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Trauma care before and after optimisation in a level I trauma Centre: Life-saving changes[☆]

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ABSTRACT

Background: The implementation of trauma systems has led to a significant reduction in mortality and length of hospital stay. In our level I trauma centre, 24/7 in-hospital coverage was implemented, and a renovation of the trauma room took place to improve the trauma care. The aim of the present study was to examine the effect of the optimised in-hospital infrastructure in terms of mortality, processes and clinical outcomes.

Methods: We performed a retrospective cohort study of prospectively collected data. All adult trauma patients admitted to our trauma centre directly during two time periods (2010–2012 and 2014–2016) were included. Any patients below the age of 18 years and patients who underwent primary trauma screening in another hospital were excluded. Logistic and linear regression were used and adjusted for demographics and characteristics of trauma. The primary endpoint was mortality. The secondary endpoints were subgroups of earlier mortality rates and severely injured patients, processes and clinical outcomes.

Results: In period I, 1290 patients were included, and in period II, 2421. The adjusted mortality in the trauma room (odds ratio (OR): 0.18; CI: 0.05–0.63) and the total in-hospital mortality (OR: 0.63 CI: 0.42–0.95) showed a significant reduction in period II. The trauma room (TR) time decreased by 30 min ($p < 0.001$), and the time until CT decreased by 22 min ($p < 0.001$). The number of delayed diagnoses and complications were significantly lower in the second period, with an OR of 0.2 (CI: 0.1–0.2) and 0.4 (CI: 0.3–0.6), respectively. The hospital length of stay and ICU length of stay decreased significantly, −1.5 day ($p = 0.010$) and −1.8 days ($p = 0.022$) respectively.

Conclusions: Optimisation of the in-hospital infrastructure related to trauma care resulted in improved survival rates in both severely injured patients as well as in the whole trauma population. Moreover, the processes and clinical outcomes improved, showing a shorter hospital length of stay, shorter TR time, fewer complications and fewer delayed diagnoses.

Background

Trauma is an important cause of death around the world [1]. In the last few decades, trauma care systems have evolved rapidly in western countries [2–4]. The benefit of the implementation of a trauma system has already proven itself with lower mortality rates and fewer hospitalisation days [5–18]. A reduction in mortality up to 15% has especially been seen in severely injured patients [5,11,18]. However, the implementation of a trauma system does not automatically lead to a reduction in preventable errors or improvements in clinical care [19]. Therefore, multidisciplinary education and on-going trauma training for trauma centres should be provided to avoid clinical variance and provide optimal care for all injured patients [12,19].

Higher survival rates were also found based on the presence of a surgeon with a higher experience level [20] and a shorter distance from the trauma room to the CT scanner [21]. The study of

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van der Vliet et al. [22] examined the effect of a 24/7 in-house attending trauma surgeon for severely injured patients (ISS > 24). They showed improved process-related outcomes, but the mortality and hospital length of stay (H-LOS) did not change. The effect of 24/7 in-hospital coverage by a trauma surgeon for the whole trauma population and its effect on different time points after a trauma is unknown. The benefits of 24/7 in-hospital coverage and therefore the implementation of 24/7 in-hospital coverage by a trauma surgeon in level I trauma centres are still under debate.

Since 2010, there has been more focus on the centralisation of the trauma care in our region. This resulted in an increased number of screened trauma patients and an increased number of severely injured patients. Therefore, in 2013, the in-hospital infrastructure related to the trauma care and the trauma team was optimised in our level I trauma centre; see Fig. 1. As part of the optimisations, 24/7 in-hospital coverage by a trauma surgeon, an intensivist, an anaesthesiologist and an emergency physician was implemented. Previously, the senior clinicians were only expected to be present within 30 min. Moreover, two new trauma rooms of 90 m [2] each were opened with a movable in room CT scanner. A distinction was also made between the basic trauma team (BTT) and the multi trauma team (MTT). Finally, optimisation in training for staff as well as residents took place. The entire MTT team is trained every two weeks with standardised trauma cases. The exercise is performed on a SimMan® ALS [23] with supervision by trained Advanced Trauma Life Support (ATLS) instructors.

The aim of the present study was to examine the effect of the optimised in-hospital infrastructure in terms of mortality, processes and clinical outcomes. The hypothesis is that these optimisations resulted in lower mortality rates, improved processes and improved clinical outcomes.

Methods

Study setting

This study was conducted in a level I trauma centre in the Netherlands. The trauma centre serves a population of 2.2 million. In 2016, there were 340 severely injured patients (ISS ≥ 16) and more than 2600 hospitalised trauma patients [24–26]. The medical ethical editorial board (METC) judged our study protocol and approved the study.

A retrospective cohort study of prospectively collected data was conducted. The results of the period before and after the optimisations were compared. The first period covers January 1st 2010 to July 1st 2012, and the second period covers January 1st 2014 to July 1st 2016.

Optimisation of Level I trauma centre

- Renovation of the trauma room
- 24/7 in-hospital coverage: Trauma surgeon, Intensivist, Anaesthesiologist, Emergency physician
- The intensive care unit reached the highest quality accreditation
- Distinction between the basic trauma team (BTT) and the multi trauma team (MTT)
- Optimised trauma care training program

Fig. 1. Applied optimisations.

Data collection

All trauma patients who were screened at the trauma room were included in the study, irrespective if they were admitted or not. Patients who were dead upon arrival were not included. Patients below the age of 18 years and patients who underwent primary trauma screening in another hospital were excluded. Data were obtained directly from the trauma registry database and the hospital records. In cases of missing data, the hospital records were checked manually.

Outcomes and definitions

The Abbreviated Injury Scale (AIS) [27,28] was used to define the severity of separate injuries. The ISS [29,30], based on the sum of squares of the three body regions with the highest AIS scores, was used to define the severity of the overall injury of the trauma patient. The Revised Trauma Score (RTS) [31], based on the systolic blood pressure (SBP), Glasgow Coma Scale (GCS) and respiratory rate (RR), was used to define a summary of circulatory, respiratory and central nervous system functions.

The data of the included patients were collected: age, sex, time of day, type of injury, ISS, severe neuro-trauma (AIS brain injury ≥3), RTS (SBP, GCS and RR), destination from trauma room (TR), ICU admission, in-hospital mortality, operative intervention, TR time, time until CT, ICU time, total length of stay, days of ventilation, complications and delayed diagnoses.

The mortality was categorised into three groups: mortality in the trauma room, mortality within 48 h and total in-hospital mortality. The three groups of mortality were also analysed for four subgroups, the most critically injured patients [19]: patients with an ISS ≥ 16, ISS > 25, ISS > 35 and patients with an AIS brain injury ≥3. These subgroups of early mortality rates and severely injured patients were analysed separately to verify if the optimisations improved the survival rate, especially at different time points or in severely injured patients.

Because of the non-linear character of the relationship between age and clinical outcome in trauma patients, their ages were divided into five groups [32]: 18–59; 60–69; 70–79; 80–89; and 90 +.

The registered complications were the following: pneumonia, delirium, urinary tract infection, delayed diagnoses, wound infection, retention bladder, cardiovascular, gastrointestinal, neurologic, failure of osteosynthesis material and others. The type of injury was divided into blunt or penetrating.

Delayed diagnosis was defined as diagnosis found after the tertiary trauma survey.

Statistical analysis

The demographics, characteristics of trauma and logistic data between the patients treated in both periods were compared with SPSS version 24.0. A logistic regression model was used to compare period I with period II. The odds ratio (OR) was used to estimate the difference in risk of in-hospital mortality. First, the ORs were calculated in a univariate logistic model. Second, the variables were entered to test for confounding factors. In the final logistic model, all confounders that changed the regression coefficient for the study period by 10 percent or more were included. All reported p-values are two-sided. The continuous variables were analysed in the same way with a linear regression model. The missing data values that remained after a manual check of the hospital records were imputed according to multiple imputation with 20 imputations and 5 iterations using the multivariate imputation by chained equations (MICE) procedure [33].

Results

A total of 4633 trauma patients were admitted during the years 2010–2012 and 2014–2016: 1676 in the first period and 2957 in the second period. After the exclusion criteria were applied, 1290 from the first period and 2421 from the second period were included. Details regarding the number of and reasons for excluded patients are listed in Fig. 2.

The two patient groups were similar in regards to sex and type of injury. The type of injury was predominantly blunt, with 1247 (96.7%) in the first period and 2365 (97.7%) in the second period. The patients in the second period were older, with a median of 46 (IQR: 28–61) years versus 51 (IQR: 33–66) years. The median ISS was equal in both periods, 5 (IQR: 2–14) in the first period and 5 (IQR: 2–12) in the second period. The median GCS and its IQR was equal in both periods (median 15; IQR: 14–15). The number of severely injured patients (ISS ≥ 16) increased from 311 (24.1%) in the first period to 494 (20.4%) in the second period, and patients with a severe neuro-trauma (AIS brain injury ≥ 3) increased from 246 (19.1%) to 395 (16.3%) in the second period. However, in percentage terms there was a slight decrease in severely injured patients and patients with a severe neuro-trauma. These results are summarised in Table 1.

Table 1
Demographic data.

	Period I	Period II
Patients (n)	1290	2421
Male, n (%)	814 (63.1)	1543 (63.7)
Age, median [IQR]	46 [28–61]	51 [33–66]
Blunt, n (%)	1247 (96.7)	2365 (97.7)
ISS, median (IQR)	5 [2–14]	5 [2–12]
GCS, median (SD)	15 [14,15]	15 [14,15]
Hospitalised, n (%)	856 (66.4)	1651 (68.2)
ICU, n (%)	342 (26.5)	520 (21.5)
ISS ≥ 16, n (%)	311 (24.1)	494 (20.4)
AIS brain injury ≥3, n (%)	246 (19.1)	395 (16.3)

Legend: *ISS* Injury Severity Score; *RTS* Revised Trauma Score; *AIS* Abbreviated Injury Score; *SD* Standard deviation.

Mortality

The absolute in-hospital mortality rate in the first period was 90 (7.0%) and in the second period was 101 (4.2%); this reveals a significant improvement in unadjusted in-hospital mortality in the second period (OR = 0.58; CI: 0.43–0.78; p < 0.001). The most common cause of death was cerebral injuries. The distribution in causes of death did not change between the two study periods, and there was no influence of the time of the day on the mortality rate.

After adjustment for confounding factors (ISS, GCS, SBP, age and severe neuro-trauma), in-hospital mortality improved significantly in the second period (OR = 0.63; CI: 0.42–0.95; p = 0.030). The number of deaths in the trauma room showed a significant decrease from 17 (1.3%) to 5 (0.2%). This resulted in an OR of 0.16 (CI: 0.06–0.42; p < 0.001) in the univariate model. After adjustment for the confounding factors, the second period was associated with a significantly lower risk of mortality in the trauma room (OR = 0.18; CI: 0.05–0.63; p = 0.008).

The unadjusted mortality within 48 h decreased significantly in the second period (OR = 0.64; CI: 0.45–0.91; p = 0.014). The adjusted mortality within 48 h was equal in both periods (OR = 0.86; CI: 0.54–1.37; p = 0.534). These results are presented in Table 2.

The analysis of the subgroups of patients with an ISS ≥ 16 (I: 312 (24.2%); II: 494 (20.4%)), ISS > 25 (I: 150 (11.6%); II: 187 (7.7%)), with an ISS > 35 (I: 55 (4.3%); II: 59 (2.4%)) and with an AIS brain injury ≥ 3 (I: 246 (19.1%); II: 395 (16.3%)) are presented in Table 3. Each subgroup showed a significant decrease in mortality in the trauma room. The mortality within 48 h decreased non-significantly in each subgroup. The total in-hospital mortality showed an odds ratio of 0.67 (CI: 0.48-0.94) for the patients with an ISS ≥ 16, 0.77 (CI: 0.49–1.21) for patients with an ISS > 25, 0.53 (CI0.5-1.12) for patients with an ISS > 35 and 0.68 (CI: 0.47-0.98) for patients with a brain injury with an AIS ≥ 3. The different subgroups showed similar odds ratios for all examined subgroups.

Processes and clinical outcomes

The proportion of hospitalised patients did not change significantly between the two groups, with 856 (66.4%) in the first period versus 1651 (68.2%) in the second period. The median of TR time, time until CT, ICU-LOS and days of ventilation were lower in the second period than in the first period. The median of H-LOS was equal in both periods. The number of patients who underwent a CT scan doubled in the second period (OR = 2.2; CI: 2.0–2.4; p < 0.001). The number of patients who were admitted to the ICU increased from 342 (26.5%) to 520 (21.5%). However, there was a decrease in percentage terms (OR = 0.9; CI: 0.8–1.0; p = 0.494). After adjustment for confounding factors, the TR time, time until CT, H-LOS and ICU-LOS were significantly shorter in the second period than in the first period; see Table 4. The TR time decreased

Fig. 2. Flowchart, number of included and excluded patients.

Table 2
Mortality rates.

	Period I n (%)	Period II n (%)	Univariate model OR [CI]; *p*-value	Adjusted model* OR [CI]; *p*-value
Mortality in the trauma room	17 (1.3)	5 (0.2)	0.16 [0.06–0.42]; <0.001	0.18 [0.05–0.63]; 0.008
Mortality within 48 hours	58 (4.5)	71 (2.9)	0.64 [0.45–0.91]; 0.014	0.86 [0.54–1.37]; 0.534
In-hospital mortality	90 (7.0)	101 (4.2)	0.58 [0.43–0.78]; <0.001	0.63 [0.42–0.95]; 0.030

Legend: period I (reference value) versus period II; *OR* odds ratio; *CI 95%* Confidence interval.
* Adjusted for ISS, GCS, SBP, age and severe neuro-trauma.

Table 3
Unadjusted mortality rates in the subgroups.

	Period I	Period II	OR [CI]
ISS ≥ 16, n (%)	311 (24.1)	494 (20.4)	
Mortality in the trauma room	16 (5.1)	5 (1.0)	0.18 [0.07–0.49]
Mortality within 48 h	53 (17.0)	66 (13.4)	0.74 [0.50–1.09]
In-hospital mortality	81 (26.0)	95 (19.2)	0.67 [0.48–0.94]
ISS > 25, n (%)	150 (11.6)	187 (7.7)	
Mortality in the trauma room	14 (9.3)	4 (2.1)	0.20 [0.06–0.61]
Mortality within 48 h	38 (25.3)	43 (22.9)	0.85 [0.52–1.40]
In-hospital mortality	56 (37.3)	60 (31.9)	0.77 [0.49–1.21]
ISS > 35, n (%)	55 (4.3)	59 (2.4)	
Mortality in the trauma room	9 (16.4)	2 (3.4)	0.18 [0.04–0.87]
Mortality within 48 hours	20 (36.4)	17 (28.8)	0.71 [0.32–1.56]
In-hospital mortality	30 (54.5)	23 (39.0)	0.53 [0.25–1.12]
AIS brain injury ≥3, n (%)	246 (19.1)	395 (16.3)	
Mortality in the trauma room	14 (5.7)	4 (1.0)	0.17 [0.06–0.52]
Mortality within 48 h	46 (18.7)	58 (14.7)	0.75 [0.49–1.14]
In-hospital mortality	68 (27.6)	81 (20.5)	0.68 [0.47–0.98]

Legend: Mortality in subgroups of patients based on ISS and AIS brain injury; Period I and period II values are expressed as n (%); *OR* Odds Ratio period I (reference value) versus period II; *CI* 95% Confidence interval.

by 30 min (CI: −33.0– −27.0; p < 0.001), and the time until CT decreased by 21.6 min (CI: −24.4– −18.9; p < 0.001). The H-LOS decreased by a day and a half ($\beta = -1.5$; CI: −2.1– −0.9; p = 0.010), and the ICU-LOS decreased by almost two days ($\beta = -1.8$; CI: −2.6– −1.0; p = 0.022). The days of ventilation decreased by a day and a half in the second period ($\beta = -1.6$; CI: −3.4–0.4; p = 0.112); however, this decrease was not significant.

After adjustment for the confounding factors, the number of operative interventions increased but it decreased in percentage terms (OR = 0.9; CI: 0.7–1.1 p = 0.145), however this result was not significant. The number of delayed diagnoses and complications decreased significantly (respectively: OR = 0.2; CI: 0.1–0.2; p < 0.001 and OR = 0.4; CI: 0.3–0.6; p < 0.001).

Within the different complication groups, a significant decrease was seen in pneumonia, delayed diagnosis, failure of osteosynthesis and the other complications group (Table 5).

Table 5
Complications after adjustment for confounding factors.

	Period I n (%)	Period II n (%)	OR [CI]
Pneumonia	33 (2.6)	30 (1.2)	0.53 [0.41–0.70]
Delirium	3 (0.2)	10 (0.4)	2.60 [0.60–10.81]
Urinary tract infection	5 (0.4)	11 (0.5)	1.13 [0.64–2.00]
Delayed diagnosis	43 (3.3)	12 (0.5)	0.16 [0.09–0.27]
Wound infection	17 (1.3)	16 (0.7)	0.56 [0.39–0.80]
Retention bladder	3 (0.2)	–	–
Cardiovascular	2 (0.2)	1 (0.0)	0.24 [0.07–0.86]
Gastrointestinal	6 (0.5)	5 (0.2)	0.50 [0.15–1.68]
Neurologic	3 (0.2)	3 (0.1)	0.78 [0.14–4.39]
Failure osteosynthesis	17 (1.3)	8 (0.3)	0.26 [0.17–0.39]
Others	52 (4.0)	33 (1.4)	0.38 [0.30–0.49]

Legend: *OR* Odds ratio period I (reference value) versus period II; *CI* 95% Confidence interval.

Discussion

The aim of the present study was to examine the effect of the optimised in-hospital infrastructure in terms of mortality, processes and clinical outcomes in a level I trauma centre. In this study, the mortality decreased significantly, and the processes and clinical outcomes improved in all trauma patients.

The organisation of the trauma care was optimised in our hospital with 24/7 in-hospital coverage by the senior clinicians. With the 24/7 in-hospital coverage, the trauma patients in our hospital received care from clinicians with the highest possible experience with higher survival chances [20,34]. Van der Vliet et al. [22] previously showed improved process-related outcomes for the most severely injured patients (ISS > 24) based on 24/7 in-hospital coverage by the trauma surgeon. Additionally, in our study, the in-hospital mortality and the mortality in the trauma room decreased significantly for all trauma patients. An improved survival rate was also shown in the individual subgroups based on ISS (ISS ≥ 16, ISS > 25 and ISS > 35) and AIS brain injury (≥3). All subgroups showed a positive trend for the second period, although not all were significant. The odds ratios of the subgroups were very

Table 4
Process and clinical outcomes.

	Period I	Period II	β [CI]*	OR [CI]*	*p*-value
TR time, minutes	159.5 [123.0–227.0]	124.0 [90.0–165.0]	−30.0 [−33.0– −27.0]		<0.001
CT	906 (70.2)	2016 (83.3)		2.2 [2.0–2.4]	<0.001
Time till CT, minutes	30.0 [15.0–53.0]	20.0 [9.0–32.0]	−21.6 [-24.4– −18.9]		<0.001
H-LOS, days	4.0 [2.0–11.0]	3.0 [2.0–9.0]	−1.5 [−2.1– −0.9]		0.010
ICU admission	342 (26.5)	520 (21.5)		0.9 [0.8–1.0]	0.494
ICU-LOS, days	3.0 [2.0–8.0]	2.0 [2.0–5.0]	−1.8 [−2.6– −1.0]		0.022
Days of ventilation	4.0 [1.0–11,5]	2.0 [1.0–8.0]	−1.6 [−3.4– 0.4]		0.112
Operative intervention	232 (18.0)	332 (13.7)		0.9 [0.7–1.1]	0.145
Delayed diagnosis	40 (3.1)	12 (0.5)		0.2 [0.1–0.2]	<0.001
Complications	130 (10.1)	109 (4.5)		0.4 [0.3–0.6]	<0.001

Legend: Period I (reference value) versus period II; Period I and period II values are expressed as median (Interquartile range) or n (%). *TR time* Trauma room time; *H-LOS* Hospital length of stay; *ICU-LOS* ICU length of stay.
* Adjusted for ISS, GCS, SBP, age and severe neuro-trauma.

similar in all subgroups suggesting an equal effect independent of the casemix of severity. The characteristics of those who died at the trauma room did not differ between the two periods. However, if we compare the total in-hospital deaths and the deaths within 48 -hs the patients in the second period were significant older.

Previous studies showed a decrease in mortality in general across most reported mature trauma systems over the last 10–20 years, irrespective of regionalisation or the presence of 24/7 trauma surgeons [35]. However, the downward mortality trend was not seen in the national (unadjusted) mortality rates in the Netherlands. The national mortality rates remains stable over the years in the total trauma population as well as the severely injured patients [25].

The first hours after a trauma is a critical period for severely injured patients [36–41]. It is notable that the improved results that are achieved in the trauma room will not last during the following hours. This could be the consequence of the shorter TR-time. The highest percentage of mortality during the first 48 h in our study is consistent with comparable international studies about the time of death distribution in trauma patients [36–41]. The expectation is that an unchanged mortality within 48 h is based on the shorter TR-time and unavoidable mortalities.

The presence of a senior clinician could also lead to improvements in secondary endpoints based on faster stabilisation of vital functions. As previously mentioned, van der Vliet et al. [22] showed improved process-related outcomes for the most severely injured patients (ISS > 24) with a shorter TR time and a shorter time from the emergency department to the ICU. Accordingly, in our study, the H-LOS decreased as did the ICU-LOS. The TR time was significantly lower, and the days of ventilation was non-significantly shorter. These improvements in mortality rates, processes and clinical outcomes shown in our study based on the presence of the senior clinician were not only seen in the severely injured patients but also in the whole trauma population.

Another important optimisation is the renovation of the trauma room with a moveable CT scanner. This enables us to perform a CT scan without the need for any patient transfers or leaving the trauma room during the trauma care. The patient transfers, which involve the preparation of the trauma patient for safe transportation, is a process that takes an average of 5 min per patient transfer [42]. The availability of the CT scan leads to a lower threshold and a shorter time until CT, resulting in a higher probability of survival [21]. In our study, the time until CT decreased by 21 min after adjustment for confounding factors. A lower threshold will also result in more clinically relevant diagnoses and therefore a change of treatment plan [43–45]. Accordingly, a significant decrease in number of delayed diagnoses is shown in our study. Most likely, partly based on fewer delayed diagnoses, more clinically relevant diagnoses and the 24/7 involvement of staff members during the hospitalisation of trauma patients, the number of complications decreased significantly.

A difference between our two study periods is the number of trauma patients. This can be explained by higher concentration of the trauma care, based on an increased adherence to the national and regional guidelines. There were no further changes in pre-hospital triage and care. The number of severely injured patients (ISS ≥ 16) increased from 311 in the first period to 494 in the second period, and the number of patients with a severe brain injury (AIS brain injury ≥) increased in the second period, from 246 to 395.

There are some limitations to this study, which are partly related to availability of data. In this study, the AIS version 1990 with an update 1998 [27] was used. Since 2015, the AIS version 2005 with an update in 2008 [28] was used in the trauma registry. A conversion tool has been used to convert the AIS and ISS scores from the patients in 2015 and 2016 in order to make the two time periods comparable. Another limitation of this study is its retrospective design, although almost all variables were determined prospectively according to protocol during the trauma care. However, not all variables were registered prospectively. There was too much missing data in the number and type of emergency interventions. The emergency interventions done at the trauma room were not registered properly, especially in the first period. Therefore, emergency interventions were not reliable at all and thus not reported in this study. Lastly, except the crude mortality rates, the data from other centres that did not have these model of care enhancements are not available. Therefore registry comparisons with other centres is not possible. The decrease in mortality may have occurred by virtue of the increase in transports and referrals to our hospital due to regionalisation. Besides, general improvements over time in medicine could have influenced the results.

Further research should attempt to identify which elements in a trauma system could be improved to reach even higher survival rates, especially during the first 48 h. In our study, the cost-effectiveness ratio was not analysed. The two-tiered trauma team activation system has proven to be cost-effective in a trauma centre [46], and improved clinical outcomes will result in lower medical costs.

Conclusion

Optimisation of the in-hospital infrastructure results in improved survival rates in severely injured patients as well as in the whole trauma population. Moreover, the processes and clinical outcomes improved significantly with a shorter hospital length of stay, shorter ICU length of stay, fewer complications and fewer delayed diagnoses.

Declaration of Competing Interest

The authors declare no conflict of interest.

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