Polytrauma patient management: Processes and performance in the Netherlands and beyond

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General discussion

"*When I can provide better care in the field with limited resources than my children and I received at the primary facility, there is something wrong with the system and the system has to be changed.*"

Since Dr. Styner said those famous words, there have been many improvements in the field of trauma care, such as the introduction of the Advanced Trauma Life Support (ATLS) course and the implementation of all-inclusive trauma systems. Still, 5 million people die each year due to their injuries and 90% of these deaths occur in low- and middle-income countries.[1] The primary aim of this thesis is to analyze the trauma systems regarding their presence and organization in two high-income countries, their processes of care and their influence on clinical outcome of trauma patients. Although the low- and middle income countries carry the brunt of the trauma mortality burden, trauma continues to claim lives even in high-income countries. Given that high-income countries may serve as examples in developing trauma systems and establishing value-based care, we chose to focus on two countries, characterized by robust economies but also subject to different cultural, organizational, economic, and administrative principles. The second aim is directed towards individualized trauma care, specifically the evaluation of the role of nutritional status in polytrauma patients. To further improve trauma care both *globally* as a system and for the individual patient per se, many more questions need to be answered and challenges must be overcome. Several of these will be discussed below.

TRAUMA SYSTEMS

Injury prevention, pre-hospital care, facility-based care, and post-hospital care are all considered essential components of a mature trauma system [Figure 1].[2,3] The crucial part of a well-functioning trauma care system is that each of those four elements (Levels 1 through 4 trauma centers) work together to assure a seamless transition of patient care from each phase to the next; this is believed to result in improved outcomes and optimal utilization of resources. In addition, quality assurance by means of clinical training and registries, is considered an essential element of mature trauma systems.

Injury prevention

Injury prevention represents one of the great opportunities to: 1) further reduce mortality, 2) prevent long-term morbidity, and 3) lower the trauma burden and related costs. Many strategies for preventing injuries (such as improving road safety, installing smoke detectors, improving safety around the house, and firearm restrictions) have already shown to be both effective and cost-effective.[4,5] For example, in this thesis it was demonstrated that the proportion of patients admitted due to gun violence was almost

Figure 1. Components of a trauma system

twice as high in the USA compared to the Netherlands, despite both countries having comparable urbanization (population density 4200/km^2 in Boston versus 5000/km^2 in the Randstad region) and violent crime rates (respectively 390 and 360/100.000 population in Massachusetts and the Dutch region, respectively). **(Chapter 4)** However, despite having similar violent crime rates there is an enormous difference in firearm-related injuries; for example, there are many more mass shooting events in the USA.[6] The high numbers of firearm-related deaths could possibly be explained by the relatively lax laws on gun ownership in the USA, with more availability of firearms directly correlated to more firearm-related deaths.[7,8] The implementation of laws restricting firearm purchase or access, as a preventive measure have led in many countries, such as South Africa, New Zealand, Australia, and Canada, to a reduction in firearm-related deaths in those countries.[9-11]

The shift in paradigm in the recent era to an increase focus on injury prevention has resulted in many new initiatives. Examples are the "Stop the Bleed" initiative in the USA and new restrictive laws for telephone use while operating a bicycle or automobile in the Netherlands.[12,13] Other effective preventive strategies include programs aimed at preventing falls and fall-related injuries in the elderly. Each year, 25% of elderly (age > 65 years) fall and in 10-25% of the cases this results in injury, hospital admission, or

even death.[14,15] Randomized controlled trials have consistently shown that strength and balance training for the elderly can reduce falls by 15-50%.[16]

Gaining insight into epidemiological patterns of injury is essential to target preventive measures and evaluate the effectiveness of those interventions. Focusing more on prevention has the greatest potential in reducing injury-related deaths.[17,18]

Prehospital care

Unfortunately, not all injuries can be prevented despite extensive preventive measures and legislation. Therefore, it is essential that all other parts of the trauma system function optimally. This thesis has shown global variation in prehospital care, varying from non-existent, to fully developed paramedic- and physician-staffed emergency medical service (EMS) systems. (**Chapter 2**) With the majority of trauma-related deaths occurring in the prehospital setting (especially in the low-and middle-income countries) there is great opportunity for improvement.[19,20] Several studies have shown that relatively low-cost interventions, such as the introduction of Prehospital Trauma Life Support (PHTLS) training and increased numbers of ambulance dispatch centers, have resulted in lower numbers of prehospital deaths.[19,21,22]

Although education and training of EMS personnel improve outcomes, the level of advanced expertise needed at the trauma scene is controversial, with studies both refuting[23,24] and supporting physician-staffed EMS.[25-30] It seems that the advantage is mainly for the severely injured and severely ill patients (cardiac arrest, myocardial infarction and respiratory distress).[25-31]The presence of physician-assisted EMS is associated with increased on-scene time and more interventions; however, this association may be confounded by the severity of the injuries of the patients rather than being related to the presence of the physician.[31-33]Other factors likely also play a role in the number of interventions performed by medics and paramedics, with a longer transport time being associated with longer on-scene time and more interventions being performed.[34] This suggests that the difference between "scoop and run" vs "stay and play" may not be as clear as suggested, and that prehospital care is a more nuanced process.

A second ongoing debate is the tradeoff between optimizing trauma center accessibility with shorter transport times and more hospitals able to provide around-the-clock care of the severely injured on one hand versus having fewer, but high-volume hospitals and longer transport times. Currently there are eleven trauma centers in the Netherlands that are geographically close (in comparison to other countries) and care for relatively low volumes of severely injured patients.[35] This raises the question if there are too many trauma centers in the Netherlands and if outcomes of patients might be improved even more by further centralizing care for the severely injured. However, centralizing the trauma care into fewer high-volume centers inherently means longer transport times. In this thesis, the geographical distribution and number of trauma centers were shown to

influence the transport times, with longer transport times in scenarios with geographically suboptimal located centers especially during rush hour. (**Chapter 5**) Literature suggests that reduced trauma center access is associated with differences in outcomes such as higher mortality rates.[36-39] However, the threshold beyond which outcomes are affected is unknown. Although a transport that lasts two hours is intuitively more risk-prone than a transfer that lasts 10 minutes, it is not known whether outcomes are affected by a transfer of 10 vs. 20 minutes. In the Netherlands, even if trauma care would be further centralized, it is unlikely that the transfer times will be prohibitively long. However, the contrary scenario, whereby each trauma center can barely treat a critical mass of severely injured patients to ensure physician expertise, may ultimately lead to less optimal outcomes.[40] On the other hand, if a hospital is overburdened beyond its optimum trauma patient capacity, adding new accredited trauma centers in the region may improve outcome by reducing the burden.[41,42] Unfortunately, despite years of research, there is still no universal standard for trauma system planning and the optimal trade-off between transport times and hospital volumes remains unclear. The annual cost for having a fully staffed around-the-clock trauma center, including physician stipends, verification, outreach and prevention costs, has been estimated to be around 2.7 million dollars per trauma center in the USA.[43]

There is a need for an internationally applicable tool to evaluate the best geographical organization of trauma care (i.e., optimal combination of trauma center access, population coverage, and hospital trauma volume). The Geographical Information System (GIS)-based model offers an objective way to evaluate the effects of different scenarios with varying numbers of trauma centers and their geographical distribution in specific regions or countries taking the local geographical and demographical characteristics into account. (**Chapter 5**) Strategic planning of geographical trauma center distribution will lead to better patient care through efficient distribution of patient volumes and resources.

The efficient distribution of trauma patients, meaning getting the right patient to the right hospital remains a challenge. 20 years after the introduction of an inclusive trauma system in the Netherlands still 30% of the severely injured patients is primarily brought to a non-trauma center **(Chapter 6).** However, studies have shown that it is hard to predict which patient will be classified as a polytrauma patient (ISS≥16) and which are not, for example, 32% of the traumatic brain injuries (TBI) and 21% of the severe traumatic brain injuries are not recognized at the accident scene.[44] EMS providers often base their decision, despite many protocols, to go to trauma or non-trauma center on their own experience, the mechanism of injury, and early visual cues of severe injury at the accident scene.[45] Future research should focus on developing tools to improve the quality of pre-hospital triage in severely injured patients, such as the TraumaTriageApp.[46-48,49]

Facility-based care

Since the introduction of formalized trauma systems, the volume-outcome relationship in trauma care has been an ongoing debate, with the literature showing both supporting and opposing evidence.[50-58] Although in many surgical specialties, the volume-outcome relationship has been ascertained, even with clear cut off points, this has not been the case for trauma surgery.[59-61] However, Chowdhury et al. showed in their review that not only hospital volume, but also specialization and high surgeon volume, are associated with improved outcomes.[62] Also in trauma care, it seems that other factors, such as the experience of the trauma surgeon[63,64], implementation of accreditation and verification measures [65,66], standardization of complex care[2,67], and the implementation of a dedicated trauma team[68,69] may potentially influence outcome independently of hospital patient volume. This is consistent with results shown in this thesis, in which it was demonstrated that mature trauma systems have similar outcomes (measured as in-hospital mortality) despite differences in volume of both blunt polytrauma and truncal penetrating trauma patients. **(Chapters 3 and 4)**.

Despite the inconclusive evidence, minimum volume requirements are still in place in many countries, including the Netherlands. The Dutch Trauma Society, in collaboration with the Dutch National Health Care Institute, raised the minimal annual volume requirement from 100 to 240 polytrauma patients per trauma center.[70] Currently, only five out of eleven level I trauma centers fulfill the minimum volume requirements [Figure 2].[35] The currently available evidence suggests that, if we want to improve outcomes for severely injured patients in the Netherlands, we should focus on improving processes of care within the hospital, rather than simply focus on volume. [2,63-67]

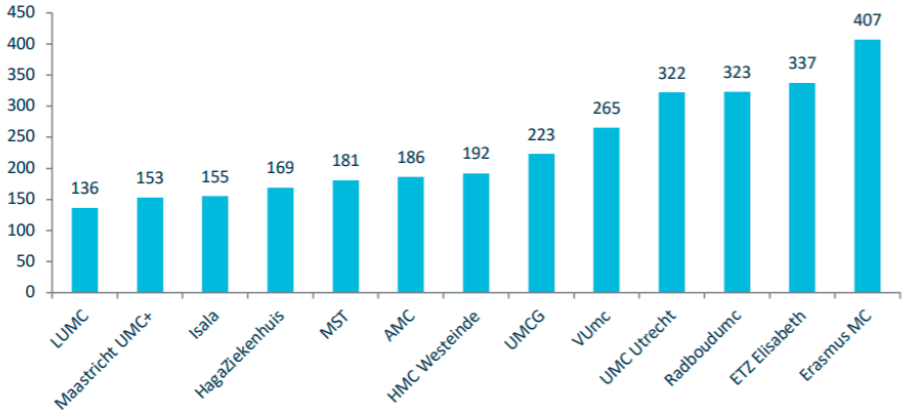

Figure 2. Polytrauma patient volumes per level-1 traumacenter in 2017 the Netherlands*[33]
*Landelijk Netwerk Acute Zorg. Traumazorg in beeld - landelijke traumaregistratie 2013-2017- rapportage Nederland. Utrecht 2018.

Post-hospital care

With an increasing number of patients surviving their injuries, focusing on mortality as the sole outcome does not seem appropriate anymore in the evaluation of the quality of trauma care. This raises two major questions: 1) which outcomes to monitor, and 2) how to improve outcomes for patients surviving their injuries?

For many studies, including the studies in this thesis **(Chapters 3 and 4),** parameters such as in-hospital mortality, hospital length of stay, and ICU length of stay are considered the primary outcomes to measure quality of care. Several studies have shown that although severely injured patients may have good functional outcomes, they have a significantly lower quality of life compared to the general population, and often do not regain preinjury functional status.[71-73] A significant proportion of these patients (about 20-25%) cannot return to their preinjury employment.[72-78] Focusing on outcomes relevant for trauma patients instead of only focusing on mortality rates could further improve quality of life. Comprehensive rehabilitation programs have been proven effective in improving outcomes in patients with severe brain injury.[79] A recently published study by Wiertsema et al. concluded that a rehabilitation program specifically for trauma patients, in which trauma surgeons work in close collaboration with hospital-based and primary care physical therapists, improved disease-specific health-related quality of life, reduced pain, and improved functional status in comparison to regular care. [80,81] It seems that further establishing cooperation between rehabilitation and trauma care for the severely injured is both effective and cost-effective. [82,83]

Quality Improvement

Improvements in mature trauma systems have been driven by evaluation of data on outcomes and processes of care in regional and national trauma registries. [84,85] However, this thesis has shown that, despite having the largest trauma burden, the majority of low-and middle-income countries lack a formal trauma registry. **(Chapter 2)**. It seems that implementation of a trauma system including a formal national trauma registry is inversely related to a country's economic status.[20]

The development of a global standardized data set with clearly defined inclusion/exclusion criteria to evaluate trauma care would not only facilitate national improvements in trauma care but also allow international comparisons. With higher survival rates, the shift towards a greater focus on patient-centered long-term outcomes is justified and much needed.[86,87] Several studies have shown that currently used parameters, such as the Glasgow Outcome Score, EQ-5D, and Functional Independence Measure were not predictive of long-term outcomes in severely injured patients.[88,89] Patient Reported Outcome Measures (PROMs), specifically developed for severely injured patients, offer new options to measure long-term outcomes.[90] Unfortunately, although some of these newer tools, such as the Trauma Quality of Life Measure (TQLM) and Trauma Outcome

Profile (TOP), they were only used in 4% of studies published.[90-92] In the future we should focus on using standardized PROM's, such as TQLM and TOP, better reflecting the patients' perspectives on outcome and quality of life, in clinic and research to provide more insight in trauma outcomes beside mortality and to improve trauma care in the long run.[93]

Training residents, surgeons, and other healthcare providers is essential to maintain good quality of care in a mature trauma system. **(Chapter 2)** Due to stricter duty-hour restrictions in both Europe and the US and the rise in non-operative and endovascular treatment, the experience in trauma care and more specifically certain operative skills are becoming more difficult to maintain for both residents and attending surgeons. [94-96] Trauma skills courses such as the Advanced Trauma Life Support (ATLS), Definitive Surgical Trauma Care (DSTC), Advanced Trauma Operative Management (ATOM) and many more have been developed to improve the residents' and surgeons' skills with regards to trauma management. Mackenzie et al. identified 21 trauma courses given all across the globe, many with overlapping parts and focal points. Although most courses demonstrated benefits for the patient when compared to no training, it is still unclear what is the most efficient and effective trauma training, mostly due to lack of standardization, different levels of trainees, and disparities in training conditions.[96] To further improve trauma training, future research should focus on standardized evaluation of both technical and non-technical skills before and after trauma courses and long-term skills in order to identify the most efficient and effective way of training (future) trauma surgeons.

MALNUTRITION IN TRAUMA PATIENTS

In this thesis, malnutrition was shown to be an underestimated and underrecognized problem in trauma patients. The review in **chapter 7** has shown that trauma patients are particularly susceptible to deterioration of their nutritional status and associated complications due to the unique metabolic response following injury. Early recognition of malnutrition and targeted interventions could prevent malnutrition-related complications. Unfortunately, malnutrition is not easy to prevent and treat. Many challenges lie ahead and questions need to be answered before we can move forward in nutritional support management.

The study in **chapter 8** showed that slowly increasing the enteral nutrition delivery rate contributes to a protein and calorie deficit. Intuitively, malnutrition could be prevented by giving the patient the needed nutritional support, e.g. sufficient energy and protein. However, the evidence supporting the stance that improved nutritional support leads to better outcomes is not robust.[97,98] Some trials have even suggested that receiving more than 75% of the daily energy and protein requirements is associated with *higher* mortal-

ity in patients with acute lung injury.[99,100] Permissive underfeeding, receiving 40-60% of the estimated needed requirements, did not improve clinical outcomes in critically ill patients.[101] However, large observational studies have demonstrated that critically ill patients with a BMI<25 kg/m^2 or >35 kg/m^2 do seem to benefit from increased energy delivery.[102,103] Unfortunately, the proportion of severely injured trauma patients enrolled in these studies was very low. Thus, the current knowledge about the best nutritional support for the severely injured patient is based upon sparse evidence, heterogeneous data, and is mostly extrapolated from studies in which trauma patients were not enrolled or only comprised a very small proportion.

Recognizing the need for more insight into the prevalence and effects of malnutrition in polytrauma patients, the Malnutrition in Polytrauma Patients (MaPP) study was initiated. (**Chapter 9**) Designing this multicenter prospective observational study, we experienced the hardships of conducting malnutrition-related research. The main problem in all malnutrition-related research is the absence of a gold standard for diagnosing malnutrition and assessing its severity.[104] Although BMI is still considered an important element of diagnosing malnutrition[104], it is actually a poor surrogate.[105,106] Nutritional deficiencies are often present in obese patients, despite their high BMI.[107-110] Higher mortality and morbidity rates have been shown in obese patients [111,112]; however, Robinson et al. advocate that it is actually malnutrition, not obesity, that causes worse outcomes.[105] This is probably also the case in so-called "sarcopenic obese elderly". These elderly patients appear to be well-nourished because of their normal or elevated BMI, but actually suffer from relative muscle loss e.g. sarcopenia.[113-115] Several studies have shown an association between worse outcomes and sarcopenic obesity. [116-118] Current definitions do not assess malnutrition in these patients. Developing a definition for malnutrition without relying on BMI is essential.

In an effort to promote consistency and agreement on malnutrition, the Academy of Nutrition and Dietetics and the American Society for Parenteral and Enteral Nutrition (A.S.P.E.N.) proposed their combined consensus guidelines for documenting and diagnosing malnutrition in 2012.[119] The adult malnutrition consensus (AMC) characteristics consists of five components: weight loss, energy intake, body fat, muscle mass, fluid accumulation, and hand grip strength. Malnutrition, classified from well-nourished to moderate and severe malnutrition, is divided in three categories: acute illness and injury-related malnutrition; chronic disease-related malnutrition; and social and environmental related-malnutrition.[120] Although these diagnostic criteria have shown some promising results in feasibility and reliability, big validation studies have not been published yet and are much needed. [121]

In addition to the need for a generally applicable definition of malnutrition, there is a need for objective diagnostic tools to identify malnutrition. As mentioned in the AMC, hand grip strength is an accurate marker of malnutrition and can be used to as-

sess malnutrition as well as evaluate nutritional support interventions.[122-124] Bioelectric impedance analysis (BIA) also offers potential as a noninvasive, low-cost, diagnostic tool that can be used to assess the body composition, in particular fat and muscle mass. [125] Some studies suggest that malnutrition is related to changes in tissue electrical properties, which can be detected by BIA.[126] However, before implementation in clinical practice, clear cutoff points for defining malnutrition in different patient groups need to be identified for all diagnostic tools.[127]

In the current practice, albumin and transthyretin (i.e., prealbumin) are often considered valuable markers of a patient's nutritional status. However, increasing evidence suggests that these biomarkers are more reflective of the acute phase response after trauma rather than the nutritional status.[128,129] The developing fields of proteomics and metabolomics may be suitable to characterize and anticipate acute changes in trauma patients' metabolism and energy needs, as it reflects the response to nutrition deficiencies and the effects of nutrition administration in trauma (i.e. oxidative stress metabolites, muscle catabolism metabolites, and nucleotide synthesis metabolites).[128,130-134] So far, several metabolites have been found to be associated with nutritional status in critically ill patients: purine, tathione, kynurenine, tryptophan pathways.[135] Fatty acid patterns are highly correlated with nutrition and the particular catabolic state in trauma patients.[130] There are several limitations to the studies that presented, including the small study sample sizes, low metabolite numbers, and the small number of measured time points. New studies designed to overcome the previously mentioned limitations are needed to further evaluate the value of metabolomics for diagnosing malnutrition in severely injured patients.

To improve nutritional support and allow for comparison between studies, we recommend a standardized data set of clinically relevant outcomes and time points affected by nutritional support for future studies.[127, 136] At the moment, the best potential for a validated standardized nutritional risk assessment tool is the Nutrition Risk in the Critically Ill (NUTRIC) score, which is also supported by the Society of Critical Care Medicine (SCCM) and A.S.P.E.N. [97,137-139].

FINAL CONSIDERATION

Although it may seem that malnutrition and trauma systems are not directly connected, this thesis has shown that both elements are essential in the management of the care for the injured patient. Trauma care improved greatly in the past 40 years; however global differences remain. There is no "one-size-fits-all" model for the optimal care for the injured, though there are certain elements essential for all trauma systems, independent of location, population, and regulation: *dedicated trauma teams*, *strategically*

planned trauma center distribution, *quality control measures* and *individualized care*. Many decennia ago it has been recognized that trauma care is built on disciplines working together; team-work is the corner stone of trauma care. In the future, we need to further focus on the continuum of trauma care, recognizing that strengthening each element of the trauma care chain improves outcomes for the severely injured patient. Further well designed studies, that take the four essential trauma system elements into account will help to take the next step in trauma care, locally, regionally and eventually globally.

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