DISCUSSION
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Trauma has changed: the patients, the mechanisms, the care. Many changes are for the better, some however are not. The past century has witnessed dramatic improvements in the care of the injured patient. Before World War I, mortality associated with closed femur fractures was greater than 50% and injuries to the abdomen resulted in a 90% probability of death\(^1\). With modern trauma care, death rates have decreased exponentially. The designation of trauma centers, institution of mobile medical teams and trauma helicopters, and the institution of Advanced Trauma Life Support (ATLS) guidelines, have lead to significant progress. However, injury is still the leading cause of death from ages 1 to 35 in the Netherlands and traffic injuries are expected to become the third leading cause of death worldwide by 2020\(^2\). This thesis identified two main explanations for the continuous and possibly even increasing mortality rate: the high incidence of severe head and neck injuries and the ageing of the population. Injury prevention measures and the aforementioned upgrades of trauma care have been caught up by these two extremely relevant factors. If trauma care had not been upgraded, perhaps the death rate would already have risen the last few years. This finding is not limited to our country, as the same trend was observed in Germany and Australia, as illustrated in this thesis.

The increase in age of severely injured patients from 33 ± 22 years to 41 ± 23 years in the last two decades, may seem trivial, but unfortunately the opposite is true (Chapter 2). Besides the fact that the risk of adverse outcomes independently increases with age, the higher age will have entailed extensive co-morbidity, adding to the increased mortality. The explanation for the higher incidence of head and neck injuries (compared to 1985 - 1990) may remain unclear, but knowing its poor outcome, it is not surprising that these injuries combined with a higher age lead to a high mortality. Additionally, it became clear that some of these patients were perhaps suboptimally treated as a result of an undervalued trauma mechanism, as illustrated in Chapter 3. Even nowadays severe head and neck injuries are difficult to treat. Maximum life support while optimizing cerebral perfusion is the main key to survival but often the cerebral damage is extensive and the patient beyond salvation.

An overwhelming sixteen percent of the severely injured patients arrived at the UMCG with life-threatening injuries and in a poor condition, scoring a GCS of 3 (Chapter 4). Whether they suffered from (a combination of) traumatic brain injuries (TBI), anoxic brain injuries (ABI) or hemorrhagic shock, outcome was very poor, with only one in twenty making a good recovery. Treatment is difficult as death is near and drastic decisions about possibly conflicting treatment modalities, often need to be made before identification of all injuries is possible. ATLS-guidelines offer some support in these challenging situations but we recommend the following streamlined approach: Establishing an airway and ventilation is crucial in these patients, followed by prevention of exsanguination in case of hemorrhagic shock. Patients who score a GCS of 3 and suffer from hemorrhagic shock...
require aggressive resuscitation and damage control surgery irrespective of other injuries (including TBI) or pre-existing comorbidities. Diagnostics need to be completed after treatment of the hemorrhage. Patients with a GCS of 3 who suffer from blunt TBI, need a cerebral CT scan as soon as the primary survey, X-rays of chest and pelvis, and focused assessment ultrasonography of the abdomen have been completed. To save time, imaging of the cervical spine should be included in the CT scan. The secondary survey and X-rays of the thoracic and lumbar spine can be performed while arrangements for further treatment (i.e. ICU admission or emergency (neuro)surgery) are made or afterwards. Half of the TBI patients described in this chapter, suffered from additional injuries. In case these need operative correction a delayed procedure or at least a damage control (orthopedic) procedure, is indicated to minimize the effect of the operative procedure on the intracranial pressure and cerebral perfusion, and prevent further aggravation of the inflammatory response. Primary survey and X-rays of chest and neck are indicated in all ABI patients, combined with a complete work-up depending on (or lack of clarity of) the trauma mechanism. This explains why ABI patients (irrespective of age) need to be treated by a trauma team. In the future total-body CT scans may replace a part of the conventional trauma work-up although it probably will not exclude the X-ray of chest and pelvis and focused assessment ultrasonography of the abdomen.

Fixed pupils and a pH < 7.10 on admission were indicative of certain death irrespective of underlying pathology. Unfortunately no additional prognosticators were found. Hopefully future advancing insights will enable better identification of patients with a good prognosis for whom aggressive treatment will be beneficial. Besides clinically relevant, prognosticators may improve dialogue with relatives, reduce costs, and not unimportantly: allow for the early identification of possible organ donors, in patients suffering from TBI.

The comparison between Germany and Queensland has taught us important lessons. Although the catchment area of the UMCG may be the largest in the Netherlands, it constitutes less than three percent of the catchment area of the Princess Alexandra Hospital in Queensland, with an equal number of inhabitants. We blame the large catchment area of the UMCG for the high number of admissions and partially for the high in-hospital mortality. The study presented in Chapter 5 however, puts this in perspective, especially the concept of ‘in-hospital mortality’. The in-hospital mortality depends largely on the pre-hospital mortality (at the scene, during transport, or in another hospital), taking into account Trunkey’s first and second peak of the trimodal distribution of death. If the catchment area is too large and the pre-hospital phase is too long, patients who otherwise would have died in-hospital (or survived), will die pre-hospital; lowering the trauma center’s in-hospital mortality, and vice versa. Perhaps the in-hospital mortality is inversely proportional to the distance between trauma scene and trauma center (Figure 1). Subsequently, we cannot prove with certainty that trauma care in our catchment area improved the last twenty years. All we know is that the in-hospital mortality was unchanged, we do not know whether the out-of-hospital mortality changed. As
A bottleneck in trauma research is the limited availability of scores that adequately enable comparison of trauma care, or ‘benchmarking’. There is no perfect score yet, and in the mean time we have to make do with scores like the ISS (this thesis), the New Injury Severity Score (NISS), the Revised Trauma Score (RTS, this thesis) and the Trauma and Injury Severity Score (TRISS, this thesis). The ISS dates from 1971 and was subsequently modified numerous times. It describes the anatomic and functional damage in the three most severely injured body regions and was developed to predict mortality. Years later, it showed also to correlate with a variety of other measures, such as length of in-hospital stay and costs. It is supposedly ‘an excellent method for retrospective comparison of overall injury data between populations differing in time or space’. However, the ISS gives equal importance to injuries with the same AIS severity, although occurring in different body regions. As such, the ISS wrongly assumes that all injured body regions have an equal effect on mortality and morbidity. Additionally, besides ignoring the remaining three possibly severely injured body regions, it does not discriminate between one injury to a body region or many injuries to the same body region. Perhaps the most illustrative being the lack of discrimination between one and four traumatically amputated extremities; the difference in mortality and morbidity is undeniably significant. In an attempt to overcome this flaw, the NISS was introduced in 1997. This modification of the ISS includes the

Figure 1. The relation between distance and in-hospital mortality?
three most severe AIS scores regardless of body region and outperforms the ISS in prediction of mortality. The RTS is a physiological score and combines the GCS, systolic blood pressure and respiratory rate\(^6\). When scored on the trauma scene it correlates to in-hospital mortality and facilitates triage of the acutely injured patient. The biggest flaw is the underestimation of head injuries. A patient who is on the verge of cerebral herniation may still score 8 out of 12 points. The current trauma population mainly suffers from severe head injuries (73\% of severely injured patients between 2002 - 2005) and leaves the RTS impracticable. Subsequently, it is not surprising that a combination of the ISS and RTS, the TRISS\(^7\), has limitations too. Combining anatomic and physiologic derangement with age and injury mechanism to predict in-hospital mortality seems ideal but unfortunately it is not. The RTS’s flaw to represent the severity of head injuries is undeniably present in the TRISS. Additionally, the TRISS is based on data from the Major Trauma Outcome Study by the American College of Surgeons in 1991\(^8\). Besides dating from almost twenty years ago, the study population contained significantly more patients suffering from penetrating injuries and not as many patients suffering from blunt head injuries as currently is the case in the Netherlands.

Recently our trauma center, in collaboration with the Polytrauma Study Group of the DGU, developed the Emergency Trauma Score (EMTRAS)\(^9\). This score combines the patient’s age, pre-hospital GCS, base excess and prothrombin time. Knowledge of the anatomical injuries is not necessary and therefore this score enables accurate outcome prediction within thirty minutes after arrival to the hospital. A high EMTRAS, i.e. a score > 8 (range 0 - 12), should alert the trauma team that the patient has a high mortality risk. Validation of the score, using a dataset containing 3314 severely injured patients (> 16 years of age) showed it to outperform the RTS (0.730), ISS (0.689), NISS (0.734) and TRISS (0.810) with an area under the receiver operator characteristic curve of 0.828 (p < 0.001).

The question is why it is so difficult to come up with an adequate trauma score. Filled with envy, we accept that for example in the care of women with breast cancer, a formula is available that incorporates patient and tumour details and adequately calculates a prediction of mortality and gain of additional therapy\(^10\). With the formula being available online, it is impossible to imagine current practice without it. Knowing that oncology is not exactly a simple field of medicine, designing the formula must have been no sinecure. What will it take to design an adequate trauma score?

Nevertheless, numerous improvements have been identified (Chapter 2). First, the designation of the UMCG as a level one trauma center had the desired effect of centralization, as objectified by the dramatic increase of severely injured trauma patients admitted to the UMCG. Second, due to the primary and secondary preventative measures a shift occurred from poly trauma patients to patients with severe isolated injuries. This increases the chance of a favorable outcome although, unfortunately, the isolated injury often entails a severe head and neck injury. Lastly, the improvements may not be reflected
by the *quantity* of lives saved but are reflected by the *quality* of lives saved. More people leave the hospital with no or minor disabilities, possibly able to participate in daily life in a similar fashion as prior to injury.

With advancements in medicine, future progress in outcome could be possible. Past studies, however, have found that even with realistic technological advances and elimination of treatment errors, only a small percentage of trauma deaths can be prevented\textsuperscript{11,12}. Two comments seem in place here: firstly, these data only concern mortality and leave morbidity out of consideration. Secondly, Chapters 6 and 7 of this thesis illustrate a part of trauma care that is relatively unknown and perhaps understanding it could eventually lead to improved outcome: the acute phase response and subsequent inflammatory response. Although the aforementioned is a desired defense response to injury, tissue ischemia and infectious agents, it often seems to overshoot its goal, resulting in a systemic inflammatory response syndrome, multiple organ dysfunction syndrome, and multiple organ failure. Needless to say, these processes are associated with a high mortality and probably occur in all critically ill patients. However, for reasons currently unknown, they seem to be more pronounced in trauma patients. Hyperglycemia, anemia and a decreased platelet count irrespective of blood loss, are three (of many) manifestations of these processes and future research should investigate whether treatment improves outcome. If so, our studies perhaps suggest that treatment should be started as soon as possible as the inflammatory response is activated early (directly?) after trauma. For now, raised physician awareness possibly improves clinical management of patients. Additionally, the indications for damage control procedures for torso and orthopaedic injuries may need to be revised in an attempt to limit the inflammatory response.

This thesis discusses two additional proposals concerning treatment. First, as a rising reticulocyte count indicates an imminent rise of the hemoglobin level, transfusion possibly can be (temporarily) withheld to await the spontaneous rise (Chapter 8). Obviously, this only applies to patients with a hemoglobin level near the transfusion threshold and without symptoms of anaemia. This saves a patient from possible transfusion side effects and additionally saves precious donor blood and subsequent costs thereof. Although the ideas about the relation between blood transfusion and acute lung injury may be changing, every transfusion does constitute an immunological hit, potentially increasing inflammation and leaving the patient prone to infection\textsuperscript{13}. Second, as the hemoglobin level and hematocrit provide similar information, there is no reason to determine both in assessing acute blood loss (Chapter 9). Determining both parameters only provides unnecessary additional information that impedes clinical judgement and leads to needless costs. The equivalence of hematocrit and hemoglobin level is neither new nor surprising, as it was already published in 1966 that both parameters, albeit in different ways, represent the hemoglobin concentration in blood\textsuperscript{14}. Exceptions are formed by a few rare hematological disorders and therefore determination of both parameters is not justified in every trauma patient.
FUTURE PROSPECTS

There is obviously room for improvement. If we think the worst is behind us in trauma care, then we need to think again. The designation of eleven trauma centers nationwide was an important step, but there is still an uphill battle to be fought. The Netherlands’ main problem is the ageing population. Trauma is no longer a disease of the young and we should brace ourselves for an increasing patient load due to trauma in elderly patients. These may not be bread-winners with their families or the treasury depending on them, but the consequences, in every aspect, may be nevertheless dramatic. Whether one takes 55 or 65 years of age as a cut-off, respectively 28% or 15% of the population is at risk for severe injury due to only minor trauma. Outcome is poor in these patients and the use of resources and subsequently financial costs are high. Improving trauma care of elderly patients is debated in the literature as studies suggest that despite aggressive care the mortality remains high and survivors often do not regain pre-injury function. However, this stoical attitude is out of place in contemporary medicine and besides preventive measures we should at all times attempt to improve trauma care of elderly patients. A first step would be the revision of the ATLS triage guidelines. Age only comes into play in the last step of the triage flowchart, and only when combined with a high-energy impact, it warrants referral to a trauma center. Even though studies illustrated the severity of injury and physiologic disturbance in elderly often to be underestimated. Therefore, we should not be surprised that these studies showed the under-triage of patients > 55 years to be twice that of younger patients. Under-triage forms an increased risk for mortality and morbidity by the prolonged time to definitive care and suboptimal care at the referring hospital. The guidelines for deployment of the Mobile Medical Team (MMT) should perhaps undergo the same revision. Perhaps some kind of Geriatric Mobile Trauma Team should be established to administer optimal pre-hospital trauma care to elderly, starting at the scene of the accident.

There is room for improvement of the pre-hospital trauma care in general. For example: When the MMT is not deployed to a trauma scene, patients are managed by ATLS-trained paramedics. Although very skillful, they are not qualified to administer sedative or neuromuscular-blocking drugs. Consequently, not every patient with an indication for endotracheal intubation will be intubated. Without the administration of drugs, endotracheal intubation is only likely to be successful in patients with a GCS of 3. Knowing that a GCS < 9 is a strong indication for intubation, we can only fear the number of patients that receive suboptimal treatment nationwide. Secondly; if we consider improvement of the pre-hospital trauma care, we should realize that some trauma centers in our country do not even have an MMT at their disposal. If the patient is ‘lucky’ his or her trauma warrants dispatch of one of the four Dutch trauma helicopters that will deliver an MMT to the trauma scene, hopefully without too much delay. One solution to these problems is an increased number of MMT’s and broadening of dispatch criteria.
Furthermore, in-hospital trauma care can be upgraded. There seems to be a difference in trauma care amongst the various trauma centers, which may be a consequence of different budgets, infrastructures and availability of fulltime trauma surgeons. A study by Haut in 2006, showed that injured patients have a lower mortality rate when treated by full-time trauma surgeons instead of surgeons who only partly cover the trauma service\textsuperscript{17}. On the other hand, there is evidence that mortality rates are not influenced by the case load of the attending surgeon\textsuperscript{18}. Although all these studies took place in the United States of America, with case loads that are very different from the Dutch case loads, it is not unthinkable that in the near future, trauma centers are required to organize fulltime on site coverage by trauma surgeons. This will not only safeguard a high level of care of severely injured patients but also of their less severely injured counterparts. This fulltime coverage will be difficult to organize, even for university hospital based trauma centers, let alone non-university hospital based trauma centers. The high costs can be expected to rise even further. One (perhaps unpopular) solution may be to further centralize trauma care by actually reducing the number of trauma centers. In review of the countries geographic features, five trauma centers should suffice. The Netherlands is small and distances between trauma centers will still be limited. The number of MMT’s and trauma helicopters should increase and subsequently these should be strategically based throughout the country. Longer pre-hospital times are not necessarily contraindicated as long as delivery of high care to the trauma scene by an MMT is safeguarded.

As the future of our world includes more people, vehicles, and weapons, we should focus more on injury prevention. Prevention seems to be the key to a significant reduction in trauma mortality. Previous studies have estimated that anywhere from 30\% to more than 90\% of all deaths are preventable in the pre-injury phase\textsuperscript{19,20}. In the last decades, numerous injury prevention measures have been established, which mainly focus on traffic. As mentioned before, the traffic related death rate declined to 750 deaths in 2008\textsuperscript{21}. Surprisingly, this decline was mostly due to a reduction of fatalities involving pedestrians. The number of car-occupants killed in a traffic incident remained stable and represented 42\% of deaths\textsuperscript{21}. This decline, despite an overwhelming rise in the number of road-users and distances travelled, seems the result of successful primary, secondary and tertiary prevention measures. However, we would like to introduce an alternative view: perhaps traffic in the Netherlands has become so busy to the extent that during the largest part of the day, it is almost impossible to gain enough speed to result in a fatal high energy trauma. The current traffic situation may very well be the only form of congestion that actually promotes health. Furthermore, as one quarter of deaths consisted of cyclists, perhaps it is time to introduce legislation to require cyclists to wear bicycle helmets. Bicycle helmets may reduce the severity of accident consequences by preventing or reducing the severity of head, brain, and face injuries. Although the Netherlands is often leading in prevention legislation, this country, with more bicycles than inhabitants, would be one of the last in Europe to institute a bicycle helmet law.
Advocates of the bicycle helmet law rely on numerous international studies that seem to confirm the measure to reduce fatalities\textsuperscript{22,23}. However, results of empirical studies seem to depend on the methods used, and to date no conclusion can be drawn about whether or nor, or to what extent, helmets protect adult cyclists against injuries\textsuperscript{24}. The effects for children are more consistent, showing reduced numbers and severity of injuries in cycle accidents. However, there is evidence that the institution of such a law significantly reduced (youth) bicycling and some studies report evidence of increased accident risk per cycling-kilometre for cyclists wearing a helmet. One study showed that wearing a bicycle helmet led to traffic getting significantly closer when overtaking and therefore increasing the risk of an accident\textsuperscript{25}. Striking detail; when the male experimenter wore a long blond wig, so that he appeared female from behind, drivers left more space when passing. The authors suggested drivers approaching a bicyclist use physical appearance to judge the specific likelihood of the rider behaving predictably and alter their overtaking accordingly. Although we are confident that a ‘blond wig law’ for cyclists is not the answer to the high incidence of severe head and neck injuries in the Netherlands, neither is it a clear-cut case in favour of the bicycle helmet law. The question how to prevent the occurrence of severe head and neck injuries in car occupants is even more difficult to answer as crushable zones, seat belts, airbags and numerous other preventive measures have not succeeded in eradicating these injuries. The relevance is proven by the following numbers: one sixth of the severely injured patients treated at the UMCG from 2002 to 2005 (Chapter 2) was injured as a car occupant of whom no less than 66\% suffered a severe head and neck injury. Are we perhaps waiting for the first representative studies to evaluate the use of helmets in cars? Would that be the easiest applicable measure to reduce mortality and morbidity in traffic incidents?

Prevention measures should in addition focus more on the elderly. Nationwide, almost three quarters of all trauma incidents happening at home involve people over 70 years of age. In 75\% it entails a fall and it often results in severe head and neck injury. Balance disturbances and diminished ability to anticipate to a fall, combined with frail intracerebral blood vessels and widespread use of anti-coagulants, play an important role in causing intracranial bleedings. Stating that a prescription for an anti-coagulant should be combined with a prescription for a helmet, like opiates and laxatives go hand-in-hand, is probably going too far. However, prescribers of anti-coagulants should be aware of this possible adverse effect and scrutinize their indications. An additional approach would be to encourage geriatric fitness programs that improve strength, endurance, balance and flexibility, in an attempt to prevent illness and injury\textsuperscript{26}.

A major step forward is the recently introduced national trauma registry in the Netherlands, ten years after the designation of trauma centers. Before the introduction, trauma centers developed their own registries of trauma patients treated within their catchment areas but these registries tended to be incomplete, labor-intensive and did
not allow for easy data exchange. Therefore, benchmarking of the trauma centers was almost impossible and it remained unclear whether trauma care in the Netherlands has improved over the years. The ideal national registry should collect, process and analyse data on all major trauma patients admitted to any hospital. Two major goals would be to contribute to the reduction of injuries and deaths by providing data for studies of national injury epidemiology and to facilitate regional and international injury comparisons. It could serve to increase awareness of injury as a public health problem and assist injury prevention and treatment programs. A combined registry with data on pre-hospital deaths would finally enable a thorough analysis of severely injured trauma patients. Again, our country is small, it should not be complicated to organise this? Well-established national registries do exist for oncology and obstetric patients, so clearly it is possible in the Netherlands, why not for trauma patients? Unfortunately, the exact reason remains unclear27. Luckily, there is no need to reinvent the wheel, numerous extensive and well-run registries exist, of which the Trauma Registry of the DGU is a successful example28,29. It constitutes a complete medical documentation of every patient’s injuries, (pre-hospital and in-hospital) management, and outcome. It conducts annual benchmarking analysis of each clinic and facilitates the currently highly relevant cost analysis of poly trauma patients. Additionally, there are no high costs and entering data (online) is not labour-intensive. Its only weakness is the voluntary participation of German trauma centers that allows for some selection bias by hospitals that join the registry. In these times of ‘one Europe’, why not ‘one Trauma Registry’ that collects a range of patient data from trauma scene to long-term outcome? At least for the countries of the European Union, trauma mechanisms will be more or less comparable. We plead to work towards one European trauma registry. It would allow for an informative comparison of trauma care between the Netherlands and other countries, and between the individual trauma centers. However, no matter which registry is used, data on pre-hospital deaths should be included, as only then is a thorough analysis of trauma care possible.

Last but not least; further improving trauma care and outcome calls for a change of society’s passive attitude towards trauma30. Even though trauma must have been the origin of medicine, no sustained passion for prevention or cure, as typified by campaigns on cancer or cardiovascular disease, has been generated. Disproportionally vast sums of money (exact amount unknown) are granted to categorical diseases affecting much smaller numbers of citizens than is the case with trauma. Why does no ‘Association of Trauma patients’ exist? Why does never a collect on behalf of trauma research take place? Apparently, people somehow do not associate themselves with (being possible) trauma victims, despite the well-known saying that ‘mischief comes without calling for’ (‘e’en ongeval zit in een klein hoekje’). Even though trauma is the leading cause of death in people under the age of 35, most people are only sensitized to trauma when a personal loss is suffered, when a celebrity falls victim, or an incident like ‘Koninginnedag 2009’30. Perhaps the most striking example of society’s passive attitude towards trauma
was the restriction of the deployment of trauma helicopters in the Netherlands; it took more than ten years before the first trauma helicopter (Lifeliner 3, University Medical Center Nijmegen) was allowed to fly during night hours. To limit flight activity around the hospital at night, the helicopter is based at a local airport. The other three trauma helicopters are scheduled to start flying during night hours within the next one to two years. Sure, there are safety-issues when flying at night, but an important reason for the limitation of operational hours seemed to be the noise abatement policy instituted for trauma centers’ neighbors. How can we justify inferior trauma care because of people’s sleep?
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