Langenbecks Arch Surg (2016) 401:531–540
DOI 10.1007/s00423-016-1428-x

ORIGINAL ARTICLE

# Change of initial and ICU treatment over time in trauma patients. An analysis from the TraumaRegister DGU®

**Andreas B. Böhmer[1] · Marcel Poels[1] · Kathrin Kleinbrahm[2] · Rolf Lefering[3] · Thomas Paffrath[4] · Bertil Bouillon[4] · Jerome Michel Defosse[1] · Mark U. Gerbershagen[1] · Frank Wappler[1] · Robin Joppich[1]**

Received: 21 January 2016 / Accepted: 5 April 2016 / Published online: 25 April 2016


**Abstract**
*Background* Clinical guidelines have been standardized for pre- and in-hospital trauma management in the last decades. Therefore, it is known that prehospital management has changed significantly. Furthermore, in-hospital course may be altered to reduce complications and length of stay (LOS). However, the development of trauma patient in-hospital management as well as LOS in the intensive care unit (ICU) has not been investigated systematically over a long-term period in Germany. Aim of our study is to examine the changes in in-hospital management and LOS in the ICU in moderately and severely injured patients.
*Methods* Patients documented in the TraumaRegister DGU® (TR-DGU) of the German Trauma Society from 2000 to 2011 and admitted to ICU were included in this study. Demographic data, the pattern of injury, injury severity, duration of mechanical ventilation, LOS in the ICU, hospital LOS, and discharge destination were evaluated. The mean values and the standard deviations are shown. The constant variables were calculated with changes over time analyzed by linear regression analysis, and categorical variables were calculated with the chi-square test.
*Results* A total of 18,048 patients were analyzed. The rate of patients being intubated at the time of ICU admission decreased from 86.8 % in 2000 to 60.0 % in 2011 ($p < 0.001$). The time of mechanical ventilation decreased from $7.5 \pm 10.5$ to $4.7 \pm 8.7$ days. The intensive care unit LOS was reduced from $11.7 \pm 12.8$ to $9.0 \pm 11.3$ days and the length of hospital stay from $27.9 \pm 28.7$ to $21.1 \pm 20.4$ days (both $p < 0.01$). The ICU LOS remained stable in the subgroup of mechanically ventilated patients ($12.7 \pm 13.2$ day in 2000, $12{,}6 \pm 12.9$ in 2011, $p = 0.6$),

✉ Andreas B. Böhmer
boehmera@kliniken-koeln.de

Marcel Poels
poelsm@kliniken-koeln.de

Kathrin Kleinbrahm
k.kleinbrahm@web.de

Rolf Lefering
rolf.lefering@uni-wh.de

Thomas Paffrath
paffratht@kliniken-koeln.de

Bertil Bouillon
bouillonb@kliniken-koeln.de

Jerome Michel Defosse
defossej@kliniken-koeln.de

Mark U. Gerbershagen
mark.gerbershagen@uni-wh.de

Frank Wappler
wapplerf@kliniken-koeln.de

Robin Joppich
joppichr@kliniken-koeln.de

1 Department of Anesthesiology, Hospital Cologne-Merheim, Cologne Medical Center, Witten/Herdecke University, Ostmerheimer Str. 200, 51109 Cologne, Germany

2 Department of Anesthesiology and Intensive Care Medicine, University of Cologne, Kerpener Straße 62, 50937 Cologne, Germany

3 Institute for Research in Operative Medicine (IFOM), Witten/Herdecke University, Cologne, Germany

4 Department of Traumatology and Orthopedic Surgery, Hospital Cologne-Merheim, Cologne Medical Center, Witten/Herdecke University, Cologne, Germany

whereas it was reduced in non-mechanically ventilated patients (5.5 ± 6.8 days in 2000, 3.6 ± 4.5 days in 2011; $p < 0.001$).
*Conclusions* The reduction LOS in the analyzed dataset is mainly explained by the relevantly reduced rate of patients being intubated at the time of ICU admission. Our data demonstrate that trauma patients' in-hospital course is influenced by reduced intubation rate at the time of ICU admission.

**Keywords** Multiple trauma · Polytrauma · Length of stay · Intensive care · Intubation

## Introduction

Every year, up to 38,000 patients suffer from severe trauma in Germany [1]. Efforts have been made to reduce the trauma-related morbidity and mortality accompanied by years of controversial discussion and numerous publications. This led to detailed recommendations for the particular phases of trauma resuscitation, including prehospital, early, and consecutive in-hospital management. These recommendations were summarized in the S3-Guideline on Treatment of Patients with Severe and Multiple Injuries [2]. According to this, pre- and in-hospital trauma management has changed over the years, undergoing more than one paradigm shift, e.g., the amount of intravenous fluid administered at scene decreased [3]. The majority of moderately or severely injured patients (>95 %) are initially treated by an emergency physician on scene (including life-saving interventions, e.g., airway management) and transported to an acute care hospital by helicopter or by ambulance. In-hospital management is mainly based on a diagnostic and treatment algorithm addressing ABCDE-problems (i.e., airway, breathing, circulation, disability, and exposure) and computed tomography. However, after the initial management of a severely injured trauma patient, resuscitation has to be continued at the intensive care unit (ICU) [4]. Therefore, many approaches in intensive care treatment have been changed to reduce morbidity and mortality, such as early goal directed therapy in the treatment of sepsis [5], lung protective ventilation and daily spontaneous breathing to reduce ventilation time [6] as well as early mobilization [7].

The changes in prehospital management in Germany have been described previously [8]. Whether there is a change in the in-hospital management within the population of moderately and severely injured trauma patients has not previously been examined. Therefore, the aim of the present study was to display the development of the rate of invasively ventilated patients at the time of ICU admission, the ICU length of stay (LOS), the length of invasive ventilation, and the length of hospital stay in a large population of moderately to severely injured trauma patients in Germany.

## Methods

### TraumaRegister DGU®

The German TraumaRegister DGU® (TR-DGU) is a prospective multi-center database that was founded in 1993. It offers a standardized and anonymous documentation of severely injured patients from the point of accident with subsequent stay in the ICU or intermediate care unit (IMC) to clinical discharge [9]. Its aim is to define standards, develop therapeutic concepts, and implement a system for evaluating trauma care. Detailed information on a patient's pre-existing condition, accident mechanisms, preclinical state, status at the time of admission, intensive care treatment, and clinical discharge, including demographics, clinical, and laboratory data, as well as a variety of standardized scoring systems such as the Glasgow Coma Scale (GCS) [10], the Injury Severity Score (ISS) [11], and the Abbreviated Injury Scale (AIS) are available. Detailed information on the TR-DGU can be found in the acknowledgement section. Currently, approximately 25,000 cases from more than 600 hospitals are entered into the database every year. The present study is in line with the publication guidelines of the TraumaRegister DGU® and registered as TR-DGU project ID 2012-016.

### Patients

Patients collected in the TR-DGU from 2000 to 2011 with an Injury Severity Score ≥9 were eligible for inclusion in this study if they were primarily admitted to the ICU (no secondary transfer in or out to another trauma center). We included all hospitals that were level I (supra-regional) or II (regional) trauma care centers in Germany that participated in the TR-DGU for at least 10 years in the respective period. To avoid large deviation from the mean LOS, those patients who stayed longer than 90 days in the ICU were excluded (these were less than 1 % of the patient total).

### Variables

Gender and age were determined demographic variables. We analyzed the LOS in the ICU, number of patients who were intubated on admission to the ICU, duration of intubation, ISS, and discharge destination. The pattern and severity of injuries is displayed by calculating the ratio of patients with an AIS of 3 or higher in the particular body region (i.e., head/neck, chest, abdomen, extremities), which is in accordance with the European definition of severe injury of the particular body region. Furthermore, we investigated the incidence of sepsis as well as single and multiple-organ failure. Data for organ failure (OF) and sepsis were not recorded before 2002, which is when the TR-DGU changed to an online data collection system. Therefore, the first 2 years were not available for this sub-analysis. OF was defined according to the Sequential Organ Failure Assessment (SOFA) score [12], where a SOFA score ≥3 for at least 2 days was considered as OF.

### Statistical analysis

Statistical analysis was performed for all trauma patients as well as separately for non-survivors and survivors. The median and mean values with standard deviations for the absolute values and percentages are shown. Changes over time were analyzed on a yearly basis using linear regression analysis. The year of treatment was an independent predictor. Categorical variables were presented as the percentage of valid cases, and differences were tested using the chi-squared test for linear association of changes over time. Due to the number of cases included in the analysis, we defined a $p$ value <0.01 as statistically significant.

## Results

Datasets of traumatized patients (18,048) reported from 34 hospitals were considered for the analysis and met the aforementioned requirements. Twenty-six hospitals registered as level I and 8 level II hospitals were enrolled in our analysis. The general characteristics of the population examined are shown in Table 1. There was no change in the gender distribution over the 12-year period of time ($p = 0.57$).

The age of the trauma patients increased over time from 41.1 ± 20.9 years to 47.2 ± 22.0 years ($p < 0.001$). The mortality is within the range of 17.4 to 12.1 % with a tendency to decrease over the observation period; however, this tendency did not reach statistical significance ($p = 0.06$).

The average ISS was 23.9 ± 12.6 points and remained stable over the entire observation period ($p = 0.76$). The ratio of patients with an ISS ≥16 was 73 % for the whole observation period not changing significantly and without revealing an increasing or decreasing trend. For the group of survivors and non-survivors, the mean ISS was 22.2 ± 11.2 and 34.8 ± 16.3, respectively, and did not have relevant alterations within the observation period. In the group of non-ventilated patients, the mean ISS was 17.3 for the whole observation period showing inconsistent variations of 2.5 ISS points from the mean value without any significance. In the group of ventilated patients, mean ISS was 26.1 with inconsistent variations of 1.9 ISS points from the mean value.

The pattern of injury and the ratio of patients with shock in the preclinical setting changed (Table 2). The ratios of patients with severe head injury was 49.3 % and chest injury was 45.7 %, respectively, both showing inconsistent changes over time. In contrast, the number of severe abdominal trauma (19.5 % in 2000, 14.0 % in 2011) as well as the ratio of severe extremity injuries (45.3 % in 2000, 29.5 % in 2011) decreased continuously over the observation period (both $p < 0.001$).

The ratio of patients with a documented systolic blood pressure ≤90 mmHg at scene decreases from 21.9 % in 2000 to 12.0 % in 2011. For the ratio of patients with an GCS of 8 or lower, such a relevant trend cannot be found. The ratio varies round 30 % except for the first and the last year of the observation period.

The proportion of patients admitted by helicopter to the destination hospital decreased continuously from a maximum of 49.3 % in 2001 to a minimum of 31.4 % in 2011 ($p < 0.01$, Fig. 1). Within the observation period, the time on scene did not change significantly, though there is a tendency of a reduced time on scene. Median time on scene was 28 min.

There were changes in both the LOS in the ICU and duration of invasive ventilation. The LOS in the ICU for all trauma patients declined from 11.7 ± 12.8 to 9.0 ± 11.3 days ($p < 0.001$). This trend was true for the group of trauma patients with an ISS 9–15 (5.6 ± 6.2 to 4.9 ± 6.7 days; $p < 0.001$) as well as for the group of severely injured trauma patients with an ISS ≥ 16 (13.8 ± 13.7 to 10.6 ± 12.3 days; $p < 0.001$).

Separate analysis of the survivors and non-survivors revealed a reduction in the LOS in the ICU for the group of survivors from 12.8 ± 13.2 to 9.3 ± 11.3 days (Table 3). This is consistent with a decline in the length of stay in the ICU of 0.25 days/year ($p < 0.001$). For the group of non-survivors, no reduction could be found in the ICU LOS (mean value 6.6 ± 10.1 days; $p = 0.12$, Fig. 2). LOS was 1 day longer (mean value and median) for both survivors and non-survivors when treatment was performed in level II trauma centers.

The LOS in the ICU remained stable for the group of ventilated patients with a mean value of 12.9 ± 12.8 days (median 9 days; 12.7 ± 13.2 days in 2000, 12.6 ± 12.9 days in 2011) for the entire observation period ($p = 0.6$). There was a reduction in the ICU LOS for the group of non-ventilated patients (5.5 ± 6.8 days in 2000, 3.6 ± 4.5 days in 2011; $p < 0.001$). The latter is mainly due to a reduction of LOS within the first years from 2000 to 2001 (5.5 to 4.2 days) and 2001 to 2002 (4.2 to 3.8 days). From 2002 to 2011, no relevant reduction (3.8 to 3.6 days) could be observed for this subgroup of trauma patients (Fig. 3). The proportion of those patients, who never required intubation in the whole process of trauma care, developed almost threefold from 4.5 % in 2000 up to 11.9 % in 2011, showing a continuous increase.

The duration of invasive ventilation for the entire population of trauma patients changed from 7.5 ± 10.5 to 4.7 ± 8.8 days ($p < 0.001$). These changes were based on two findings. First, the duration of ventilation in the intubated patients was marginally reduced over the observation period from 8.6 ± 10.9 to 7.9 ± 10.1 days ($p < 0.01$). Second, there was a clear decline of more than 25 % in the rate/portion of trauma patients who were already intubated at the time of ICU admission (from 86.8 % in 2000 to 60.0 % in 2011; $p < 0.001$).

**Table 1** General characteristics of the study population

| Year | No. of patients | Age (mean ± SD) | Male (%) | ISS (median; mean ± SD) | Mortality (%) |
|---|---|---|---|---|---|
| 2000 | 1008 | 41.0 ± 20.9 | 68.2 | 24; 25.4 ± 13.6 | 17.4 |
| 2001 | 1088 | 40.3 ± 20.7 | 72.9 | 24; 24.9 ± 13.0 | 14.3 |
| 2002 | 1076 | 41.3 ± 20.9 | 74.8 | 20; 22.8 ± 13.4 | 13.2 |
| 2003 | 1217 | 41.2 ± 20.3 | 72.9 | 20; 22.6 ± 13.0 | 13.9 |
| 2004 | 1315 | 40.9 ± 20.2 | 74.6 | 19; 22.0 ± 12.5 | 13.8 |
| 2005 | 1408 | 41.8 ± 20.3 | 71.7 | 22; 23.6 ± 12.5 | 12.3 |
| 2006 | 1532 | 42.8 ± 21.6 | 72.9 | 22; 24.6 ± 13.1 | 13.4 |
| 2007 | 1912 | 43.6 ± 20.6 | 73.9 | 22; 25.0 ± 13.2 | 11.9 |
| 2008 | 1562 | 45.6 ± 21.1 | 72.6 | 22; 24.1 ± 12.3 | 13.4 |
| 2009 | 1944 | 46.2 ± 21.6 | 72.0 | 22; 24.7 ± 12.4 | 14.8 |
| 2010 | 1866 | 46.2 ± 21.9 | 72.1 | 22; 23.7 ± 12.1 | 14.7 |
| 2011 | 2120 | 47.2 ± 22.0 | 70.9 | 21; 23.1 ± 12.3 | 12.1 |
| Significance | $p < 0.001$ | $p = 0.57$ | $p = 0.76$ | $p = 0.06$ | |
| Total | 18,048 | 43.7 ± 21.3 | 72.4 | 22; 23.9 ± 12.8 | 13.6 |

*SD* standard deviation, *ISS* injury severity score

Separate analysis of both subgroups of patients with an ISS <16 (moderate trauma) and those with an ISS ≥16 (severe trauma) revealed a decrease in the intubation rate to the time of ICU admission from 77.9 to 38.9 % for the moderate trauma subgroup and from 89.9 to 68.1 % for the severe trauma subgroup (both $p < 0.001$, Fig. 4).

The occurrence of secondary complications following trauma, such as single or multiple-organ failure, did not change during the observation period. However, the incidence of sepsis following trauma decreased from 11.4 to 7.8 % without reaching level of significance ($p = 0.09$, Table 4).

The overall in-hospital stay declined from 27.9 ± 28.7 days (2000) to 21.1 ± 20.4 days (2011) for all trauma patients ($p < 0.001$). Separate analysis of the survivors' length of stay in the hospital changed from 32.3 ± 29.4 days (2000) to 22.9 ± 20.6 days (2011; $p < 0.001$). In contrast, no change could be found for the subgroup of non-survivors ($p = 0.5$, Table 4).

The number of patients who were primarily discharged home after being treated in the normal ward following the intensive care treatment period increased from 32.1 to 47.2 % ($p < 0.001$). The frequency of discharge to rehabilitation centers remained stable over time ($p = 0.04$), while the number of patients who were

**Table 2** Development of AIS ≥3 ratio in particular body regions, ratio of GCS ≤8 and systolic blood pressure ≤90 mmHg in the study population

| Year | No. of patients | Head/Neck (%) | Chest (%) | Abdomen (%) | Extremities (%) | GCS ≤8 (%) | RRsys ≤90 mmHg (%) |
|---|---|---|---|---|---|---|---|
| 2000 | 1008 | 46.8 | 45.3 | 19.5 | 45.3 | 34.3 | 21.9 |
| 2001 | 1088 | 46.8 | 46.6 | 18.3 | 40.3 | 30.3 | 19.5 |
| 2002 | 1076 | 46.5 | 44.7 | 18.5 | 40.5 | 31.2 | 18.0 |
| 2003 | 1217 | 45.5 | 42.0 | 17.5 | 39.5 | 28.0 | 18.9 |
| 2004 | 1315 | 48.3 | 40.5 | 16.1 | 37.9 | 30.1 | 18.9 |
| 2005 | 1408 | 48.8 | 43.3 | 17.7 | 38.1 | 29.2 | 18.0 |
| 2006 | 1532 | 54.6 | 45.9 | 17.1 | 37.5 | 32.5 | 20.3 |
| 2007 | 1912 | 51.0 | 48.5 | 17.3 | 37.2 | 28.8 | 17.3 |
| 2008 | 1562 | 53.6 | 45.1 | 15.0 | 32.1 | 30.0 | 16.2 |
| 2009 | 1944 | 50.7 | 49.9 | 15.3 | 33.3 | 31.1 | 15.1 |
| 2010 | 1866 | 49.2 | 45.3 | 15.0 | 32.2 | 30.2 | 16.6 |
| 2011 | 2120 | 46.5 | 47.5 | 14.0 | 29.5 | 25.8 | 12.0 |
| Significance | $p = 0.02$ | $p < 0.01$ | $p < 0.001$ | $p < 0.001$ | $p < 0.01$ | $p < 0.01$ | |
| Total | 18,048 | 49.3 | 45.7 | 16.5 | 36.1 | 29.9 | 17.3 |

*AIS* abbreviated injury score, *RRsys* systolic blood pressure

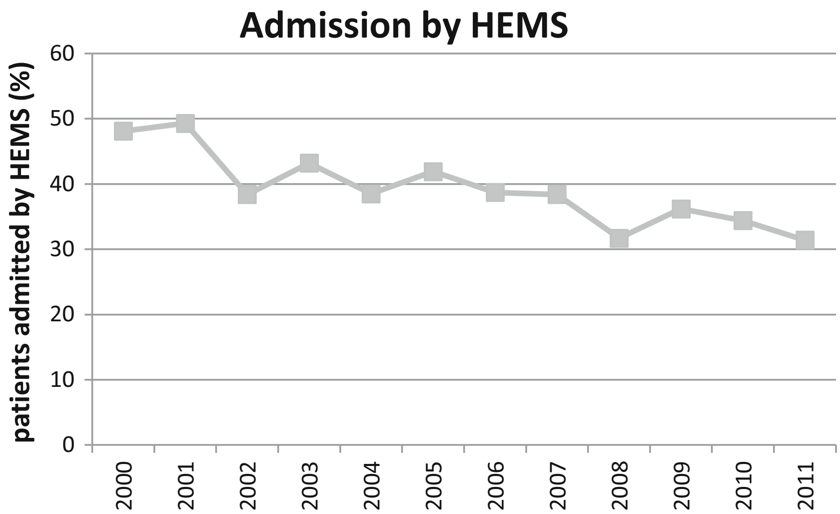


**Fig. 1** Development of the proportion of HEMS admitted patients from 2000 to 2011. Percentage per year; *HEMS*, helicopter medical service

discharged to another hospital declined from 14.8 % (2000) to 11.0 % (2001; $p < 0.001$).

## Discussion

Our data contributes the development of some aspects in in-hospital trauma care in Germany. It is based on three main findings:

1. If a moderately or severely injured patient was already intubated and invasively ventilated when admitted to the ICU, there would be no relevant reduction of ventilation time as well as length of stay in the ICU over the last decade.
2. Fewer patients were intubated and invasively ventilated at the time of ICU admission.
3. The reduction LOS in the analyzed dataset is mainly explained by the relevantly reduced rate of patients being intubated at the time of ICU admission.

Furthermore, the reduced ICU LOS cannot be explained by a reduction of ICU LOS in the non-survivor group, which could be taken as a hint that there were no alterations in the duration of treatment efforts for very severely injured patients.

Our data suggest a relevant modification of early phase trauma care strategies in Germany which is well in concordance with other previous publications [3, 8]. It is already known that the frequency of intubation at scene decreased over the last two decades in Germany, especially in those patients who were conscious; according to an analysis of actual trends in trauma care, the rate of intubation in those patients with an GCS of 9 or higher continuously decreased from 2002 (approximately 50 %) to 2012 (approximately 20 %), while the intubation rate in unconscious patients having a GCS <9, remained constantly high with about 90 % [13]. Our data complements the finding that the frequency of patients admitted to the intensive care unit being intubated has been reduced from more than 80 to 60 % even though there was no change in the injury severity or the ratio of severely injured patients over the years. In the underlying data set, both groups of patients were severely injured, but within the group of ventilated patients ISS was relevantly higher.

One possible influencing factor might be the relevant decrease of patients admitted to the hospital by helicopter in our collective, which is well in accordance with the general development in German trauma care [13]. It is known that the proportion of patients with intubation at scene is significantly higher when admitted by HEMS [14], but the decrease of intubation rate cannot be explained by reduction of HEMS admission alone. There are many single steps in the early treatment procedure of a trauma patient, only beginning with an adequate prehospital management including a secure transfer to the hospital, followed by the treatment at the emergency ward and, in most of the moderately or severely injured patients, some kind of surgical intervention. In all these single steps of the procedure, intubation and invasive ventilation can become necessary.

It seems that the reduced ratio of patients being intubated in the early treatment phase can be—at least partially—explained by a summation of several effects (i.e., reduction of HEMS admission, reduction of preclinical shock, reduction of severe extremity and abdominal injuries). Whether there has been additively a philosophical change in trauma management cannot be answered by the design of our study; furthermore, it will be difficult to answer this question in all its particulars by analyzing registry data. The aspect of time has gained more attention in trauma management [8]. While many physicians were focused on complete therapy at scene in former years, the premise today seems to have changed; the approach

**Table 3** Time of invasive ventilation, length of stay in the ICU and the overall hospital stay of the examined trauma population separated for survivors and non-survivors

| Year | No. of patients | Time of invasive ventilation (days) (median; mean ± SD) | | LOS ICU (days) (median; mean ± SD) | | Hospital LOS (days) (median; mean ± SD) | |
|---|---|---|---|---|---|---|---|
| | | Survivor | Non-survivor | Survivor | Non-survivor | Survivor | Non-survivor |
| 2000 | 1008 | 3; 7.8 ± 10.9 | 2; 6.1 ± 8.6 | 8; 12.8 ± 13.2 | 3; 6.8 ± 8.9 | 25; 32.3 ± 29.4 | 3; 7.2 ± 10.1 |
| 2001 | 1088 | 3; 7.5 ± 10.6 | 2; 6.7 ± 11.0 | 7; 12.1 ± 12.2 | 3; 7.7 ± 12.6 | 23; 32.3 ± 31.4 | 3; 8.0 ± 12.9 |
| 2002 | 1076 | 5; 7.8 ± 11.5 | 2; 6.5 ± 10.0 | 7; 12.7 ± 13.5 | 3; 7.1 ± 10.5 | 26; 32.7 ± 30.0 | 3; 9.1 ± 15.9 |
| 2003 | 1217 | 4; 7.5 ± 10.8 | 3; 7.3 ± 11.0 | 8; 12.4 ± 13.5 | 4; 8.2 ± 11.6 | 23; 31.3 ± 27.3 | 4; 10.0 ± 15.7 |
| 2004 | 1315 | 3; 6.5 ± 10.1 | 2; 4.9 ± 7.7 | 6; 10.8 ± 11.9 | 2; 5.3 ± 7.9 | 21; 27.9 ± 27.4 | 2; 6.3 ± 9.1 |
| 2005 | 1408 | 5; 7.3 ± 10.2 | 3; 6.8 ± 11.6 | 8; 12.1 ± 12.2 | 3; 7.5 ± 12.6 | 22; 29.1 ± 26.9 | 3; 8.8 ± 13.3 |
| 2006 | 1532 | 4; 7.0 ± 10.2 | 2; 6.3 ± 9.6 | 7; 11.4 ± 11.6 | 3; 6.6 ± 9.8 | 21; 27.7 ± 23.7 | 3; 7.2 ± 10.3 |
| 2007 | 1912 | 4; 6.5 ± 9.9 | 2; 5.6 ± 8.7 | 7; 11.2 ± 11.5 | 3; 6.2 ± 9.0 | 21; 27.0 ± 23.6 | 3; 7.5 ± 12.1 |
| 2008 | 1562 | 4; 5.7 ± 8.7 | 2; 5.7 ± 9.6 | 6; 10.9 ± 11.3 | 3; 6.5 ± 10.5 | 20; 26.0 ± 23.1 | 3; 8.3 ± 14.4 |
| 2009 | 1944 | 4; 5.7 ± 9.2 | 2; 5.4 ± 7.1 | 6; 10.8 ± 11.9 | 2; 6.0 ± 7.9 | 20; 26.0 ± 25.6 | 3; 7.4 ± 11.0 |
| 2010 | 1866 | 3; 5.8 ± 9.8 | 1; 5.0 ± 8.1 | 5; 10.7 ± 12.4 | 2; 5.6 ± 8.5 | 19; 25.0 ± 23.0 | 2; 6.5 ± 8.9 |
| 2011 | 2101 | 4; 4.6 ± 8.7 | 2; 5.5 ± 8.7 | 5; 9.3 ± 11.2 | 2; 6.9 ± 11.5 | 17; 22.9 ± 20.6 | 3; 8.5 ± 13.2 |
| Change in days per year | | −0.28 | −0.13 | −0.26 | −0.12 | −0.9 | −0.06 |
| Significance | | $p < 0.001$ | $p = 0.04$ | $p < 0.001$ | $p = 0.12$ | $p < 0.001$ | $p = 0.5$ |
| Total | 18,048 | 4; 6.4 ± 10.0 | 2; 5.9 ± 9.2 | 7; 11.2 ± 12.1 | 3; 6.6 ± 10.1 | 21; 27.6 ± 25.6 | 3; 7.8 ± 12.2 |

*LOS* length of stay, *SD* standard deviation

nowadays is to stabilize the patient by simple means and/or maneuvers that are vital for life at scene and transport them to the hospital. These changes may be due to the introduction of education programs or training courses for pre- and early in-hospital trauma management, e.g., the ATLS® concept. It therefore appears that, although the prerequisites may be better in the in-hospital setting, the intubation as a "gold-standard" for every injured patient has been replaced by an intubation based on more specifically defined indications. Though it was not the object of our analysis, it is to assume that some of the (pre- and in-hospital) intubations and the following ventilation treatment without early liberation from the ventilator in former times were performed without clear indication—and therefore could be specified as erroneous from today's point of view.

According to the actual national and international guidelines for the treatment of trauma patients, the following four scenarios necessitate intubation in the prehospital setting: posttraumatic apnea or hypoventilation, severe brain injury with a GCS score ≤9, shock due to bleeding with a systolic blood pressure ≤90 mmHg and severe thoracic trauma with respiratory failure and a respiratory rate ≥29/min [2, 15, 16]. However, there still exists some controversy regarding the safety and appropriateness of intubating a patient with hemorrhagic shock with regard to the reduction of venous return to the heart caused by positive pressure ventilation [17]. A matched-pair analysis of 1200 patients from the same registry examined intubation at the scene as an independent risk factor for the posttraumatic course of moderately injured patients. Also in this analysis, the LOS in the group of patients who were not intubated was significantly lower [18]. Whether the reduced number of patients with abdominal or extremity injuries may be an influencing factor for a reduced intubation rate when the patients is admitted to the ICU is not to be answered on the basis of our analysis. One could presume that the reduced proportion of severe extremity and abdominal injury might lead to a reduced number of patients with need for intubation due to hemorrhagic shock. Indeed the ratio of patients with a documented hypotension (i.e., systolic blood pressure of 90 mmHg or lower) in the initial treatment phase decreased over time.

However, it was not our intention to evaluate the correctness of airway management decisions; at least, it seems that the increasing number of patients not being primarily intubated does not lead to an increasing number of patients that secondarily required intubation. However, the underlying analysis does not allow a stratification, which patients would have been presumably benefitting from earlier intubation in our dataset.

The implication of early phase airway management decisions for the ICU LOS is revealed in our data. Whether a trauma patient is or is not intubated significantly influences the potential for reducing the ICU LOS in this population. However, the reasons for this relevant difference cannot be determined on the basis of our data. The lack of LOS reduction in the population of ventilated patients might be a result of

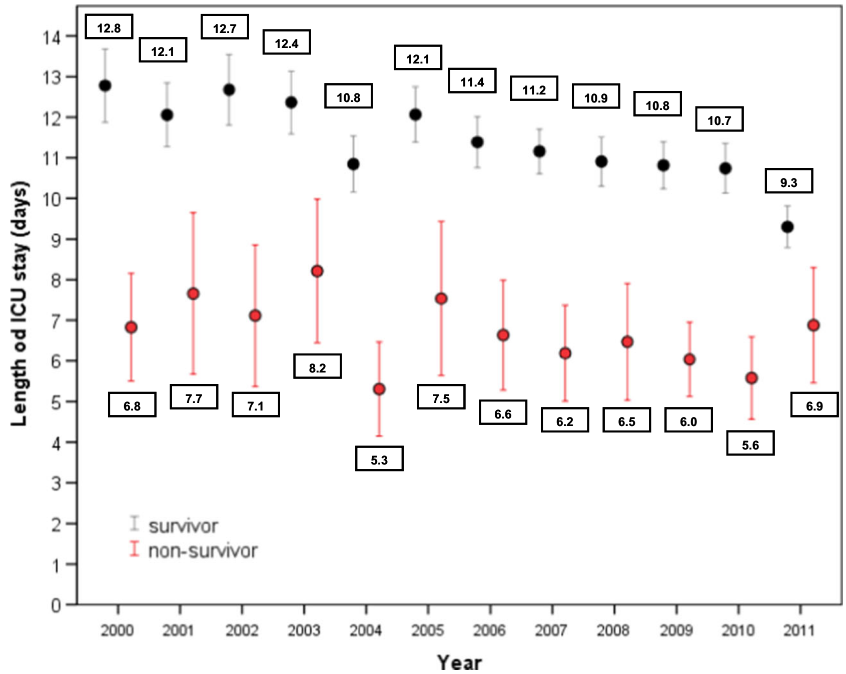


**Fig. 2** Development of the length of stay in the intensive care unit from 2000 to 2011 for survivors and non-survivors. *ICU*, intensive care unit. Mean ± 95 % CI

the severity of injuries. On the other hand, it seems that in spite of many efforts and innovations that have been made to reduce the time of invasive ventilation (e.g., weaning protocols, daily spontaneous breathing trials, periodical monitoring of sedation depth and protocols for lung protective ventilation, antimicrobial therapy regimens, etc.), ventilation time is not affected relevantly once a trauma patient is administered invasively ventilated to the ICU of a hospital in Germany. Unfortunately, the structure of the registry does not allow detailed analysis of ventilation treatment, which leaves the question unanswered, whether ventilation strategies changed over the time or not. However, it is well-known that there is a relevant gap between the perception of change concerning ICU treatment strategies (including lung protective

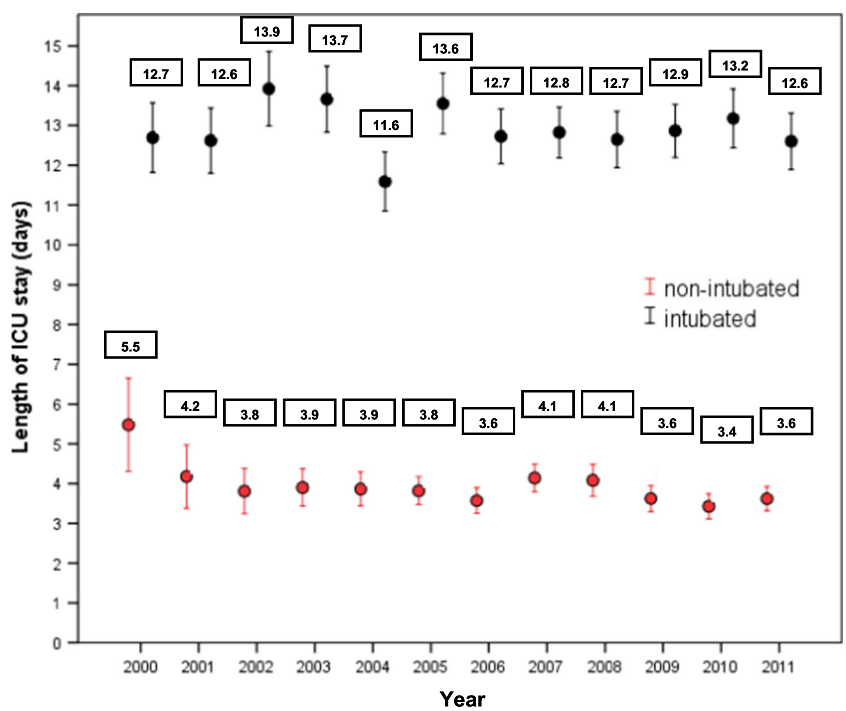


**Fig. 3** Development of the length of stay in the intensive care unit from 2000 to 2011 for intubated / invasively ventilated and not intubated patients. *ICU*, intensive care unit. Mean ± 95 % CI

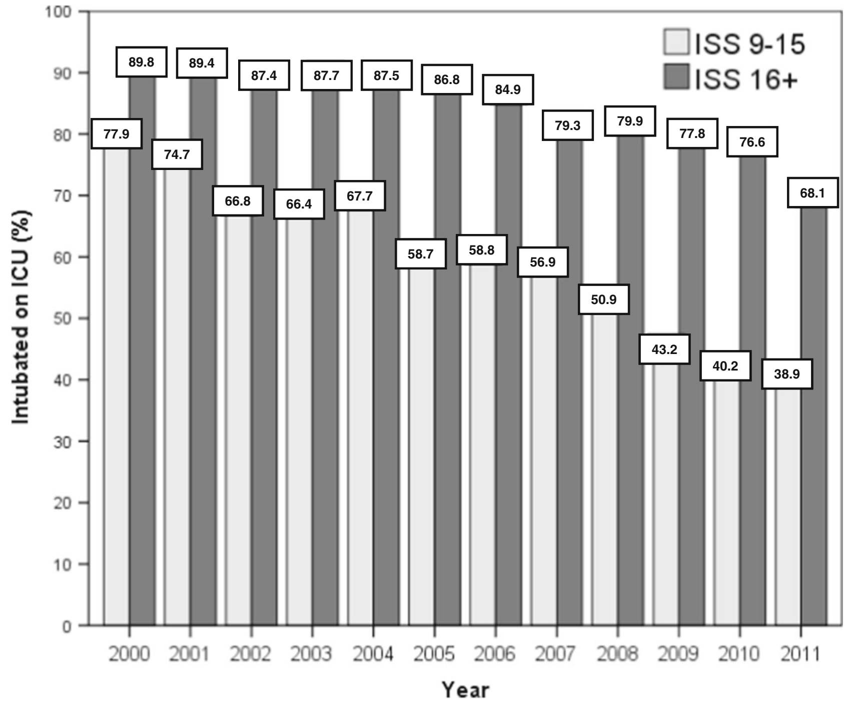


**Fig. 4** Development of the rate of intubated patients (%) at the time of admission to the ICU presented separately for patients with moderate (ISS 9–15) and severe (ISS 16+) trauma. *ISS*, injury severity score; *ICU*, intensive care unit

ventilation) and the daily practice in German hospitals [19]. Therefore, further studies should focus on changes on the ICU treatment of trauma patients with respect to ventilation strategies. There might be some potential to reduce ventilation time in these patients.

According to our analysis, the occurrence of complications, such as single or multi-organ failures that are renowned influencing factors for LOS in the ICU [20], did not change during the observed period. Thus, these possible factors influencing the ventilation time and LOS could be excluded as explanations for our findings. On the other hand, it seems that a decrease in the intubation rate does not affect the occurrence of organ failure complications.

**Table 4** Development of the incidence of sepsis, single organ and multi-organ failure

| Year | No. of patients | Sepsis | Single OF | Multi OF |
|---|---|---|---|---|
| 2000 | – | – | – | – |
| 2001 | – | – | – | – |
| 2002 | 962 | 11.4 % | 40.4 % | 21.7 % |
| 2003 | 1060 | 9.5 % | 45.3 % | 28.4 % |
| 2004 | 1272 | 7.2 % | 45.9 % | 29.7 % |
| 2005 | 1367 | 8.9 % | 46.9 % | 28.8 % |
| 2006 | 1465 | 7.6 % | 48.9 % | 31.3 % |
| 2007 | 1869 | 9.0 % | 43.7 % | 27.7 % |
| 2008 | 1517 | 7.9 % | 44.4 % | 26.8 % |
| 2009 | 1891 | 7.5 % | 44.9 % | 27.7 % |
| 2010 | 1814 | 8.2 % | 46.9 % | 29.8 % |
| 2011 | 2054 | 7.8 % | 41.9 % | 25.4 % |
| Changes in % per year | | −0.25 % | +0.04 % | +0.14 % |
| Significance | | $p = 0.009$ | $p = 0.61$ | $p = 0.92$ |
| Total | 15,271 | 8.4 % | 44.9 % | 27.8 % |

In the last decade, a reduction in the LOS has been described for several diseases. Clinical guidelines, standardized operating procedures (SOPs), or quality management systems (QMS) were established and improved to bring about and also meet the challenge of this development [21].

In several studies, the increasing economic pressure on a country's health care system and the implementation of a new reimbursement system was taken into account to partially explain these developments [22–25]. During the observation period of our study, the payment system in Germany was altered stepwise from a fee-for-service to a prospective payment system with the German Diagnosis-related group (G-DRG) system. The trauma centers were confronted with a negative reimbursement for the treatment of severely injured patients [26–28]. Furthermore, intensive care treatment is one of the most expensive hospital treatments [27]. Though there have been specific modifications in the former G-DRG versions that lead to a more appropriate reimbursement, underfunding could still be found in a recent analysis [29]. Unfortunately, owing the retrospective design of our analysis, it is impossible to analyze the effects of payment system alterations on trauma management in Germany. Therefore, the question, whether patients are going to be discharged to the normal ward and home earlier based on the rising economic pressure, has to be remained unanswered.

Our study has several limitations:

First of all, there are typical pitfalls of registry analysis, such as completeness of reporting, different policies in care, and so on, which should be taken into consideration [30].

We only used data from German hospitals, which represents a trauma population with a majority of blunt trauma [31]. However, these results might not be representative for the whole Western European population due to, e.g., different economical and structural properties. The proportion of level I and level II hospitals is not representing the nationwide proportion. According to the annual reports, the proportion of level I and level II hospitals reporting in the TraumaRegister DGU® was 95 to 226 (which reflects a ratio of approximately 1:2.5). This is a result of the fact that level I hospitals participated earlier in the history of the TraumaRegister DGU® and therefore more level I hospitals contributed annually to the dataset. Because of our intention to display a development over time, we only included those hospitals that reported their data constantly over the observation period. In a more representative collective of hospitals, the LOS might be longer than in the underlying dataset. On the other hand, LOS was steadily 1 day longer in level II than in level I hospitals. Therefore, the influence of the hospital level may be of limited impact.

We cannot entirely explain the initial change in LOS for the group of non-ventilated patients; there has been a modification from a paper-based documentation in the first 2 years to an online and double-checked documentation system beginning in 2002. With this change, the documentation of LOS has been switched from days of ventilation to hours of ventilation (the amount of hours was than recalculated to an amount of days). We can only assume that within the first 2 years, a small amount of patients who were solely intubated for a few hours at the day of hospital admission were not assigned to the group of ventilated patients but to the group of non-ventilated patients. Therefore, the decrease within the first 2 years might be partially explained by a documentation artefact and must not be overrated.

Furthermore, this study is based on registry data only and is thus limited by the lack of a more detailed description of the airway and ventilation management that was performed, for example, the rate of tracheostomy or non-invasive ventilation. According to a meta-analysis that investigated the effect of NIV on the clinical course and outcome of patients with chest trauma, the use of NIV reduces the intubation rate as well as the LOS in the ICU [32]. The role for non-invasive ventilation in patients with chest injury is discussed controversially given the fact that the quality of provided data for this topic is still limited. A further meta-analysis summarized the existing evidence stating that the use of non-invasive ventilation in patients with chest injury without respiratory distress may prevent the need for intubation. However, the beneficial effect for those patients suffering acute lung injury or acute respiratory distress syndrome cannot be evaluated definitely due to the lack of good-quality data [33]. Nevertheless, the decreasing frequency of tracheal intubation might be an effect of increasing in-hospital use of NIV in the last decade, which cannot be differentiated by the data derived from the registry and may limit our results. Finally, we did not analyze whether trauma patients who were admitted to the hospital were treated correctly with respect to invasive ventilation. Our results might be biased by patients who were not intubated at the scene even when there was a clear indication for invasive ventilation according to the criteria mentioned above and vice versa.

## Conclusion

In spite of the increasing age and constant injury severity in the trauma patient population, the rate of patients being invasively ventilated at the time of ICU admission has decreased over the last decade. But in case of invasive ventilation at the time of ICU admission, there was no relevant reduction in both, LOS and ventilation time.

Our results reveal the impact of airway management during the first hours of treatment on trauma patients' in-hospital course. Further studies should focus on the possible causation of this development to optimize the trauma patients' LOS.

**Acknowledgments** The infrastructure for documentation, data management, and data analysis is provided by AUC-Academy for Trauma Surgery (AUC-Akademie der Unfallchirurgie GmbH), a company affiliated with the German Trauma Society. The scientific leadership is provided by the Committee on Emergency Medicine, Intensive Care and Trauma Management (Sektion NIS) of the German Trauma Society. The participating hospitals submit their data anonymously into a central database via a web-based application. Scientific data analysis is approved according to a peer review procedure established by Section NIS.

Participation in TraumaRegister DGU® is voluntary. For hospitals associated with TraumaNetzwerk DGU®, however, the entry of at least a basic data set is obligatory for quality assurance.

**Author contributions** ABB, MUG, and RJ designed the study and participated in the statistical analysis. ABB, MP, and MUG drafted the manuscript. RL performed the statistical analysis, participated in the study design, and helped draft the manuscript. FW helped design the study and helped draft the manuscript. KK helped design the study and draft the manuscript. TP, JD, and BB contributed to the study design and revision of the article. All authors read and approved of the final manuscript.

**Funding** None.

**Compliance with ethical standards**

**Conflict of interest** The authors declare that they have no competing interests.

## References


1. Ruchholtz S, Lefering R, Paffrath T et al (2008) Reduction in mortality of severely injured patients in Germany. Dtsch Arztebl Int 105:225–231. doi:10.3238/arztebl.2008.0225
2. 012-019e_S3_Severe_and_Multiple_Injuries_2012-11.pdf.
3. TraumaRegister DGU(®) (2014) 20 years TraumaRegister DGU(®): development, aims and structure. Injury 45(Suppl 3): S6–S13. doi:10.1016/j.injury.2014.08.011
4. Shere-Wolfe RF, Galvagno SM Jr, Grissom TE (2012) Critical care considerations in the management of the trauma patient following initial resuscitation. Scand J Trauma Resusc Emerg Med 20:68. doi:10.1186/1757-7241-20-68
5. Dellinger RP, Levy MM, Carlet JM et al (2008) Surviving Sepsis Campaign: international guidelines for management of severe sepsis and septic shock: 2008. Intensive Care Med 34:17–60. doi:10.1007/s00134-007-0934-2
6. Bakowitz M, Bruns B, McCunn M (2012) Acute lung injury and the acute respiratory distress syndrome in the injured patient. Scand J Trauma Resusc Emerg Med 20:54. doi:10.1186/1757-7241-20-54
7. Siu AL, Penrod JD, Boockvar KS et al (2006) Early ambulation after hip fracture: effects on function and mortality. Arch Intern Med 166:766. doi:10.1001/archinte.166.7.766
8. Hussmann B, Lendemans S (2014) Pre-hospital and early in-hospital management of severe injuries: changes and trends. Injury 45(Suppl 3):S39–42. doi:10.1016/j.injury.2014.08.016
9. Ruchholtz S, AG Polytrauma der Deutschen Gesellschaft für Unfallchirurgie (2004) Das externe Qualitätsmanagement in der klinischen Schwerverletztenversorgung. Unfallchirurg 107:835–843. doi:10.1007/s00113-004-0814-y
10. Teasdale G, Jennett B (1974) Assessment of coma and impaired consciousness. A practical scale. Lancet 2:81–84
11. Baker SP, O' Neill B, Haddon Jr W, Long WB (1974) The injury severity score: a method for describing patients with multiple injuries and evaluating emergency care. J Trauma 14:187–196
12. Vincent JL, Moreno R, Takala J et al (1996) The SOFA (Sepsis-related Organ Failure Assessment) score to describe organ dysfunction/failure. On behalf of the Working Group on Sepsis-Related Problems of the European Society of Intensive Care Medicine. Intensive Care Med 22:707–710
13. TraumaRegister DGU(®) (2014) 20 years of trauma documentation in Germany—actual trends and developments. Injury 45(Suppl 3): S14–19. doi:10.1016/j.injury.2014.08.012
14. Andruszkow H, Hildebrand F, Lefering R et al (2014) Ten years of helicopter emergency medical services in Germany: do we still need the helicopter rescue in multiple traumatised patients? Injury 45(Suppl 3):S53–58. doi:10.1016/j.injury.2014.08.018
15. Jeremitsky E, Omert L, Dunham CM et al (2003) Harbingers of poor outcome the day after severe brain injury: hypothermia, hypoxia, and hypoperfusion. J Trauma: Inj Infect Crit Care 54:312–319. doi:10.1097/01.TA.0000037876.37236.D6
16. Dunham MC, Barraco RD, Clark DE et al (2003) Guidelines for emergency tracheal intubation immediately after traumatic injury. J Trauma: Inj Infect Crit Care 55:162–179. doi:10.1097/01.ta.0000083335.93868.2c
17. Taghavi S, Duran JM, Jayarajan S et al (2012) Still making the case against prehospital intubation: a rat hemorrhagic shock model. J Trauma Acute Care Surg 73:332–337. doi:10.1097/TA.0b013e3182584447
18. Hussmann B, Lefering R, Waydhas C et al (2011) Prehospital intubation of the moderately injured patient: a cause of morbidity? A matched-pairs analysis of 1,200 patients from the DGU Trauma Registry. Crit Care 15:R207. doi:10.1186/cc10442
19. Brunkhorst FM, Engel C, Ragaller M et al (2008) Practice and perception—a nationwide survey of therapy habits in sepsis. Crit Care Med 36:2719–2725. doi:10.1097/CCM.0b013e318186b6f3
20. Böhmer AB, Just KS, Lefering R et al (2014) Factors influencing lengths of stay in the intensive care unit for surviving trauma patients: a retrospective analysis of 30,157 cases. Crit Care 18:R143. doi:10.1186/cc13976
21. Breckenkamp J, Wiskow C, Laaser U (2007) Progress on quality management in the German health system—a long and winding road. Health Res Policy Syst 5:7. doi:10.1186/1478-4505-5-7
22. Kahn KL, Keeler EB, Sherwood MJ et al (1990) Comparing outcomes of care before and after implementation of the DRG-based prospective payment system. JAMA 264:1984–1988
23. Kosecoff J, Kahn KL, Rogers WH et al (1990) Prospective payment system and impairment at discharge. The "quicker-and-sicker" story revisited. JAMA 264:1980–1983
24. Rogers WH, Draper D, Kahn KL et al (1990) Quality of care before and after implementation of the DRG-based prospective payment system. A summary of effects. JAMA 264:1989–1994
25. Geissler A, Scheller-Kreinsen D, Quentin W, EuroDRG group (2012) Do diagnosis-related groups appropriately explain variations in costs and length of stay of hip replacement? A comparative assessment of DRG systems across 10 European countries. Health Econ 21(Suppl 2):103–115. doi:10.1002/hec.2848
26. Grotz M, Schwermann T, Lefering R et al (2004) DRG reimbursement for multiple trauma patients—a comparison with the comprehensive hospital costs using the German trauma registry. Unfallchirurg 107:68–75. doi:10.1007/s00113-003-0715-5
27. Flohé S, Buschmann C, Nabring J et al (2007) Definition of polytrauma in the German DRG system 2006. Up to 30% "incorrect classifications". Unfallchirurg 110:651–658. doi:10.1007/s00113-007-1300-0
28. Probst C, Schaefer O, Hildebrand F et al (2009) The economic challenges of polytrauma care. Unfallchirurg 112:975–980. doi:10.1007/s00113-009-1684-0
29. Mahlke L, Lefering R, Siebert H et al (2013) Description of the severely injured in the DRG system : is treatment of the severely injured still affordable? Chirurg. doi:10.1007/s00104-013-2490-3
30. Lefering R (2014) Strategies for comparative analyses of registry data. Injury 45(Suppl 3):S83–88. doi:10.1016/j.injury.2014.08.023
31. Annual Reports. http://www.traumaregister.de/index.php?option=com_content&view=article&id=49&Itemid=55&lang=en. Accessed 14 Apr 2013
32. Chiumello D, Coppola S, Froio S et al (2013) Noninvasive ventilation in chest trauma: systematic review and meta-analysis. Intensive Care Med 39:1171–1180. doi:10.1007/s00134-013-2901-4
33. Duggal A, Perez P, Golan E et al (2013) Safety and efficacy of noninvasive ventilation in patients with blunt chest trauma: a systematic review. Crit Care 17:R142. doi:10.1186/cc12821