Do designated trauma systems improve outcome?

Purpose of review
Trauma systems are introduced worldwide with the goal to improve survival and outcome of the injured patient. This review is focused on the influence of trauma systems on the survival and outcome of injured patients.

Recent findings
Large population-based studies have been published over the last 2 years strengthening the hypothesis that trauma systems indeed improve survival rates in injured patients. Mortality was reduced by 15–25% when severely injured patients were treated at a trauma center. Although ‘inclusive’ trauma systems have been advocated since 1991 only recently did the first population-based study prove that ‘inclusive’ trauma systems do better than ‘exclusive’ trauma systems. Because further improvements in survival in mature trauma systems are likely to be small, more focus should be given to quality of life studies, rather than to survival in trauma system evaluation.

Summary
Trauma systems indeed improve survival rates in injured patients. Inclusive trauma systems do better than exclusive trauma systems. More attention should be given to quality of outcome.

Keywords
inclusive, performance outcome, trauma center, trauma registry, trauma system, triage

Introduction
Trauma is a leading cause of death in the world. Injury is an increasingly significant health problem throughout the world. Everyday, 16 000 people die from injuries and for every person who dies, several thousand more are injured, many of them with permanent sequelae. Injury accounts for 16% of the global burden of disease. Approximately 90% of the total burden of injury occurs in low and middle-income countries [1]. In Western countries injury is the leading cause of death between ages 1 and 44. Trauma strikes at all ages. Young and working age adults are more likely to be injured, but if injury strikes at geriatric age the death rate is much higher. Disability caused by traumatic injury is often long lasting up to a lifetime, and especially in our younger population this might be a very long time, accounting for the largest loss of productive years. Implementation of trauma centers and trauma systems decreases the burden of death and disability from injury, but given the staggering social, economic, and personal costs of trauma, prevention needs to be pushed harder, ‘for an ounce of prevention is clearly worth far more than the best trauma care in the world’ [2].

A little over 40 years ago a major step towards a more optimal care for the injured patient was marked by the publication of Accidental Death and Disability: The Neglected Disease of Modern Society [3]. Since then and especially over the last two decades regionalized trauma systems have been developed and implemented.

Trauma care within a trauma system is an organized approach to care for injured patients.

In 1991 the term ‘inclusive trauma system’ was introduced [4,5]. An inclusive trauma system is designed to care for all injured patients in a given geographical area and therefore all acute care hospital facilities are expected to participate in such trauma systems. This is in contrast to ‘exclusive’ trauma systems in which care is organized around a high level (I) trauma center, and mainly takes care of only the severely injured patients. An inclusive trauma system includes responsibility for the entire chain of multidisciplinary treatment from prehospital care to hospital and rehabilitation care, this all in a defined geographic area. In an inclusive trauma system there should be collaboration between (local/state/national) government, emergency medical services, and acute care hospitals. The acute care hospitals should be categorized according to their ability to provide trauma care (level I–IV) [6]. Between the acute care hospitals
and the emergency services there should be a preplanned triage scheme to get the right patient at the right time to the right hospital.

Although trauma systems were introduced over 30 years ago, proof of their effectiveness is an ongoing issue. Since the early 1990s the positive influence of trauma center admission on trauma patient survival has been reported. In the last 2 years a number of papers have been published on trauma system and trauma center benefit on patient outcome. In this paper we review the recent literature on this subject.

**Trauma systems in general**

Population-based studies on trauma system and trauma center performance with statistical analysis by logistic regression are considered strong class III evidence [7]. Although they are considered as only class III evidence, these studies represent the strongest available evidence on the effect of trauma centers and trauma systems on patient outcome; this is because of their nearly complete sample and large, sometimes very large, sample size.

Until 2004 only 14 of these studies were published [8**]. In a systematic review Celso et al. [8**] evaluated the outcome of severely injured trauma patients following the establishment of trauma systems. The review yielded 14 published articles. Trauma systems demonstrated to be beneficial to survival rates in eight of the 14 reports. One of the 14 papers reported a reduction in ICU and hospital stay with more experience. Six reports met all criteria for inclusion in a meta-analysis. The meta-analysis showed a 15% reduction in mortality in favor of the presence of a trauma system.

Over the recent years four more population-based studies have been published [9**,10**,11**,12**].

Papa et al. [10*] performed a population-based study on mortality from motor vehicle crashes in Florida, USA. Motor vehicle crashes constituted about 50% of all trauma cases. They reported a significant reduction in case fatality rate for patients treated at a trauma center compared with patients treated at a nontrauma center. The mean case fatality rate was 2.8%; for patients treated at a trauma center the rate was 1.4% and for patients treated at a nontrauma center it was 3.2%.

Durham et al. [12*] reported on the Florida trauma system in a population-based study enrolling all ‘true’ trauma admissions in this state between 2001 and 2003. Survival of patients treated in trauma centers versus nontrauma centers, and the cost effectiveness of the trauma system were evaluated. A statewide hospital discharge database was used to identify patients on the basis of International Classification of Diseases (ICD)-9 codes. Triage to a Florida trauma center is associated with a decreased risk in mortality of 18%, this in an inclusive trauma system.

For each trauma patient returned to work there is a five to 15-fold return of the investment, and this compares favorably with the cost of treating other major public healthcare problems.

A USA wide study of trauma system effectiveness in urban and suburban areas was reported by MacKenzie et al. [11*]. Patients were initially identified from discharge database on basis of ICD-9 codes, and were stratified according to the type and severity of injury and age. Detailed information on important covariates known to influence the risk of death was collected. Enrolled patients were contacted for consent and an interview, and their medical records were retrieved and reviewed; 5191 patients were enrolled in this study selected from 18198 patients who met the inclusion criteria. In-hospital mortality rate was significantly lower in patients who received treatment at a trauma center than in patients who received treatment at a nontrauma center: 7.6% versus 9.5%. The 1-year mortality rate for trauma center versus nontrauma center treatment was 10.4% versus 13.8%. The differences in risk of death between trauma centers and nontrauma centers were primarily found in patients with Abbreviated Injury Scale scores of 4 and higher. There is a suggestion that patients with scores of less than 4 could benefit from treatment at a trauma center, by reducing complications and improving functional outcome. Mortality is low in this group and therefore differences in mortality are hard to prove.

The risk of death is significantly lower, 25%, when care is provided in a trauma center versus when care is provided in a nontrauma center, and provides a call for continued efforts at regionalization of trauma care.

Although considerable advances have been made in the implementation of trauma systems in the US and their efficacy has been demonstrated as discussed before, the European experience has not been as successful. Until now no positive studies have been published. Osterwalder [13] published a Swiss prospective observational study between 1990 and 1996, comparing primarily trauma center admitted and secondary referred patients, but could not demonstrate any significant reduction in mortality. Nicholl and Turner [14] evaluated all trauma patients with an Injury Severity Score (ISS) over 15 in one region in the United Kingdom, in a controlled before and after study in the years 1990–1993. He also could not demonstrate a significant reduction in mortality after the institution of a trauma center. A comparison between the USA and the French trauma system was made by Nathens et al. in 2004 [15]. In the USA there is a focus on the trauma center, with a lesser emphasis on prehospital
care, whereas in France there is more emphasis on pre-hospital care coordinated by the Service d’Aide Médicale Urgente. A review of databases was done to obtain comparative evidence on the effectiveness of the two systems. Direct comparison of outcomes across the two systems proved to be difficult, because of a lack in uniform data collection in the two countries. Crude injury mortality rates and fatality rates from motor-vehicle crashes are higher in France than in the USA, although adjustment for potential confounders is difficult. Adjusted mortality rates suggest equivalent outcomes among patients who survive to hospital. Components of the trauma systems that are effective or components that offer little benefit could not be identified.

**Inclusive trauma systems**

In an inclusive trauma system only the most serious cases are treated or transferred to a trauma center, leaving the largest number of injury cases for treatment in a non-trauma center [16]. In an inclusive trauma system in one region in the Netherlands 78% of major trauma patients were primarily presented to a trauma center [17]. For analyzing a complete trauma system and not only the level I centers in such a system, record linkage between population and hospital databases allows inexpensive description of an inclusive trauma system and may contribute to quality improvement [16].

An organized system combining a communications center with formal trauma center cooperation improves patient flow and reduces trauma transfers [18].

Another large population-based study focused on the differences in patient outcome in inclusive and exclusive trauma systems. Utter et al. [9*] used state inpatient databases to identify all trauma patients from 24 US states for 2001. Trauma systems in those states were classified as ‘exclusive’ (eight states), ‘more inclusive’ (eight states), and ‘most inclusive’ (eight states). In total 61,496 patients with an ISS of 16 or higher were enrolled in this study. When adjusted for primary payer status, mechanism of injury and trauma system maturity, the most inclusive trauma systems have significant lower odds of death than more inclusive and exclusive trauma. The odds of triage to a trauma center were similar in inclusive and exclusive systems. Severely injured trauma patients have greater inpatient survival in inclusive trauma systems even though they are not more likely to be hospitalized at a regional trauma center.

Even in a mature trauma system preventable trauma deaths will occur. In a review by Gruen et al. [19*] of all inpatient trauma death at a level I trauma center from 1996 to 2004, the overall mortality rate for trauma admissions was 5.8% (2594/44401); 601 of these deaths were classified as patients with low to medium mortality risks. In 64 patients an error that contributed to their death was recognized. Important error patterns were failure to maintain a patent airway, 16%; delayed control of acute abdominal or pelvic hemorrhage by operative or angiography treatment, 16%; delayed intervention for ongoing intra-thoracic bleeding, 9%; more definitive surgery than damage control in unstable patients, 8%; overresuscitation with fluids, 5%; and complications of feeding tubes, 5%. Error patterns are identified that are likely common in all trauma systems. Policy interventions were taken in some error patterns and showed to be effective.

Analysis of response and resource use after the London bombings by Aylwin et al. [20] shows a test of the trauma system by large resource consumption in a very short period. In total there were 775 casualties and 56 deaths, of which 53 deaths were at the scene. Fifty-five patients were triaged as priority 1 and 2 (severely injured). Twenty of the 55 priority 1 and 2 were critically injured. The over-triage rate was 64%. Three patients died in hospital. A hospital wide damage control philosophy, keeping investigations to a minimum and transferring patients rapidly to definitive care is suggested in case of mass casualty. The critical mortality rate of the London bombings of 15% was lower than other bombings/terrorist attacks, and was unrelated to over-triage. The study demonstrates robustness of a trauma system also under special circumstances.

Trauma registries play an important role in the trauma system, although success is hard to measure in terms of related publications and official use for quality control [21]. In many trauma systems only the level I trauma centers are obliged to participate in a trauma registry, making it harder to retrieve data from non-trauma center acute facilities.

As in the above-mentioned studies, the monitoring of trauma system performance is predominantly based on mortality rates. Because the absolute numbers of preventable deaths in established trauma systems are relatively low, potential improvement will be small. Progress towards system monitoring of the quality of survival is necessary. While function and quality of life have been identified as important factors to measure trauma populations, a standardized protocol has not been established [22*]. Recently suggestions for a standardized approach to functional evaluation have been proposed [23*]. In these guidelines on evaluation of injury related disability the authors advise to use a combination of EuroQol-5D and Health Utilities Mark III, next to injury specific evaluation. In this evaluation all relevant health domains are represented, whereas it is practical and usable in clinical practice. Nirula and Brasel [24] reported on improved functional outcome after treatment in advanced level trauma centers. A multivariate logistic regression analysis
of the USA National Trauma Data Bank from 1994 to 2001 was performed. Functional outcome was measured using the modified Functional Independence Measure. This score contains three domains, which are feeding, locomotion, and expression. There is an indication that complex care delivered by advanced level trauma centers is associated with improved functional outcomes, especially in penetrating injury.

Conclusion
The study of the effectiveness of trauma centers and trauma systems to improve outcome in trauma patients has its limitations, because the evidence is mainly based on population-based studies representing strong class III evidence. The recently published studies have very large sample sizes and present stronger evidence than ever before that designated trauma systems and centers do improve outcome in trauma patients. This is especially true for severely injured patients. A reduction in mortality between 15 and 25% can be expected for severely injured patients if treated in a designated trauma center, compared to treatment in a nontrauma center.

Although the term ‘inclusive’ trauma system was introduced in 1991, up until 2006 no studies were published to prove that the inclusive system outperforms exclusive trauma systems. The recent study of Utter et al. [9**], however, proved that inclusive trauma systems improve outcome of the severely injured. The more inclusive a trauma system is organized the larger the improvement of outcome will be.

In Western countries many of the trauma systems have a mature status and a reduction in mortality for severely injured trauma patients has been accomplished. Further reductions in mortality are expected to be small and may only be achievable in subpopulations like elderly severely injured patients. Because of this evaluation, trauma systems and trauma centers should focus more on quality of outcome.

In conclusion designated trauma centers and trauma systems do improve outcome. Inclusive trauma systems outperform exclusive trauma systems in terms of survival of the severely injured. More focus should be given to quality of outcome.

References and recommended reading
Papers of particular interest, published within the annual period of review, have been highlighted as:
• of special interest
** of outstanding interest
Additional references related to this topic can also be found in the Current World Literature section in this issue (pp. 758–760).
2 An ounce of prevention is better than the best trauma care. Lancet 2006; 367:370.
This is a very good meta-analysis of the existing literature on trauma systems consisting of 14 articles from which eight had shown a positive effect of trauma system institution. The positive effect on mortality appeared to be 15% on average after trauma system institution.
10 Utter and co-workers compared the measure of inclusiveness of the system instituted and were the first to show that an inclusive system has benefits over a noninclusive system.
MacKenzie and co-workers researched in a nationwide study with over 5000 patients and a death rate of approximately 20% the question of whether maintaining trauma centers is worthwhile. A total of 18 trauma centers and 51 nontrauma centers in 14 states were involved. They conclude that the risk of death in a trauma center is significantly lower (RRR 0.80) than in a nontrauma center. At 1 year this risk reduction is even higher (RRR 0.75).
13 Durham and co-workers reviewed based on ICD-9 codes the Florida trauma system, a mature system in the US and compared trauma with nontrauma center admissions. They found that triage to a Florida trauma center is associated with a decreased risk of death. Whereas the cost/life year saved is favorable when compared with societal expenditures for other health problems. Improved deployment of trauma centers is necessary to optimize access. In addition they demonstrated that this kind of assessment is feasible for evaluation of mature trauma systems.
In this study triage criteria were evaluated after the institution of a trauma system in the Netherlands. It demonstrated the effect of triage in that indeed the most severely injured patients were managed in the trauma center. A low sensitivity for the T-RTS was found, however; a reason to advise to reevaluate this tool in future.
Even a mature trauma system has to rely on procedures to reveal errors which can be prevented in the daily care of the traumatized patient. In an overview of medium to low probability deaths in a mature trauma center environment of Harbourview hospital, a level one trauma center for many years, the authors revealed that preventable deaths will occur even in mature trauma systems. This review has identified error patterns that are likely common in all trauma systems, and for which policy interventions can be effectively targeted.


This article details the necessity of more than alone mortality data in the evaluation of trauma systems. It reveals the first experiences with outcome data, other than risk adjusted mortality rates, in Australia.


As in the preceding reference this article details the necessity of more than alone mortality data in the evaluation of trauma systems and does a proposal based on an extensive literature review of empirical studies into injury related disability which comprises EQ-5D, the Health Utilities Mark III and an injury specific scale.