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Older polytrauma: Mortality and complications

Rob de Vries[a,*], Inge H.F. Reininga[a,b], Max W. de Graaf[a], Erik Heineman[c], Mostafa El Moumni[a], Klaus W. Wendt[a]

[a] Department of Trauma Surgery, University Medical Centre Groningen (UMCG), Groningen, the Netherlands
[b] Emergency Care Network Northern Netherlands, AZNN, Nothern Netherlands Trauma Registry, Groningen, the Netherlands
[c] Department of Surgery, University Medical Centre Groningen (UMCG), Groningen, the Netherlands

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ABSTRACT

Introduction: Older adults enduring a polytrauma have an increased mortality risk. Apart from age, the role of other predisposing factors on mortality are mainly described for the total polytrauma population. This study aimed to describe the mortality pattern of older polytrauma patients, its associated risk factors, and the role and etiology of in-hospital complications.
Methods: An eight-year retrospective cohort was constructed from 380 polytrauma patients aged ≥65 in a Dutch level 1 trauma center and linked to the national trauma database (DTR). Demographics, injury characteristics, comorbidity, clinical characteristics, in-hospital mortality, mortality etiology and complications scored according to the Clavien-Dindo classification were analyzed. Primary outcome was the identification of risk factors associated with in-hospital mortality, followed by identification of in-hospital complications and their nature.
Results: Overall in-hospital mortality was 36.3%, rising significantly with age. For patients aged ≥85 in-hospital mortality was 60.8%. Polytrauma patients aged ≥75 showed a peak of late-onset deaths one week following trauma. Age, a Glasgow coma score ≤8, coagulopathy, acidosis, injury severity score and the presence of a large subdural hematoma were significant risk factors influencing in-hospital mortality. Respiratory failure was the most prevalent severe and fatal complication. The proportion of fatal complications grew significantly with age ($p < 0.01$).
Conclusions: Age is strongly associated with in-hospital mortality in polytraumatized elderly. Coagulopathy, acidosis, a low Glasgow coma score, presence of a large subdural hematoma and injury severity score were independently of age associated with an increased mortality. Patients older than 75 years showed a unique trimodal distribution of mortality with a late onset one week following the initial trauma. Elderly were more susceptible for fatal complications. Respiratory failure was the most prevalent severe and fatal complication. Aggressive monitoring and treatment of the pulmonary status is therefore of utmost importance.

Introduction

The shift toward a larger proportion of elderly people comprising the population is ubiquitous. In the Netherlands, it is expected that by 2040 approximately 25% of all Dutch inhabitants will be 65 or older [1]. As a result, the number of trauma-related deaths within the elderly in the Netherlands has been growing since 2010 [2]. The majority of elderly polytrauma is due to a low-energy trauma, such as falls from low heights [3]. In the last two decades, there has been an ensuing surge of interest in older trauma patients in order to improve and standardize their complex care. Yet, little is known about the posttraumatic course of polytraumatized older adults, a growing population with a high mortality [3–8].

Previous research has shown that mortality in polytraumatized patients is independently associated with age and injury severity [5,9]. The Glasgow Coma Scale (GCS), coagulopathy and acidosis are known to be independently connected with mortality in polytrauma patients [10–12]. Preexisting medical conditions do have an impact on mortality in trauma patients but lose their effect as injury severity increases [13,14]. All these risk factors have been thoroughly analyzed for a mostly young or non-age stratified

* Corresponding author at: University Medical Centre Groningen, Department of Trauma Surgery, P.O. Box BA13, 9700VB Groningen, the Netherlands.
E-mail addresses: r.de.vries03@umcg.nl (R. de Vries), i.h.f.reininga@umcg.nl (I.H.F. Reininga), m.w.de.graaf@umcg.nl (M.W. de Graaf), e.heineman@umcg.nl (E. Heineman), m.el.moumni@umcg.nl (M. El Moumni), k.w.wendt@umcg.nl (K.W. Wendt).

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polytrauma population, but have not focused on older patients exclusively. These known risk factors may conceivably be inapplicable to polytraumatized older patients and should therefore be validated.

Complications are known to contribute to lengthened hospital stay, increased costs and mortality. Polytraumatized patients are at a high risk of developing in-hospital complications. Complication rates up to 60% have been described [15]. Immobilization, limited immunologic response, emergency interventions and the frequent need for mechanical ventilation are used as causes for this high complication rate [16]. In addition, elderly have diminished physiological reserves, such as pulmonary and cardiovascular frailty, making them even more susceptible for complications. Older trauma patients are known to suffer the same complications as younger adults, albeit at a higher rate [17]. However, severity and impact on mortality has never been thoroughly analyzed for older polytrauma patients.

It has been widely suggested that older polytrauma patients might benefit from early, intensive monitoring and aggressive resuscitation, yet these patients with multiple injuries are often under-triaged and therefore under-resuscitated [18]. For this reason the post-traumatic course of older polytraumatized patients needs to be clarified so that high-risk patients can be identified, in order to enhance the development of age-adapted therapeutic strategies to minimize mortality and complications. Hence the aim of this study was to map out the complications, etiology, spatial distribution and risk factors of mortality among older polytraumatized patients.

Methods

A retrospective cohort study was conducted, with data from the Dutch Trauma Registry (DTR) and a chart review of a level 1 trauma center in the Netherlands over the period 2008-2016. The DTR is a mandatory ongoing national trauma registry, currently gathering data of all trauma patients admitted to Dutch hospitals [19]. The DTR is based on the Major Trauma Outcome Study (MTOS+) [20] and is supplemented according to the Utstein template since 2014 [21]. It includes patient demographics, vital signs on admission, injury mechanism, anatomical injury characteristics and outcome [20]. All data on trauma care at the emergency room (ER) are prospectively collected by the DTR from the medical ER record, which is nationally standardized. Data on length of stay, intensive care unit (ICU) admission and hospital mortality were collected by the DTR after admission or death.

In this study, polytrauma was defined as a minimal injury severity score (ISS) [22] of 16. All patients with a minimum age of 65 and an ISS $\geq$ 16 admitted to a Dutch level 1 trauma center were identified in the DTR database. Exclusion criteria were patients with chronic subdural hematomas, and submersed or hypothermic patients with absence of other traumatic injuries.

Demographics, vital signs on admission, initial care (intensive care unit or nursing ward) and interventions were included. Age was categorized into pre-specified ranges for analysis (65–74, 75–84, $\geq$85). In the DTR, all injuries per patient are coded by means of the abbreviated injury score (AIS). Data of patients admitted to DTR between 2008 and 2014 contained AIS version 1998, and since 2015 the updated AIS version 2008 is used. For that, AIS98 codes were recoded to the updated AIS08 codes. Next, the ISS that is based on the AIS, was calculated. This led to an ISS change in 33.9% of the patients with a mean difference of -1.9 (SD: 4.3). A total of 35 patients were therefore excluded since their updated ISS was below 16. Additionally, injury characteristics were described for severe injuries (AIS $\geq$ 3) for the different AIS regions. Comorbidity was scored according to the ASA score, age-adjusted Charlson comorbidity index (CCI) [23] and comorbidity-polypharmacy score (CPS) [24]. Coagulopathy and acidosis were scored by respectively the international normalized ratio (INR $\geq$ 1.4) and arterial base excess (ABE $\leq$-6) on admission. Subdural bleeds were analyzed according to the AIS scores and manually checked by reviewing CT images, then categorized for small (<1 cm) and large subdural hematomas ($\geq$1 cm).

The local Medical Ethical Review Board reviewed the methods employed and waived further need for approval (ref.nr. M17.218694).

Mortality

Causes of death were categorized as follows: central nervous system (CNS) injury, exsanguination, respiratory failure, multi-organ failure (MOF), sepsis, cardiac arrest and other. CNS injury was defined as primary injury to the brain, brainstem or high cervical spine, or a secondary cerebral hemorrhage or ischemia. Exsanguination was defined as death due to bleeding from the thorax, abdomen or extremities. Death due to respiratory failure was defined as airway and inhalation injury, pneumonia, pulmonary embolism or respiratory fatigue. MOF was defined by the Denver post injury multiple organ failure score as used by Moore [25]. Sepsis was defined as suspected infection with a score of more than 2 points in the Sequential Organ Failure Assessment (SOFA) as stated in the third definition of sepsis [26]. These definitions include both primary trauma deaths and late-onset deaths. Mortality was analyzed for its causes and spatial distribution over the specified age groups.

Complications

Complications were scored according to the adapted Clavien-Dindo scoring system [27], which includes all complications in conjunction with a severity-grading system ranging from any deviation from the normal course without need for treatment (grade 1) up to death (grade 5). Grades 1 and 2 were defined as minor complications, grade 3 and higher as severe. Complications were extracted from the complication registry and checked by reviewing the medical charts. Complications leading to evolving severity grading, for example a pneumonia that turns to sepsis and evolves into septic shock and eventually death, was scored only with the most severe grading – in this case death (grade 5). Deaths resulting directly from trauma, such as exsanguination or traumatic brain injury, were not included in this complication scoring so we could focus on complications leading to late-onset deaths exclusively.

Statistics

GCS (EMV score $\leq$ 8), systolic blood pressure ($\leq$90 mmHg), INR ($\geq$1.4) and ABE (≤ -6) were dichotomized in concordance with the new 'Berlin definition' [10]. Categorical variables were presented using frequencies and percentages and tested using Pearson's chi-square test (with continuity correction) or Fischer's exact test, depending on the expected count (>5: Pearson, <5: Fischer) per cell. Normally distributed continuous variables were presented using means and standard deviations, and tested with repeated measures ANOVAs. Non-Gaussian distributed variables were presented as median and inter quartile range (IQR) and tested with the Kruskall-Wallis test. Statistical analyses were performed with IBM SPSS Statistics 23.0 (IBM, Armonk, NY). Significance of statistical differences was attributed to $p < 0.05$.

Missing data was present in the following variables: ASA (2.9%), CCI (2.9%), CPS (6.3%), SBP (6.8%), INR (6.3%) and ABE (70.8%). Multiple imputation with chained equations was used to handle this missing data [28]. Missingness at random was assumed. The

Nelson-Aalen estimated cumulative hazard was used as predictor in the imputation process instead of time to survival as recommended by White et al. [29]. Data was imputed using: the outcome (in-hospital mortality), all variables that were used in the multivariable regression model, and auxiliary variables with a correlation coefficient >0.2 with respect to the imputed variable. A total of 5 complete datasets were generated, using 50 iterations. The accuracy and acceptability of the imputed data was assessed using propensity plots as guided by Raghunathan and Bondarenko [30].

After imputation, cox-regression analysis was used to evaluate the time-based relation of the variables with the outcome; in-hospital mortality. Variables included in the model were: age, sex, GCS, INR, SBP, ABE, ASA, CCI, CPS and presence of a subdural hematoma. Secondly, an additional analysis with ISS included in the model was performed, by repeating the prior cox regression analysis with inclusion of ISS. Variables were removed using stepwise backward selection, using the Pooled Sampling Variance Method (D1) [31]. A p-removal value of 0.157 was used to warrant inclusion and prevent omission of important variables. Multiple imputation was performed in R (version 3.4.2), using the MICE package [28]. Cox regression analysis was performed in R, using the PSFMI package and survival package [31,32].

Results

Demographics, injury characteristics and comorbidity

A total of 385 polytrauma patients aged 65 or older were identified in the DTR database. Two patients were excluded

Table 1
Baseline characteristics.

		65–74 years (n = 186)	75–84 years (n = 143)	≥85 years (n = 51)	p-value	Total (n = 380)
Females		53 (28.5%)	66 (46.2%)	26 (51.0%)	<**0.01**	38.2%
Mean age (SD)		69.4 (2.7)	78.9 (2.9)	88.4 (3.1)	NP	75.5 (7.3)
Injury characteristics						
Blunt trauma		182 (97.8%)	143 (100%)	50 (98.0%)	NA	375 (98.7%)
Median ISS (IQR)		24.5 (18–30)	25 (17–29)	25 (19–29)	0.94	25 (18–29)
AIS Head ≥3		135 (72.6%)	105 (73.4%)	40 (78.4%)	0.71	280 (73.7%)
AIS Face ≥3		2 (1.1%)	3 (2.1%)	0 (0.0%)	0.70	5 (1.3%)
AIS Thorax ≥3		75 (40.3%)	58 (40.6%)	23 (45.1%)	0.82	156 (41.1%)
AIS Abdomen ≥3		13 (7.0%)	11 (7.7%)	1 (2.0%)	0.41	25 (6.6%)
AIS Extremity ≥3		28 (15.1%)	29 (20.3%)	11 (21.6%)	0.37	68 (17.9%)
AIS External ≥3		5 (2.7%)	2 (1.4%)	2 (3.9%)	0.67	9 (2.4%)
Clinical characteristics						
ASA (IQR)[a]		2 (2–3)	3 (2–3)	3 (2–3)	<**0.01**	2 (2–3)
CCI (IQR)[b]		3 (2–4)	5 (4–5)	5 (4–6)	<**0.01**	4 (3–5)
CPS (IQR)[c]		4 (2–8)	6 (3–9)	8 (5–10)	<**0.01**	5.5 (2–9)
Glasgow coma score ≤8		76 (40.9%)	61 (42.7%)	18 (35.3%)	0.66	155 (40.8%)
Systolic blood pressure ≤90[d]		12 (6.8%)	15 (11.5%)	2 (4.2%)	0.18	29 (8.2%)
INR ≥ 1.4[e]		35 (20.0%)	35 (26.1%)	15 (31.9%)	0.18	105 (29.5%)
Arterial base excess ≤-6[f]		17 (27.0%)	13 (33.3%)	4 (44.4%)	0.51	34 (30.6%)
Small subdural hematoma (<1 cm)		51 (27.4%)	29 (20.3%)	9 (17.6%)	0.29	89 (23.4%)
Large subdural hematoma (>1 cm)		14 (7.5%)	20 (14.0%)	8 (15.7%)	0.09	42 (11.1%)
Mean length of stay in days (SD)		16.6 (16.0)	13.1 (14.2)	8.2 (8.2)	<**0.01**	14.1 (14.7)
Initial ICU admission		116 (62.7%)	83 (58.0%)	20 (39.2%)	**0.01**	219 (57.9%)
Secondary ICU admission		13 (7.0%)	15 (10.5%)	2 (3.9%)	0.32	30 (7.9%)
Surgery performed		71 (38.4%)	42 (29.4%)	11 (21.6%)	**0.04**	124 (32.8%)
Complications						
≥1 complications during admission		111 (61.0%)	75 (53.2%)	28 (57.1%)	0.37	241 (57.5%)
Mean no. of complications (SD)		1.3 (1.4)	1.2 (1.6)	1.2 (1.4)	0.83	1.3 (1.5)
Grade 1	*Resolves without intervention*	51 (27.4%)	32 (22.4%)	12 (23.5%)	0.56	95 (25.0%)
Grade 2	*Resolves with medical intervention*	140 (75.3%)	88 (61.5%)	33 (64.5%)	**0.02**	261 (70.2%)
Grade 3	*Requires operative treatment*	10 (5.4%)	5 (3.5%)	2 (3.9%)	0.70	17 (4.5%)
Grade 3a	*With local anesthesia*	4 (2.2%)	1 (0.7%)	–	NA	5 (1.3%)
Grade 3b	*With general anesthesia*	6 (3.2%)	4 (2.8%)	2 (3.9%)	NA	12 (3.2%)
Grade 4	*Unplanned IC admission*	26 (14.0%)	18 (12.6%)	2 (3.9%)	0.12	47 (12.4%)
Grade 4a	*With single-organ failure*	25 (13.4%)	17 (11.9%)	2 (3.9%)	0.16	42 (11.1%)
Grade 4b	*With multi-organ failure*	1 (0.5%)	1 (0.7%)	–	NA	2 (0.5%)
Grade 5	*Death*	10 (5.4%)	23 (16.1%)	14 (27.2%)	<**0.01**	47 (12.3%)
Grade 5a	*Not actively treated*	3 (1.6%)	14 (9.8%)	13(25.5%)	<**0.01**	30 (7.9%)
Grade 5b	*Actively treated*	7 (3.8%)	9 (6.3%)	1 (2.0%)	0.35	17 (4.5%)
Mortality						
In-hospital mortality		44 (23.7%)	63 (44.1%)	31 (60.8%)	<**0.01**	138 (36.3%)
Exsanguination		7 (15.9%)	13 (20.6%)	5 (16.1%)	0.78	25 (18.1%)
CNS		28 (63.6%)	28 (44.4%)	13 (41.9%)	0.09	69 (50.0%)
Respiratory failure		2 (4.5%)	14 (22.2%)	7 (22.6%)	**0.02**	23 (16.7%)
Multi-organ failure		4 (9.1%)	2 (3.2%)	4 (12.9%)	0.16	10 (7.2%)
Sepsis		2 (4.5%)	3 (4.8%)	1 (3.2%)	1.00	6 (4.3%)
Cardiac arrest		–	2 (3.2%)	1 (3.2%)	0.60	3 (2.2%)
Unknown		1 (2.3%)	1 (1.6%)	–	0.99	2 (1.4%)

Statistically significant results are bolded.
Abbreviations: SD, standard deviation; IQR, inter quartile range; NP, not performed; NA, not applicable; CCI, Charlson comorbidity index; CPS, comorbidity-polypharmacy score; INR, international normalized ratio; ICU, intensive care unit; CNS, central nervous system.
[a] 2.9% missing data.
[b] 2.9% missing data.
[c] 6.3% missing data.
[d] 6.8% missing data.
[e] 6.3% missing data.
[f] 70.8% missing data.

because of absence of traumatic injuries – they were admitted after a submersion. Three patients were excluded because they were transferred from the ER to another medical center. Hence, a total of 380 patients were analyzed. Table 1 displays all baseline characteristics by age category. Mean age of older polytrauma patients was 75.5 years. The majority of the population were men (61.8%), although the proportion of females grew with increasing age. Nearly all injuries were due to blunt trauma (98.7%), with a median ISS of 25 (IQR: 18–29); this did not differ significantly between the age groups. The three most frequent severely injured body regions (AIS ≥ 3) were the head (73.7%), thorax (41.1%) and extremities (17.9%). No significant differences were seen with increasing age. For all three comorbidity scores (ASA, CCI and CPS) a significant increasing trend is seen with age.

Mortality

Overall in-hospital mortality was 36.3%, rising significantly with age. For patients aged ≥85 in-hospital mortality was 60.8%. Of all fatalities, 44.9% were within the first 48 h after trauma. Fig. 1 displays the temporal distribution of trauma deaths by age group. One peak can be observed within the first two days for all age groups, and a clear second peak in mortality is seen around six day, which was most striking for the patients aged ≥75 years. Fig. 2 displays the cause of death per day following trauma.

Regarding the etiology of in-hospital mortality, some trends were noted for the different age groups, as shown in Table 1. Overall CNS injury was the leading cause of death (50.0%) but tended to decrease for the very old. By contrast, respiratory failure raised significantly with age as cause of death ($p = 0.02$). Exsanguination was the second most frequent cause of death and remained consistent across all age groups.

Concerning risk factors associated with in-hospital mortality, two multivariable Cox regression analyses were performed after multiple imputation of missing data. The final model showed age, a GCS ≤ 8, INR ≥ 1.4, ABE ≤-6 and the presence of a subdural hematoma exceeding 1 cm to be significant risk factors associated with in-hospital mortality for older polytrauma patients. In the second analysis, with inclusion of the ISS, the variables in the final model were: age, a GCS ≤ 8, INR ≥ 1.4, ABE ≤-6, presence of a subdural hematoma exceeding 1 cm and ISS. Presence of comorbidities (ASA, CCI, CPS) and SBP did not influence mortality significantly in both multivariable analyses. The models are presented in Table 2.

Complications

The mean number of complications was comparable for all age groups (1.3 complications/patient). Most patients (57.4%) had one or more complications, and 23.4% endured one or more severe complications (grade 3 or higher) during admission. The three most frequent complications overall were delirium (20.1%), pneumonia (15.3%) and electrolyte imbalance (11.1%) – all grade 1 or 2 complications. The most frequent severe complication was respiratory failure (infectious and non-infectious), followed by complications affecting the central nervous system (CNS), cardiac arrest and multi-organ failure. An overview of the frequency and etiology of severe complications is displayed in Fig. 3 and Table 3. Forty-seven patients (12.4%) died due to a complication. Although the proportion of severe complications did not differ between age groups, the proportion of fatal complications increased significantly with age (65–74:5.6%, 75–84:16.1%, ≥85:27.5%, $p < 0.01$).

Discussion

The majority of older polytrauma fatalities are due to CNS damage after traumatic brain injury and exsanguination, which is in concordance with the current literature [33]. Fatalities due to complications increased with age. Polytraumatized older patients were at a substantial risk of dying, especially those older than 75. Coagulopathy, acidosis, a large subdural hematoma, a low GCS score and injury severity were independently of age associated with a higher mortality. The most fatal in-hospital complications were respiratory failure and multi-organ failure.

We found that in-hospital mortality rates raised significantly for older patients. For the polytrauma population these mortality rates are higher than previously described, especially for those aged over 75. The classical trimodal distribution of trauma deaths, presented by Trunkey in 1983 [34], describes a peak of immediate deaths, a second peak 1–4 h after trauma, and a third peak 3–4 weeks following trauma. Thanks to improvements in resuscitation and critical care, current literature shows a decline of late-onset deaths, which were mostly due to MOF and sepsis. This results in a largely bimodal rather than trimodal distribution [35–38]. Our study did not include the first peak, as these persons do not arrive at the ER alive. Most older polytrauma fatalities happen within the first 48 h, mostly due to CNS damage or exsanguination. This is in concordance with the second peak of Trunkey and literature describing the etiology of trauma deaths [39]. Those older than 75 years however, showed a 'third peak' in mortality approximately six days after trauma. This peak incorporates predominantly deaths due to CNS injury and respiratory failure. Moreover, this peak developed earlier than the original third peak described by Trunkey, which was estimated at around three weeks. These findings trigger a number of questions. First, is it possible to identify those at risk, taking into account factors other than age? And second, is there room for improvement of care?

To address the first question, quickly accessible factors independently associated with mortality are age, coagulopathy (INR ≥ 1.4), acidosis (ABE ≤-6) and a lower level of consciousness (GCS score ≤ 8). This is in concordance with the latest consensus on the definition of polytrauma patients of Pape et al. [10]. This study also

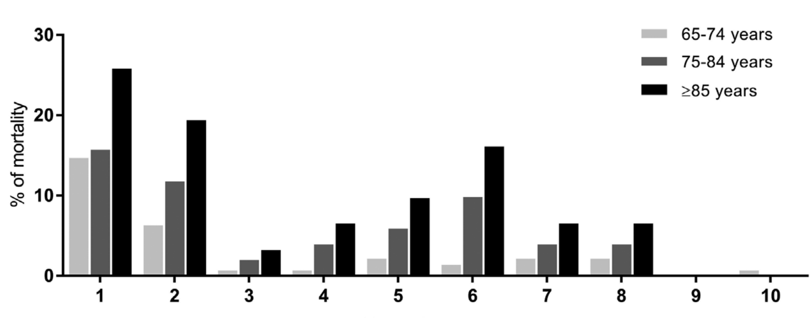

Fig. 1. Temporal distribution of mortality per age group.

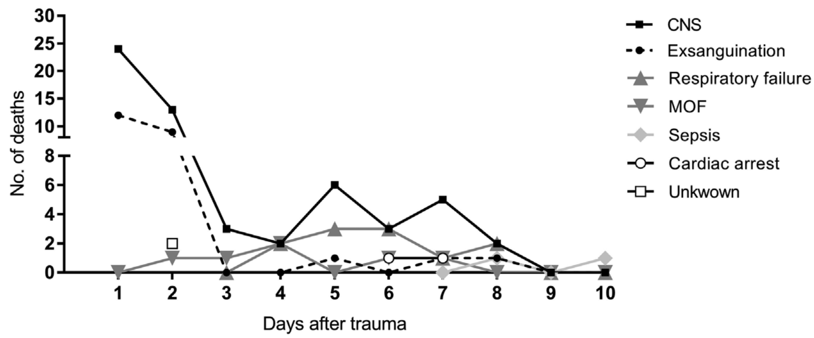

Fig. 2. Etiology of mortality per day.

Table 2
Multivariable Cox regression analysis on in-hospital mortality after multiple imputation.

	HR	95% Confidence interval		p-value
		Lower	Upper	
Final multivariable model without ISS				
Age (years)	1.08	1.06	1.11	**0.00**
Glasgow coma score (EMV ≤ 8)	4.71	3.06	4.25	**0.00**
INR ≥ 1.4	1.57	1.08	2.27	**0.02**
Arterial base excess (ABE ≤-6)	2.19	1.22	3.95	**0.01**
Subdural hematoma ‡				**0.03**
Small (<1 cm)	0.90	0.56	1.46	0.68
Large (>1 cm)	1.80	1.13	2.88	**0.01**
Final multivariable model with ISS				
Age (years)	1.09	1.06	1.11	**0.00**
Glasgow coma score (EMV ≤ 8)	4.23	2.79	6.44	**0.00**
INR ≥ 1.4	1.53	1.05	2.21	**0.03**
Arterial base excess (ABE ≤-6)	2.06	1.12	3.77	**0.02**
Subdural hematoma ‡				**0.07**
Small (<1 cm)	0.95	0.59	1.54	0.84
Large (>1 cm)	1.68	1.06	2.68	**0.03**
ISS	1.03	1.00	1.05	**0.05**

Statistically significant results are bolded; ‡ Reference: no subdural hematoma; ISS, injury severity score; HR, hazard ratio; INR, international normalized ratio; ABE, arterial base excess.

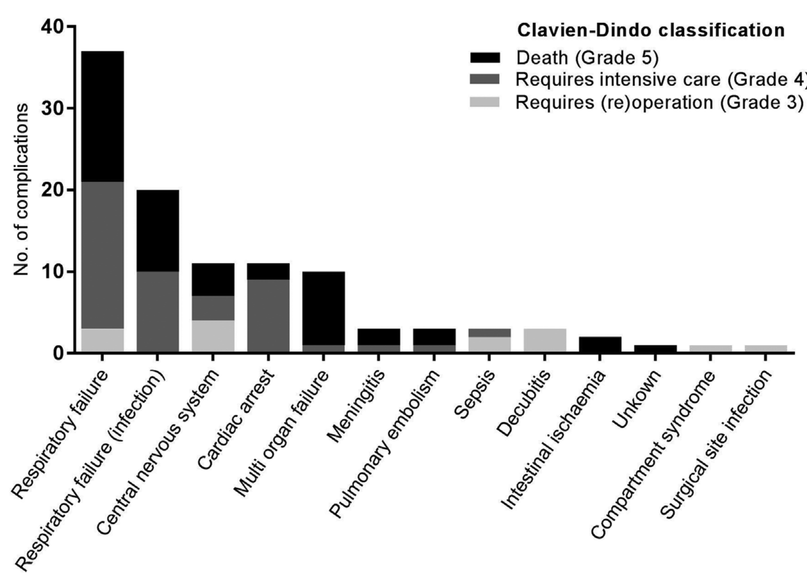

Fig. 3. Frequencies and nature of severe complications.

pointed out the increased mortality risk of older adults after enduring a large subdural hematoma, independently of the aforementioned variables. After inclusion of ISS in the model these early obtainable parameters remained independently associated with in-hospital mortality. Hence, these factors should be taken into account when assessing risk profiles for the older polytraumatized.

Recent studies identified the role of comorbidities on outcome after trauma [40,41]. We tested three comorbidity scoring systems

Table 3
Frequencies and nature of severe complications for the different age categories.

	65–74 years (n = 186)	75–84 years (n = 143)	≥85 years (n = 51)	Total (n = 380)
Grade 3a	**4 (2.2%)**	**1 (0.7%)**	–	**5 (1.3%)**
Respiratory failure (drainage)	2 (1.1%)	1 (0.7%)	–	2 (0.5%)
Fall	1 (0.5%)	–	–	1 (0.3%)
Coiling carotid cavernous fistula	1 (0.5%)	–	–	1 (0.3%)
Grade 3b	**6 (3.2%)**	**4 (2.8%)**	**2 (3.9%)**	**12 (3.2%)**
Respiratory failure (thoracotomy)	1 (0.5%)	–	–	1 (0.3%)
CNS (re-craniotomy)	2 (1.1%)	2 (1.4%)	–	4 (1.1%)
Wound infection	1 (0.5%)	–	1 (2.0%)	2 (0.5%)
Abdominal sepsis	1 (0.5%)	1 (0.7%)	1 (2.0%)	3 (0.8%)
Abdominal compartment syndrome	1 (0.5%)	–	–	1 (0.3%)
Decubitus	–	1 (0.7%)	–	1 (0.3%)
Grade 4a	**25 (13.5%)**	**17 (11.8%)**	**2 (3.9%)**	**44 (11.6%)**
Respiratory failure	12 (6.5%)	7 (4.9%)	–	19 (5.0%)
Respiratory failure (infection)	6 (3.2%)	4 (2.8%)	–	10 (2.6%)
CNS	2 (1.1%)	1 (0.7%)	–	3 (0.8%)
Cardiac arrest	5 (2.7%)	3 (2.1%)	2 (3.9%)	10 (2.6%)
Lung embolism	–	1 (0.7%)	–	1 (0.3%)
Meningitis	–	1 (0.7%)	–	1 (0.3%)
Grade 4b	**1 (0.5%)**	**1 (0.7%)**	–	**2 (0.5%)**
Multi-organ failure	1 (0.5%)	1 (0.7%)	–	2 (0.5%)
Grade 5a	**3 (1.6%)**	**14 (9.8%)**	**13 (25.5%)**	**30 (7.9%)**
Respiratory failure	1 (0.5%)	8 (5.6%)	4 (7.8%)	13 (3.4%)
Respiratory failure (infection)	–	4 (2.8%)	4 (7.8%)	8 (2.1%)
Multi-organ failure	1 (0.5%)	1 (0.7%)	3 (5.9%)	5 (1.3%)
CNS	1 (0.5%)	–	1 (2.0%)	2 (0.5%)
Meningitis	–	1 (0.7%)	1 (2.0%)	2 (0.5%)
Grade 5b	**7 (3.8%)**	**9 (6.3%)**	**1 (2.0%)**	**17 (4.5%)**
Respiratory failure	1 (0.5%)	2 (1.4%)	–	3 (0.8%)
Respiratory failure (infection)	2 (1.1%)	–	–	2 (0.5%)
Multi-organ failure	1 (0.5%)	2 (1.4%)	1 (2.0%)	4 (1.1%)
Cardiac arrest	–	2 (1.4%)	–	2 (0.5%)
Intestinal ischemia	1 (0.5%)	1 (0.7%)	–	2 (0.5%)
Lung embolism	1 (0.5%)	1 (0.7%)	–	2 (0.5%)
CNS	–	1 (0.7%)	–	1 (0.3%)
Unknown	1 (0.5%)	–	–	1 (0.3%)
Total	**46 (24.8%)**	**46 (32.2%)**	**18 (35.3%)**	**110 (29.0%)**

that been associated with mortality in an older trauma population [42–44]. Yet these commonly used comorbidity scores did not show predictive on in-hospital mortality of the older polytrauma patient. Therefore we would encourage research on exploring other predisposing factors on mortality among older polytrauma patients, such as sarcopenia and osteopenia, which are known to be risk factors for this geriatric population [45].

The overall complication rate of older polytrauma patients was comparable with complication rates mentioned in recent literature, also for younger persons [15]. Yet this study showed that the rate of fatal complications rises significantly with age. This indicates that the more elderly patients are susceptible to fatal adverse events, mainly of the respiratory system. Although it was not a primary study objective, this study pointed out that delirium was the most common complication among polytraumatized older patients. It has been associated with long-term mortality and known to be an independent risk factor for long-term cognitive functioning [46].

To address the second question; In our opinion there is still room for improvement of care for the older polytrauma population. Centralization of geriatric trauma care and implementation of a dedicated geriatric trauma service are associated with beneficial outcome of the elderly [47–49]. Besides this we would plea for the use of the found early-obtainable risk factors, and more involvement of dedicated geriatric trauma surgeons in polytrauma care of the older patient. This may enable earlier identification and trigger fast resuscitation and rehabilitation, such as early start of parenteral feeding, ventilation support, aggressive pulmonary screening and minimized use of opioids.

Although polytrauma patients are diverse in their presentation, making this subject complex to investigate, the Dutch trauma registry provided a solid base for the evaluation of care. Still, this research is of a retrospective character and is therefore susceptible to inherent limitations. Multiple imputation was performed to minimize the bias in the estimation of the relevant parameters. The ability to generalize the results of this study might be a subject of discussion, since this was a single center study performed in a level 1 trauma center. Yet, to our knowledge this is the largest study on mortality etiology and its pattern in combination with the in-hospital complications in older polytrauma patients. This study therefore provided a wide perspective on the post-traumatic course of the older polytrauma patient.

Conclusions

Polytraumatized elderly, especially those aged over 75, had an elevated mortality risk. This specific group showed a unique peak of late-onset fatalities due to CNS injury and respiratory failure approximately one week following trauma. Coagulopathy, acidosis, a low Glasgow coma score, presence of a large subdural hematoma and injury severity score were independently of age associated with an increased mortality. within this population. Comorbidities as measured in this study did not seem to impact in-hospital mortality in this population significantly. Future research considering this population should not only investigate the improvement of care for mortality and its predisposing factors, but also focus on patient-reported outcomes of survivors to fully understand the impact of polytrauma among older patients.

Author contributions

R. de Vries: Study design, conceptualization, literature search, data curation, data interpretation, data analysis, statistics, drafting manuscript.

I.H.F. Reininga: Study design, conceptualization, data analysis, data interpretation, critical revision.

M.W. de Graaf: Data analysis, data interpretation, statistics, critical revision.

E. Heineman: Study design, conceptualization, critical revision.

M. El Moumni: Study design, conceptualization, statistics, critical revision.

K.W. Wendt: Study design, conceptualization, data interpretation, critical revision.

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