or emergency medicine physician team leader		After adjustment primary survey tasks were performed faster ($p < 0.001$) after the checklist was implemented	
Kelleher et al. (30)				
Controlled before- and-after study	30 ATLS items	Workflow	After checklist implementation, the fitness (0.80 vs 0.91; $p = 0.007$) and conformance (26.1% vs 59.4%; $p = 0.01$) improved for resuscitations without notification	Moderate
Monocenter	Local Delphi procedure			
435 pediatric trauma patients	Paper checklist			
Retrospective analysis of videotaped trauma resuscitations	Surgical or emergency medicine physician team leader			
Lashoher et al. (31)				
Controlled before- and-after study	19 core items of which 11 are ATLS items	Adherence	18 of the 19 tasks clinical tasks were significant ($p < 0.02$ more frequently)	Weak
Multicenter, 11 sites	Based on literature review of medical errors during initial resuscitation of severely injured patients	Complications	The incidence of one of the ten complications (pneumonia) was slightly higher after the introduction of the checklist (AOR 1.69, 95% CI 1.03–2.80). There AOR for the other nine complications was not significantly different	
3422 adult trauma patients	Not described	Missed injuries	Incidence of missed injuries did not differ before and implementation of a checklist (AOR 0.62; 95% CI 0.19–2.03; $p = 0.437$)	
Trauma resuscitation was assessed by live observants	Not described	Mortality	(AOR 0.62; 95% CI 0.19–2.03; $p = 0.437$) Trauma resuscitation was assessed by live observants Not described Mortality No difference in odds of mortality in the overall study sample (OR 1.02; CI 0.77–1.34 $p = 0.904$ 50% reduction (AOR 0.51; 95% CI 0.30–0.89; $p = 0.018$) in mortality among patients with the most severe injuries (ISS > 25)	

encouraged to modify the checklist to be relevant in their unique setting. The study team of the core checklist approved site-specific final versions. The responsible member of the trauma team and form (e.g. paper or electronic) of the checklist during resuscitation was not described in the included article.

Effects measured

Six different outcomes-related to the applications of a check- list during trauma resuscitation were identified: Mortality, complications, missed injuries, task adherence, mean time to task completion, and workflow. junior resident or trauma nurse practitioner) and other team members. In the study of Lashoher et al., (31) the application of the World Health Organization Trauma Care Checklist was investigated. The WHO trauma care Checklist is based on a literature review of medical errors during initial resuscitation of severely injured patients (33), and contains 19 core items, of which 11 items are tasks also described in the ATLS™ guidelines. Hospital staff of all 11 hospitals participating in the study received checklist- and patient safety training. Furthermore, hospital staff of each participating hospital were encouraged to modify the checklist to be relevant in their unique setting. The study team of the core checklist approved site-specific final versions. The responsible member of the trauma team and form (e.g. paper or electronic) of the checklist during resuscitation was not described in the included article.

Effects measured

Six different outcomes-related to the applications of a check- list during trauma resuscitation were identified: Mortality, complications, missed injuries, task adherence, mean time to task completion, and workflow.

Mortality

Lashoher et al. (31) found no difference in odds of mortality in the overall study sample after adjusting for patient demographics and injury severity. After an injury-severity-stratified analysis, checklist implementation was associated with a 50% reduction (adjusted odds ratio (aOR) 0.51, 95% Confidence Interval (CI) 0.30–0.89) in mortality among patients with the most severe injuries (Injury severity score > 25). No such association was found among patients who were less severely injured (injury severity score < 25). (31)

Complications

Only the incidence of one of the ten complications, pneumonia, was slightly higher after the introduction of the checklist after adjusting for patient characteristics (aOR 1.69, 95% CI 1.03–2.80) in the study of Lashoher et al. (31) No differences were found for the other nine assessed complications. (31)

Missed injuries

The incidence of missed injuries was zero in both groups and did not differ before and after implementation of a checklist after adjusting for patient characteristics and injury severity (aOR 0.62; 95% CI 0.19–2.03; $p = 0.437$) in the study of Lashoher et al. (31)

Task adherence

Fourteen of the thirty ATLS-related tasks that had been assessed in the study of Kelleher et al. (29) were completed significantly more frequently after checklist introduction (for all $p \leq 0.05$). None of the 30 ATLS-related were performed less frequently. After adjustment for type of resuscitation factors and type of tasks (tasks were not further specified), the odds of completing primary survey tasks were 2.66 (95% CI 2.07–3.42) times higher after implementation, and the adjusted odds of secondary survey task completion were 2.46 (95% CI 2.04–2.98) times higher. Lashohor et al. (31) found 18 of the 19 clinical tasks to be significantly ($p < 0.05$) more frequently performed after implementation of the WHO trauma care checklist.

Mean time to task completion

Kelleher et al. (30) found that the average adjusted time to task completion was 9 s faster with the application of a checklist (95% CI –13.8 to –4.8 s) Furthermore, six of the 12 primary survey tasks (full exposure, temperature measurement, blood pressure, heart rate measurement, respiratory rate measurement, and oxygen saturation) were performed significantly (all $p < 0.05$) faster (–20 till –43 s). (29)

Workflow

A predefined ideal process model of six ATLS primary survey tasks was created in the study of Kelleher et al. (30) The six ATLS tasks were categorized into Airway (A), Breathing

(B), Circulation (C), and Disability (D) which is well known from the ABCDE mnemonic as described in the ATLS Guidelines. The model required that “A” tasks are done before “B” tasks, “B” tasks are done before “C” tasks, and “C” tasks are done before “D” task. Model fitness (degree of agreement with the ideal process model, ranging from 0 to 1), conformance (“yes” if fitness 1; “no” if fitness < 1) was measured and the frequency of unique workflow traces were analyzed. Besides the comparison of the application of a checklist, analysis of a brief pre-arrival notification was performed. The authors found that after implementation of a checklist workflow improved. Model fitness (0.80 vs 0.91; $p = 0.007$), conformance frequency (26.1% vs 59.4%; $p = 0.01$), and number of unique workflow traces (19 vs 16; $p = 0.01$) improved for resuscitations without notification. Comparable improvement was shown after the implementation of the checklist when a brief notification was given, in which case Model fitness (0.90 vs 0.96; $p < 0.001$), conformance frequency (50.8% vs 77.6%; $p < 0.001$), and frequency of unique workflow traces (63 vs 35; $p = 0.005$) also improved. Finally, the effect of the absence of pre-arrival notification on model fitness was also smaller after checklist implementation compared to before the use of the checklist (Cohen’s $d = 0.75$ (95% CI 0.73–0.82) vs. Cohen’s $d = 0.52$ (95% CI 0.51–0.56)).

Discussion

Our systematic review shows that the application of a checklist may improve adherence to ATLS guidelines and workflow during resuscitation. Furthermore, we found that the application of a checklist might lead to a reduction of mortality among severely injured patients. However, there was no effect found on missed injuries and the incidence of one out of ten complications investigated was even slightly higher when a checklist was applied during resuscitation.

Several limitations in our systematic review and included studies should be considered. First, only three studies could be included and besides adherence to task performance, all effects including patient-related outcomes were investigated only in one study per effect. Therefore, no meta-analysis or other forms of analysis were performed on the collected data. Second, the quality of the only study investigated patient-related outcome was weak. (31) The limitations in this study may have affected the effect of a checklist on patient-related outcomes. For example, the increased incidence of pneumonia in patients resuscitated

with the application of a checklist is unexpected. The authors clarified that there may be systematic errors or misclassifications in both process and outcome measures, such as different available imaging modalities across centers for the diagnosis of complications such as pneumonia. Furthermore, the incidence of missed injuries was zero in both groups. Previous studies, however, show that missed injuries vary between 1.3 and 39%. (34) These low numbers may, therefore, be a result of information bias, which was caused by suboptimal registration of missed injuries. Furthermore, the study of Lashoher et al. (31) did not only measure the effect of a checklist on trauma resuscitation. Hospital staff received checklist- and patient safety training in the context of trauma care and, therefore, the impact of checklist implementation was also studied. Third, the populations of two of the three studies were pediatric trauma patients. Although ATLS principles are used for resuscitation of injured children and adult patients, interpretation of cardiorespiratory variables, airway anatomy, response to blood loss, thermoregulation, and the trauma team composition are different in pediatric resuscitation and may have influenced ATLS adherence rates and workflow. (35,36)

Finally, different checklists were applied in the included studies. We did not predefine the type and application style of the checklist for trauma resuscitation since we did not find any evidence in literature on optimal composition and application of checklists during trauma resuscitation. The composition of the checklists was different in the included studies, whereas 30 items were included in the checklist applied in the Kelleher studies and in the study of Lashoher et al. (31) 14 tasks with variation per hospital were formed based on a literature search.

Although this systematic review and included articles have several limitations, the application of a checklist during trauma resuscitation may improve patient- and process-related outcomes. The improvement of ATLS adherence is in line with the results of studies investigating the application of checklists in other fields of medicine, whereas adherence to guidelines for surgical safety procedures and adherence to protocols improved. (20, 37–42)

Additional research is needed for a more reliable estimation of the effect of the application of a checklist during trauma resuscitation on patient's- and process-related outcomes.

Future studies investigating the effect of the application of a checklist should use a before-and-after study design, whereas in a randomized controlled design introduces recall bias as the members of the trauma team not using the checklist are likely to remember details about the checklist. To minimize bias by observers, the same observer(s) should assess the trauma resuscitations. Analyzing videos of recorded trauma resuscitations could obviate the need for multiple observers to observe all resuscitations, especially during the night and weekend, or when there are multiple trauma resuscitations at the same time. Furthermore, missed injuries should be actively searched, for example, by a 30-day follow-up with a clinical re-evaluation of included patients and a retrospective re-evaluation of performed diagnostic imaging. Finally, to our knowledge, no research has been performed to investigate optimal checklist composition and application for trauma resuscitation. Improvement of composition and application may improve the user-friendliness of a checklist and may potentially improve the trauma resuscitation process even further.

Although the evidence is marginal, the application of a checklist during trauma resuscitation seems to improve processes during trauma resuscitation and may even improve the chance to survive for the most severely injured patients. Thereby, no adverse events were noticed at the three included studies. On the other hand, the implementation of a checklist may be paired with several barriers. In the study of Nolan et al. (43) barriers to implementing the World Health Organization's Trauma Care Checklist are described, including unclear roles, lack of enforcement, poor understanding of the purpose and professional hierarchy. These barriers were comparable to barriers that have been described by previous studies investigating the implementing of the WHO's Surgical Safety Checklist, (44–47) which have shown to reduce mortality and morbidity. (20,48)

In conclusion, considering the results of our systematic review including limitations and included studies, the application of a checklist could be useful and may be considered to be introduced into daily practice. Further research is needed for a more reliable estimation of the effect of the application of a checklist during trauma resuscitation on patient- and process-related outcomes.

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Author contributions

OEC defined the search strategy and eligibility criteria, supervised study selection, interpreted data, wrote the major part of the manuscript, acts as corresponding author, and checked the references. WHW Supervised development of work, wrote parts of the manuscript, helped in data interpretation, and manuscript evaluation. NLM and TFF performed study selection, wrote parts of the manuscript and checked the references. LPH Supervised development of work, helped in data interpretation and manuscript evaluation.

Conflict of interest

The author declares that they have no competing interests.

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Chapter

10

Summary and Future Perspectives

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Summary

The resuscitation of severely injured patients is one of the most challenging processes in healthcare. A trauma team must assemble rapidly at unpredictable times and must be prepared for unique and chaotic circumstances involving one or more patients with unknown injuries. Historically, the assessment and resuscitation by a varied spectrum healthcare professionals acting together as a team has improved the care of critically injured patients. The central goal of this thesis was to gain knowledge of how to enhance trauma team performance. The focus of this thesis is on evaluating, organizing and supporting trauma teams in order to enhance trauma resuscitations.

Part 1 describes the origin and development of the trauma team and outlines the importance of team organization, training, and evaluation.

Chapter 1 introduces the trauma team and the context in which a trauma team provides care for severely injured. Thereby the importance of gaining knowledge of evaluation, organization and support of trauma teams to achieve enhance trauma team performance are described together with an outline of this thesis.

Chapter 2 outlines the importance of team organization, training, and evaluation. The trauma team is a multidisciplinary group of health-care professionals who collaborate during the in-hospital resuscitation of severely injured patients. As the initially the injuries of the patients are unknown and potential life threatening, an effective and systematic approach is required to identify and treat these injuries rapidly. A team focused approach allows for the distribution of the tasks involved in the patient's assessment and resuscitation among several healthcare professionals, which result in a shorter interval between injury and essential interventions. The trauma team leader is responsible for a well-coordinated resuscitation and decision making. Furthermore, we described that simulation training of teams improves technical skills and teamwork (non-technical skills), which results in improved team performance. Finally, we described that video analysis of real and simulated trauma resuscitations can be used for training and audit.

Part 2 evaluates the use of video analysis as method to evaluate trauma resuscitations.

Chapter 3 reported and discussed the results of comparing live observations to video analyses as methods to analyze trauma teams. Validity and reliability during simulated and real-life resuscitations of these two methods were compared. Live observers and video analysts both attempted to identify a predefined list of twenty-eight tasks based on the Advanced Trauma Life Support guidelines and then the results of the live observers and video analysis were compared. The main finding was that video analysis was more valid for purposes of reviewing Advanced Trauma Life Support adherence, as more tasks could be identified. Further, the video analysis was more reliable as there was a higher interrater agreement among video analysts when compared to the live observers. These results indicate that a video analysis of trauma resuscitation is a better method than live observations for evaluating a trauma team.

Chapter 4 describes an observational study where the reliability of video analysis to assess non-technical skills was evaluated. Here we used T-NOTECHS, which stands Trauma Nontechnical Skills. The T-NOTECHS is a valid and simple instrument developed in previous research to assess non-technical skills of the trauma team during trauma resuscitations. Analyzing non-technical skill with the video analysis method was more reliable than live observations in previous studies. All this indicates that video analysis is the method of choice when analyzing the non-technical skills of the trauma team.

Part 3 discusses how the composition of the trauma team influences trauma team performance and introduces methods to support the trauma team and improve its performance.

Chapter 5 evaluates the extent of variation in trauma team staffing. Trauma team composition of consecutive resuscitations were evaluated using video analysis. During a one-week period the composition of the trauma teams consisted of more than 101 unique members and on average two-thirds of the trauma team staff rotated during a successive resuscitation. The circumstances during the resuscitations of severely injured patients are stressful and sometimes unpredictable, which requires highly adaptive teams. Therefore, extrapolating from the findings of extremely high variation in trauma team composition and existing literature on familiarity within teams, trauma team performance may be enhanced when there is less variance in staffing.

Chapter 6 describes a before and after study where the effects of introducing an on-site

trauma surgeon and the effect their presence has on resuscitation pace and guidelines were evaluated. Before to this transition, trauma surgeons were available for on-call consultation and a senior resident in general surgery served as house officer. The trauma team leader is responsible for the coordination of the team members and should give direction regarding the clinical and logistical implications during the resuscitation. With that in mind, it is reasonable to argue that the presence of on-site surgeon, who are more experienced trauma team leaders, result in improved quality of care for severely injured patients. This argument is strengthened by the results of the study as directly after the introduction of an on-site trauma surgeon, there was an acceleration of the resuscitation process and improvements in adherence to Advanced Trauma Life Support guidelines.

Chapter 7 describes a before-and-after study where process-related outcomes were analyzed after the introduction of a new attendance policy. An in-house attending trauma surgeon replaced the out-of-hospital (OH) on-call attendance policy, while before this transition a senior resident in general surgery served as house officer. In this study, we found an acceleration of the initial care of severely injured patients as patients spent less time in the emergency department, reached the Intensive Care Unit earlier, and the number of patients that reached the operating room within half an hour doubled. These results indicate that having more experienced trauma team leaders enhance the care of severely injured patients.

Chapter 8 extends an observational study on successive trauma resuscitations. More experienced staff trauma surgeons acting as trauma team leaders were compared to their less experienced fellow trauma surgeon colleagues. The pace of resuscitations led by a staff trauma surgeon was found to be faster than resuscitations led by a fellow trauma surgeon, which further indicates that a team leader with more experience in leading trauma resuscitations is required for optimal care of severely injured patients. Secondly, there is a strong correlation between severity of injury and resuscitation pace as patients suffering from more severely injuries were resuscitated faster. This strong correlation is thought to be a result of situational awareness of the team (patients needing treatment fast) leading to an expedited resuscitation.

Chapter 9 describes the results of a systematic review of the literature on the application

of a checklist during the trauma resuscitations. The main finding was that the application of a checklist during trauma resuscitation improves adherence to Advanced Trauma Life Support guidelines, enhance workflow during trauma resuscitation, and may even improve the chance of survival for the most severely injured patients. As a result, the application of a checklist could be useful, and its introduction should be considered to support the trauma team.

Future Perspectives

There is continuous drive to optimize healthcare for severely injured patients. In the next paragraphs suggestions are made to introduce higher stands for organization, support and evaluation of trauma teams.

Evaluation

Higher Standards for Evaluation

To obtain a better understanding of the interplay of the complex team and task-based challenges during trauma resuscitation, we propose to use a synchronized data capturing system and analysis platform including machine learning techniques, like the OR black box as described for the OR environment. (1) This system should continuously capture video and audio during trauma resuscitations, as well as patient physiological data, environmental data, and imaging data. In the trauma bay, multiple wall-mounted cameras and microphones should be installed in order to capture team positioning, movements, and communication. Furthermore, sensors and data synchronization of existing vital signs and imaging capturing systems should be implemented. For further analysis, all data should be anonymized, synchronized, encrypted, and securely stored. Expert analysts and software-based algorithms should analyze the entire resuscitation process and individual technical and non-technical skills. This novel evaluation system could play an important role in continued efforts to improve trauma resuscitations, without the need for extended workload of personnel. An advantage of utilizing machine learning techniques is that more data could be analyzed by computers which also reduces the workload of human reviewers.

Although there are currently no reports of institutes using such a system in trauma bay, very similar technology has used to evaluate surgical procedures in the Operating Room (OR) during surgical procedures and is called the OR Black Box. (1) Within the last

decade, the OR black Box has been used to identify distractions, adverse events, and to evaluate teamwork during surgical procedures in the OR. For instance, a recent report of one year's worth of data using this technology revealed that there were 138 distractions per surgical procedure and a medians of 20 intraoperative mistakes. (2) Another recent study using captured audio, video, and synchronized data of the patient's vitals found that the non-technical skills of the surgical team could be measured reliably using the Non-Technical Skills for Surgeons (NOTSS) behavior marker system. (3,4)

Support

Clinical decision support

Strategies to improve trauma teams have traditionally focused on technical and non-technical skills training, as well as retrospective evaluations of their management during specific cases. (5–8) However, these methods do not actively support the trauma team in anticipating adverse events, nor do they help in decision making during the trauma resuscitation itself. The suggested improved data collecting method, in combination with available artificial intelligence techniques to interpret the data, pave the way for real-time predictions of a patient's physiological state and decision support. Warnings for upcoming events and real time treatment suggestions may be given to the trauma team to help them make clinical decisions. An example of how such a system could work was described in the article of Lundberg et al in 2018,(9) where they revealed an artificial intelligence based warning system called 'Prescience' that was able to predict hypoxemia during surgical procedures up to 5 minutes in advance. This system continuously analyzes vital signs and delivers a risk score to the clinician that updates in real time, along with the rationale for its predictions, which would be extremely useful in a trauma resuscitation.

Electronic Medical Records

Electronic Medical Records aim to improve patient care, but on the other hand administrative burden in healthcare is a well-known problem, and uncompleted descriptions of trauma resuscitations are common. However, this is due to issues such as the one described in Golob et al. (10) who stated that a busy trauma surgeon has a huge portion of their time dedicated to documentation. During a one-year period there were 3,111 patients admitted to their level one trauma center and the attending trauma surgeon wrote 26,455 documentation entries which took 1,760.5 hours to write. Beside

the heavy administrative burden, the notes that physicians and nurses write about trauma resuscitations and their findings are retrospectively written and this form documentation often lacks meaningful details and may even be inaccurate. (11)

Theoretically, data input from various sources (such as video, audio, sensors, existing data capturing of vital signs and imaging) can be linked to a patient's electronic medical records, allowing for improved patient records. Recently, Maas et al. (12) describes a system that is potentially able to automate medical reporting, and it consists of three phases that generate an electronic medical report. During the first phase, audiovisual and sensory data, including patient vital parameters, are collected and synchronized. During the second phase, data are interpreted by using and combining speech recognition and motion recognition techniques. In the case of trauma resuscitation, a simple example is that the introduction of an IV line can be detected by using motion recognition. A more advanced example is that the results of auscultation could be detected first by motion recognition (physician listening to the lungs) and speech recognition (physician sharing findings to the rest of the team) while finishing by combining the results. The third phase the medical report is generated during a complex process, which in detail is described by Maas et al. (12) In short: extrapolated text is used to document trauma resuscitations, the medical report generation is based on a database of previous reports, ATLS guidelines and the data gathered during the trauma resuscitation. Artificial intelligence techniques make it possible to combine these elements to a complete and understandable medical documentation.

Organization

Managing a severely injured patient in the trauma bay poses significant demands on the management process, and multiple specialties are involved in the acute and dynamic setting of trauma resuscitations. The foundation of consistent and good quality handling of these resuscitations is fine-tuned teamwork among these different medical disciplines to achieve a streamlined and simultaneous execution of tasks. Teamwork within trauma teams has gained attention last decades and it has become widely acknowledged that the non-technical skills of trauma team members are an important part of having and maintaining effective teamwork between physicians, nurses and ancillary personnel during trauma resuscitation. (13–16) It is critical for every hospital to have a trauma resuscitation algorithm that coordinates amongst the specialties involved and to practice

together on a regular basis in order to engaged trauma team members to be familiar with these algorithms. Nevertheless, most of the focus, when it comes to teamwork, has been on trauma team training, while team composition and staffing have unfortunately received less attention.

The trauma team leader is an important part of the trauma team and is responsible for the team coordination as well as keeping track of the clinical and logistical implications during the resuscitation. (17–19) With that in mind, experienced trauma surgeons may be able to see the big picture and concomitant treatment requirements more quickly than their less experienced colleagues. Previous studies have shown that a more experienced trauma team leader speeds up the pace of trauma resuscitations and could lead to a reduction on mortality. (20,21) Experienced trauma team leaders are most beneficial for patients requiring fast intervention to treat acute life threatening injuries such as a severe hemorrhage. (22) Therefore, trauma centers should consider having a trauma team that includes an experienced trauma team leader in cases where a resuscitation with a high pace is desired, which is typically the resuscitation of the most severely injured patients. For every trauma center, resuscitation of the most severely injured patients by experienced trauma team leaders is likely beneficial for patient outcome, however it is intuitively more feasible to organize a staff occupation with enough experienced surgeons at larger volume trauma centers. Besides the benefits an experienced trauma team leader brings during the trauma resuscitation, their additional experience for managing the severely injured may also have beneficial implications for the process after the resuscitation in the trauma bay, such as time to the operation room or additional imaging. For the management pace of severely injured patients, a recent systematic review showed that ten out of sixteen included studies found at least one process related outcome was improved after implementing an in-house attendance policy for trauma surgeons instead of the on-call attendance policy during which less experienced surgical residents act as the house officer. (23)

Finally, staffing variation should get more attention as the nature and consequences of staffing changes within trauma teams is understudied. Previous studies showed that familiarity between team members improved results for teamwork, processes or patient care in trauma teams during simulated resuscitations, (24), vascular surgical teams, (25) abdominal surgical teams, (26) and gynecological surgical teams. (27) Trauma teams

may benefit even more from familiarity, since, in contrast to predictable circumstances during elective surgery or simulated environments, the circumstances during severe injury resuscitations are more stressful and unpredictable, necessitating highly adaptive teams that could rely on their team members. More familiarity within teams could be achieved by less staffing variation within teams. This could be achieved by forming literally forming multiple trauma teams within one trauma center. We propose that each team's core group should be composed of a limited number of team members and should vary relatively little over time. The core group of team members should consist of members who accomplish the majority of the actions and/or bear most of the responsibility during trauma resuscitations. Finally, the team members of the same team should then be scheduled concurrently.

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Samenvatting in het Nederlands

De opvang van zwaar gewonden patiënten is een van de meest uitdagende processen binnen de gezondheidszorg. Een trauma team moet snel bijeenkomen op onvoorstelbare momenten en breid zijn voor unieke en chaotische omstandigheden waarin één of meer patiënten komen met nog onbekende verwondingen. De opvang van ongevalsslachtoffers door een samenwerking van een breed spectrum aan zorgprofessionals heeft de zorg voor zwaar gewonden patiënten over de tijd verbeterd. Het centrale doel van dit proefschrift is om kennis te vergroten over de evaluatie, organisatie en ondersteuning van trauma teams om zodoende de opvang van ongevalsslachtoffers te verbeteren. Deel 1 beschrijft het ontstaan en de ontwikkeling van trauma teams en geeft een overzicht waarom team organisatie training en evaluatie van belang is.

Hoofdstuk 1 introduceert het trauma team en de context waarin het trauma team zorg verleent aan zwaar gewonden patiënten. Daarbij wordt de importantie van het vergaren van kennis over evaluatie, organisatie en ondersteuning van trauma teams om zodoende tot betere prestaties van het trauma team te komen beschreven en wordt een uiteenzetting van dit proefschrift gegeven.

Hoofdstuk 2 geeft een overzicht van het belang van organisatie, training en evaluatie. Trauma teams zijn multidisciplinaire groepen van zorgprofessionals die samenwerking gedurende de opvang van ongevalsslachtoffers in een ziekenhuis. Aangezien bij aanvang de verwondingen van de patiënt onbekend en potentieel levensbedreigend zijn, is een effectieve en systematische aanpak vereist om zodoende deze verwondingen snel op te sporen en te behandelen. Een team gestuurde aanpak maakt het mogelijk om taken te verdelen die nodig zijn om de patiënt zijn of haar verwondingen snel in kaart te brengen. Deze verdeling moet ervoor zorgen dat het tijdsinterval tussen de verwonding en essentiële behandeling daarvan korter word. De leider van het trauma team is verantwoordelijk voor een goed gecoördineerde opvang en het nemen van beslissingen. Daarnaast wordt in dit hoofdstuk beschreven dat simulatietrainingen van teams zowel de technische als teamwork (niet-technische vaardigheden) verbeterd, wat resulteert in een betere teamprestatie. Tot slot beschrijven we dat video analyse van echte of gesimuleerde trauma opvangen gebruikt kan worden voor training en kwaliteitsdoeleinde.

Deel 2 evalueert het gebruik van video analyse als een methode om de opvang van

ongevalsslachtoffers te evalueren.

Hoofdstuk 3 beschrijft en bediscussieert de resultaten van een vergelijking tussen live observaties met video analyses als methodes om trauma teams te analyseren. De validiteit en betrouwbaarheid van deze twee methodes werden bij zowel simulaties en echte opvangen van ongeluisslachtoffers vergeleken. Live observanten en video analisten probeerde beiden op een vooraf opgestelde lijst van achtentwintig taken (gebaseerd op de Advances Trauma Life Support richtlijnen) te identificeren. De resultaten hiervan werden met elkaar vergeleken. De belangrijkste bevinding was dat video analyse meer valide is om de naleving dan de Advances Trauma Life Support richtlijnen te evalueren, aangezien er meer taken werden geïdentificeerd. Daarnaast is video analyse betrouwbaarder vergeleken met evaluatie met live observanten. Deze resultaten duiden erop dat video analyse van de opvang van ongeluisslachtoffers een betere methode is dan live observanten voor evaluatie van het trauma team.

Hoofdstuk 4 beschrijft een observationele studie waar de betrouwbaarheid van video analyse van niet-technische vaardigheden werd geëvalueerd. We hebben de T-NOTECHS gebruikt. Wat staat voor Trauma Niet Technische Skills. De T-NOTECHS is een valide en simpel instrument, die is ontwikkeld in voorgaand onderzoek om niet-technische vaardigheden van het trauma team gedurende de opvang van ongeluisslachtoffers te onderzoeken. Analyseren van niet-technische vaardigheden bleek uit deze studie met video is betrouwbaarder dan tot nu toe was beschreven in de literatuur met live observanten. Dit duidt erop dat video analyse de methode van keus is voor het analyseren van niet-technische vaardigheden van het trauma team

Deel 3 bediscussieert hoe de samenstelling van het trauma team invloed heeft op haar prestatie en hoe de teamprestaties verder kunnen worden verbeterd.

Hoofdstuk 5 evalueert de mate van variatie in de samenstelling van het trauma team. De samenstelling van het trauma team achtereenvolgende opvangen van ongeluisslachtoffers in het UMC Utrecht werden geëvalueerd met video analyse. Gedurende een periode van een week werden er 101 unieke leden van trauma teams geïdentificeerd. Gemiddeld was twee-derde van het trauma team vervangen bij de daaropvolgende trauma opvang.

De omstandigheden gedurende de opvang van ernstig gewonden patiënten kunnen stressvol en soms onvoorspelbaar zijn. Dit maakt dat teams een hoog aanpassingsvermogen dienen te hebben. Als we de resultaten die we gevonden hebben van extreem hoge variatie van samenstelling van trauma teams en de huidige literatuur over bekendheid van elkaar binnen teams extrapoleren, zouden trauma teams erbij gebaad kunnen zijn als er minder variatie van samenstelling zou zijn.

Hoofdstuk 6 beschrijft een voor-en-na studie, waar het effect van de introductie van de aanwezigheid van een trauma chirurg en het effect van zijn of haar aanwezigheid op de snelheid van de opvang en naleving van de richtlijnen werden geëvalueerd. Voor de transitie waar trauma chirurgen oproepbaar en deed een oudste assistent heekunde de voorwacht. De trauma team leider is verantwoordelijk voor de coördinatie van het trauma team en moet beslissingen nemen over klinische en logistieke implicaties gedurende de opvang. Met dat in gedachten is het redelijk om te stellen dat de aanwezigheid van een chirurg ter plaatse, die meer ervaren traumateamleiders zijn, resulteert in een betere kwaliteit van zorg voor ernstig gewonde patiënten. Deze gedacht wordt versterkt door de resultaten van het onderzoek, aangezien er direct na de introductie van een traumachirurg ter plaatse een versnelling van het reanimatieproces was en verbeteringen in de naleving van de Advanced Trauma Life Support richtlijnen.

Hoofdstuk 7 beschrijft een voor-en-na studie waarin proces gerelateerde uitkomsten werden geanalyseerd als gevolg van nieuw aanwezigheidsbeleid van de trauma chirurg. Voorheen was de traumachirurg oproepbaar en had de oudste arts assistent heekunde een voowachtdienst en was in het ziekenhuis. Bij het nieuwe beleid was er altijd een traumachirurg in het ziekenhuis aanwezig. In dit onderzoek vonden we een versnelling van de eerste zorg van ernstig gewonde patiënten doordat patiënten minder tijd op de spoedeisende hulp doorbrachten, eerder op de Intensive Care kwamen en het aantal patiënten dat binnen een half uur de operatiekamer bereikte verdubbelde. Deze resultaten geven aan dat het hebben van meer ervaren traumateamleiders de zorg voor ernstig gewonde patiënten verbetert.

Hoofdstuk 8 geeft de resultaten van een observationeel onderzoek naar opeenvolgende opvangen van ongevalsslachtoffers weer en bediscussieert deze. In dit onderzoek werden

de prestaties van het trauma team van opvangen van ongevalsslachtoffers waar meer ervaren traumachirurgen als trauma team leiders fungeerden (die staflid waren), vergeleken met opvangen waar minder ervaren collega traumachirurgen (die fellow waren) de leiding hadden. Het tempo van reanimaties onder leiding van een de meer ervaren staf-traumachirurg bleek sneller te zijn dan reanimaties onder leiding van een collega-traumachirurg, wat verder aangeeft dat een teamleider met meer ervaring in het leiden van traumareanimaties nodig is voor optimale zorg voor ernstig gewonde patiënten. Ten tweede is er een sterke correlatie tussen de ernst van de verwonding en het tempo van de opvang van ongevalsslachtoffers, aangezien patiënten met ernstiger verwondingen sneller werden opgevangen. Aangenomen wordt dat deze sterke correlatie het resultaat is van het bewustzijn van het team is (patiënten die snel behandeld moeten worden), wat leidt tot een versnelde opvang van ongevalsslachtoffers.

Hoofdstuk 9 beschrijft de resultaten van een systematische literatuurstudie over het toepassen van een checklist tijdens de opvang van ongevalsslachtoffers. De belangrijkste bevinding was dat het toepassen van een checklist tijdens de opvang van ongevalsslachtoffers de naleving van de Advanced Trauma Life Support-richtlijnen verbetert, de workflow tijdens traumareanimatie verbetert en zelfs de overlevingskans van de ernstigst gewonde patiënten verbetert. Het gebruik van een checklist zou daarom nuttig kunnen zijn en de invoering ervan zou moeten worden overwogen ter ondersteuning van het trauma team.



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