ORIGINAL ARTICLE

Reduction in Mortality of Severely Injured Patients in Germany

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SUMMARY

Introduction: The trauma registry of the German Society of Trauma Surgery is a multicentric prospective record of the treatment of severely injured patients.

Methods: The present study examines the effect of a quality management system on key processes and outcomes, in hospitals included in the trauma registry. The study is based on data of 11 013 severely injured patients (injury severity score = 16) who were treated in 105 hospitals between 1993 and 2005. A variety of parameters relating to early diagnosis and treatment were considered. Outcome quality was measured by a comparison between observed and calculated mortality (revised injury severity classification).

Results: During the 13 year long study period mortality could be significantly reduced from 22.8% to 18.7%. The time to initial radiological and ultrasound diagnosis was reduced, the use of computed tomography increased, the time until emergency operations in hemorrhagic shock was reduced, and damage limiting orthopedic interventions were performed more frequently.

Discussion: The German Trauma Registry records processes and treatment results in severely injured patients. This information is fed back to participating hospitals. The continuous data feedback is associated with a continuous improvement of process and outcome quality in the treatment of severely injured patients.

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In Germany, 7 to 8 million accidents occur every year, resulting in 580 000 injured parties (1). In most cases, injuries will be moderate and require only outpatient treatment or brief inpatient treatment. Severe injuries are still a major challenge for Germany's healthcare system. According to current data, 33 000 to 38 000 patients suffer severe trauma (injury severity score (ISS) of 16) in Germany every year (2, 3, 4).

In many of Germany's regions, the preclinical and clinical treatment of these patients is of high quality, thanks to the strong commitment of Germany's accident and emergency surgeons, all disciplines involved, and emergency rescue services. However, individual accidents that have sparked intense public discussion, as well as numerous scientific investigations, have shown that the quality of trauma care in Germany is not consistently high (5, 6, 7). According to reports from the Federal Statistical Office, for example, the proportion of fatal road traffic accidents varies widely in the federal states. For example, in Mecklenburg-Western Pomerania, mortality due to road traffic accidents involving injured persons is 2.7%, compared with 1.1% in North Rhine-Westphalia. Allowances need to be made for the fact that hospitals in Mecklenburg-Western Pomerania deliver care to an area of 4634 km² each, whereas hospitals in North Rhine-Westphalia cover an area of 541 km² each (7). Data from the trauma registry of the German Society of Trauma Surgery (Deutsche Gesellschaft für Unfallchirurgie, DGU) show substantial differences among participating hospitals in death rates after severe trauma (8).

Two main causes are underlying these differences in quality:

- Geographical and infrastructural differences between federal states and regions
- Different treatment concepts and varying equipment in those hospitals that deliver polytrauma care.

To notably improve treatment quality in future, it is of utmost importance to capture information on strengths and weaknesses in the care process and to report this information to the responsible hospitals, rescue services, and medical specialties involved (9).

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FIGURE 1

Number of hospitals participating in the trauma registry from 1993 to 2005

FIGURE 2

Numbers of total patients captured

The trauma registry of the German Society of Trauma Surgery was founded in 1993, to enable capture, analysis, and quality control of the preclinical and clinical care for trauma patients. The process analysis is intended to help participating hospitals to identify weaknesses and establish new, better treatment concepts where necessary, and monitor these. Participating hospitals have therefore received annual feedback in the form of an anonymized, individual annual report. This article aims to show how the treatment

situation as regards survival prognosis has changed in the hospitals participating in the trauma registry since the annual report was introduced.

Methods

Data collection in the trauma registry

The German trauma registry was set up in 1993 to enable multicenter collections of treatment data from patients with severe injuries in the German speaking area (10). The registry collects prospective and anonymized data of severely injured patients from the location of the accident to discharge from hospital. The registry data were initially documented on forms, in a standardized format, at four different time points (emergency physician, trauma room, intensive care unit, discharge). Since 2002, online data entry has been an option (www.traumaregister.de). The data entered are available for downloading to the participating hospitals for the purpose of their own evaluations at all times.

Because the number of hospitals that actively participate has been increasing, the trauma registry has enabled the setting out of a comprehensive, international quality management system. Since the trauma registry was set up, numbers of hospitals and captured patients have risen every year (*figures 1 and 2*). At the end of 2006, 125 hospitals were participating in the registry (*figure 1*). Currently, hospitals from Germany, Austria, Switzerland, Slovenia, and the Netherlands are participating (*e-figure*). 30% of participating hospitals have contributed data only intermittently.

Quality management

The collected routine data can be documented with a certain amount of additional effort. Each hospital that participates in the trauma registry receives a confidential report of results once a year, describing the cohort, diagnostic and therapeutic measures, and the outcome of the care provided (mortality, duration of inpatient stay, condition at discharge).

Simultaneously, quality indicators are being evaluated that are partly based on the assessment criteria of the American College of Surgeons (11). These are compared with the results of preceding years, the entire hospital, and the entire trauma registry.

RISC analysis

Further to these variables of the quality of the process, attention is paid to the most important quality variable relating to trauma patients: survival. Since direct comparisons of death rates between hospitals can be misleading, owing to the different degree of patients' injuries, some adjustments are required.

The trauma registry therefore initially used the internationally used TRISS score (trauma injury severity score) (12). This prognostic formula is used to calculate an expected result by using the means of the individual prognoses for groups of patients, which are then compared with the actual health status of the patients. In 2004,

the TRISS was replaced by the "revised injury severity classification" (RISC) (figure 3) as an instrument to assess prognosis. In contrast to the TRISS method, which is based on 20 year old data from the North American Major Trauma Outcome Study, the RISC uses data from the patients in the trauma registry.

The RISC combines 10 items that usually become available shortly after admission of the patient (box). The RISC was developed using data from 1200 patients in the trauma registry from 1993 to 2000 and validated repeatedly in the following years. Its discriminatory ability – measured using the area under the receiver operating characteristic (ROC) curve – is notably superior to that of scoring systems used thus far (revised trauma score [RTS]: 0.76; ISS: 0.79; TRISS: 0.86; RISC: 0.91). A detailed publication outlining the RISC development is in preparation. Details are available from the trauma registry annual reports or in Oestern's book "Das Polytrauma" [the polytrauma] (13).

The prognoses calculated using TRISS or RISC are compared with the actually observed survival rates, for example, directly, as in figure 3, or as standardized mortality rates (SMR). This means that the observed death rate is divided by the expected rate (figure 4). For the observed death rate, a 95% confidence interval is calculated, based on a Poisson distribution. If the prognosis for a group of patients is outside the confidence interval the deviation is deemed significant. By adjusting severity in this way, hospitals with patients with injuries of varying severity can be compared with each other.

Selection of patients: According to the importance of rapid and targeted therapy for severely injured patients, our quality/mortality analysis includes only patients receiving initial treatment whose injury severity scores at least 16 points in the ISS (3).

The criteria time in the trauma suite, time to emergency surgery in hemorrhagic shock, whole body computed tomography (CT) scanning, and admission to intensive care have been captured in the online documentation only since 2002.

Results

Demographic data

The table shows essential treatment data for all patients in the trauma registry up to 2005. According to our research question, we have evaluated patient data only since 1999, the first time that structured feedback was given to the participating hospitals (annual report). In the period under observation (1999 to 2005), data from a total of 11 013 severely injured patients (ISS = 16) in 105 hospitals were documented.

Adjustment of severity

We used the RISC to calculate the prognosis in the form of expected mortality for the cohorts from the individual years according to the anatomical and physiological severity of the patients' injuries. This

Observed mortality and prognosis, on the basis of the "revised injury severity classification" (RISC), using as an example a participating hospital from the 2004 annual report of the trauma registry

was then compared with the actual mortality, the SMR. Over the seven-year period under observation, mortality decreased notably (figure 4). In 1999, the proportion of actual mortality versus expected mortality was 22.8% versus 22.0%. In 2005, the balance was 18.7% to 22.1%. This effect was significant in 2005, as shown by the 95% confidence interval in figure 4.

Therapeutic variables

We found improvements over time for the time to initial diagnostic tests as well as for important therapeutic variables.

Diagnostics: The time taken to perform initial radiological sonographic diagnostics – consisting of ultrasonography of the abdomen and x-radiography of thorax and pelvis – decreased from 25 minutes to 15 minutes in the time period under observation (figure 5). The proportion of whole body CT scanning – usually performed subsequently, and captured only since 2002 – rose from 10% to 36% (figure 6).

Treatment: One of the most important time spans in trauma room care is the time to hemostatic surgery in patients with traumatic shock. Among participating hospitals, this time fell from 45 minutes to 39 minutes from 2002 to 2005. Over the same time period, the time to admission to intensive care for patients who were not operated on fell from 121 minutes to 113 minutes (figure 7).

In severely injured patients with a fractured femur, external fixation was increasingly used in the sense of a "damage control" exercise (increase from 41% to 53%) (figure 6). "Damage control" describes temporary and less invasive stabilization and control of bleeding.

FIGURE 4

Standardized mortality rates (SMR) on the basis of RISC ("revised injury severity classification") for patients with ISS ≥ 16 (n = 11 013). Values below 1 indicate that fewer patients died than was expected in the prognosis

Discussion

The trauma registry is a scientific database used to analyze treatment strategies and factors that influence the care of severely injured patients, as well as an instrument used for quality reporting and quality management. This article focused mainly on the quality management aspect. The database of the trauma registry has thus far spawned more than 80 national and international publications.

In addition to describing the treatment situation of severely injured patients, we have attempted to show that consistent feedback of the treatment data to the hospitals is associated with positive changes to therapy and prognosis. Using a statistical method to calculate prognosis (RISC analysis) that includes anatomical injury as well as disrupted vital parameters, we showed a decrease in mortality after severe trauma.

Bearing in mind the lengthy and complex treatment administered to these patients in the prehospital setting, trauma suite, operating theater, and intensive care unit, the reasons for this drop in mortality in severely injured patients in the participating hospitals has to be considered as multifactorial. With regard to survival, however, especially the hours immediately after the accident are crucial. About half of the patients who die in hospital succumb to their injuries within the first 48 hours (14). Simultaneously, later death due to multiorgan failure and severe craniocerebral trauma can be critically influenced by targeted early treatment, e.g., by reducing mass transfusion or rapid therapy to lower intracranial pressure (15).

External control of early clinical care is difficult, owing to the different treatment priorities that depend on the severity of the injury and injury patterns, the interdisciplinary treatment approach, and the timeliness of care. Because data collection is complex, as is the allocation of causes of possible complications, we

BOX

Definition of RISC

- Age: −1.0 points from 55 years of age; −2.0 points from 65; −2.3 points from 75
- Overall severity of injuries (new ISS): −0.03 points per ISS point
- Grade of head injury: −0.5 for AIS ("abbreviated injury scale") severity 4; −1.8 for severity grade 5/6
- Pelvic injuries with relevant blood loss: −1.0 point
- Unconsciousness at accident site: Glasgow coma scale 3 to 5 points; −0.9 points
- Preclinical resuscitation: −2.5 points
- Initial laboratory values such as base excess (BE): 0.8 points for BE < −9 mmol/L; −2.7 points for BE < −20 mmol/L
- Clotting (partial thromboplastin time [PTT]): −0.8 points if PTT 40 to 49 sec; −1.0 point if 50 to 79 sec; −1.2 points from 80 sec
- Number of indirect bleeding signs: systolic blood pressure <90 mm Hg; hemoglobin <9 mg/dL; massive blood transfusion with more than 9 units. If a bleeding sign is present the score reduces by 0.4 points, in two signs by 0.8 points, and in all three signs by 1.6 points.

The resulting score is transformed into a survival probability by using a logistic function $1/1 + \exp(-x)$.

did not use quality indicators from intensive medicine and technical operating skills.

For this reason, the trauma registry defines a set of variables that can be collected objectively and in a way that is comparable between hospitals. To this end, quality criteria have been taken into consideration whose direct (time to emergency surgery) or indirect (time to initial imaging) influence on the patient's prognosis can be proved or is highly likely. In developing these criteria, the catalogue of criteria from the American College of Surgeons (11), which is defined in a similar manner, has been used.

In the variables time to diagnosis and time to emergency surgery, a significant improvement in the all-hospital average was shown in areas for which comparisons in services and feedback have been given since 1999 or 2002. The clinical relevance of the shortened time interval to the start of the investigated measures is hard to assess in severely injured patients with monotrauma or polytrauma and is to be seen mainly as an indicator for optimized management.

On the other hand it was shown for the time interval to emergency surgery in hemorrhagic shock that for

TABLE

Variables for all patients in the trauma registry treated to 2005

Number	24 771
Mean age	40.8 years
Number of men	72%
Blunt trauma	95%
Injury severity score (mean)	23.9
Care at site of accident	
Unconscious (GCS < 9)	31%
Shock (systolic RR < 90 mm Hg)	19%
Intubation by emergency physician	55%
Care in trauma room	
Stopped owing to emergency surgery	9%
Use of CT	65%
Transfusion before admission to intensive care unit	28%
Further in-hospital care	
Operated patients	77%
Number of operations per patient (mean)	3.9
Patients requiring intensive care	87%
Result	
Mean duration of hospital stay	25.9 days
Mean duration of stay in intensive care	11.7 days
Mean duration of intubation	9.0 days
Early death (<24 hours)	7%
Death (including early death) in hospital	15%
Patients with organ failure	35%
Transfer to another hospital	25%

every three minutes' delay to hemostatic emergency surgery the patient's prognosis worsened by 1% (16). In the trauma registry cohort, the time to surgery for this subcohort was found to be reduced by six minutes.

Although this was not emphasized as a quality management variable but only documented in the annual report, a notable increase was found for the variables whole body CT scanning and external fixation of the fractured femur. Although no unequivocal scientific proof of a prognostic improvement has been shown for either of those two methods, a relevant influence on the prognosis may be assumed especially in severely injured patients (17, 18). The selected parameters can therefore be used as indicators for more or less well functioning management of early clinical care provision for patients with severe injuries. The reasons for delays in the process cannot be shown in the trauma registry. The meaningfulness of the study is limited because the data quality of the voluntarily participating hospitals has not been compared with local controls. It is therefore not impossible that particularly poor processes and outcomes are not being reported. The

FIGURE 5

Duration of ultrasound-radiological basic diagnostics in minutes
(*p < 0.05 for 2005 compared with 1999)

correlation between continual optimization of the process and improvements in the quality of results, however, would imply reliability. It is also possible that further measures with an influence have not been captured.

In principal, in each individual hospital the quality of care in internal organization and interdisciplinary coordination can be further improved only through a functional internal quality management system. For this purpose, the trauma registry provides important pointers for hospitals to assess their own process quality, especially by means of inter-hospital comparisons. Because the quality of care for trauma patients in Germany varies widely and because of the fact that treatment quality can be influenced positively through using an external feedback system, the German Society of Trauma Surgery has recently developed the concept of a trauma network (9).

Initiating local trauma network structures among supraregional and regional trauma centers and institutions involved in providing emergency surgical care is intended to guarantee that every severely injured patient can be transported from the site of the accident into the trauma suite of a suitable hospital within 30 minutes.

The main constituents of a regional trauma network include:

- Defined criteria for admitting patients from the accident site to the trauma center or institution of emergency surgical care
- Introduction of standardized staffing, structural, and organizational conditions, e.g., the equipment in the trauma room
- Formulation of standardized treatment processes and transfer criteria for the early phase of care for patients with severe injuries on the basis of the evidence based guidelines of the German Society of Trauma Surgery.
- Standardization of medical qualifications by joint training programs such as "advanced trauma life support" (www.atls.de)
- Participation in internal and external quality improvement measures and capture of the current

FIGURE 6

Incidence of whole body CT scanning (data collected only since 2002) and damage control operation in fractured femur (external fixation) in severe trauma (ISS = 16)

FIGURE 7

Time to emergency surgery in hemorrhagic shock and time to admission to intensive care if no surgery was performed, in minutes. The variables have been collected generally only since 2002 (* $p < 0.05$ for 2005 compared with 2002).

care data and processes on the basis of the trauma registry of the German Society of Trauma Surgery (www.traumaregister.de)

- Establishing telecommunications systems that enable participating hospitals to exchange information during or immediately after the acute treatment phase and to discuss further proceedings.

Conclusions

The trauma registry of the German Society of Trauma Surgery was set up to provide scientific, epidemiological, and health economic data. On the basis of a continually growing number of hospitals, the current quality of care is therefore being documented. By analyzing the results, the hospitals participating in the

registry are able to identify weaknesses and work out, implement, and monitor improved concepts.

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Conflict of interest statement

Prof. Ruchholtz, PD Lefering, Dr. Paffrath, Prof. Oestern, Prof. Neugebauer, Prof. Nast-Kolb, Prof. Pape, and Prof. Bouillon declare that no conflict of interest exists according to the guidelines of the International Committee of Medical Journal Editors.

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