



# Evaluating the need to reform the organisation of care for major trauma patients in Belgium: an analysis of administrative databases

Koen Van den Heede<sup>1</sup> · Cécile Dubois<sup>1</sup> · Patriek Mistiaen<sup>1</sup> · Sabine Stordeur<sup>1</sup> · Audrey Cordon<sup>1</sup> · Marie Isabel Farfan-Portet<sup>1</sup>

Received: 22 January 2018 / Accepted: 23 February 2018 / Published online: 26 February 2018  
© Springer-Verlag GmbH Germany, part of Springer Nature 2018

## Abstract

**Purpose** In light of the international evolutions to establish inclusive trauma systems and to concentrate the care for the most severely injured in major trauma centres, we evaluated the degree of dispersion of trauma care in Belgium.

**Methods** We used descriptive statistics to illustrate the dispersion of major trauma care in Belgium based on two independent administrative databases: the registry of Mobile Intensive Care Units (2009–2015) and the Belgian Hospital Discharge Dataset (2009–2014).

**Results** Patients with a severe trauma ( $n = 3856$  in 2015) were transported towards 145 different hospital sites (on a total of 198 hospital sites) resulting in a median of 17 cases per hospital site (min = 1; P25 = 4; P75 = 30; max = 165). A minority of major trauma patients is after admission transferred to another hospital (8%) with a median of 10 days after admission to the hospital (IQR 3.5–24).

**Conclusions** The dispersion of care for major trauma patients in Belgium is so high that a reorganisation of care for severe injured patients in major trauma centres concentrating professional expertise and specialised equipment is recommended to guarantee a high quality of care in a qualitative and sustainable way.

**Keywords** Trauma centres · Quality of health care · Multiple trauma · Health care reform

## Introduction

Major trauma is a serious public health problem and is worldwide one of the leading causes of deaths and a significant cause of short- and long-term morbidity [1–4]. Internationally, major trauma centres emerged to organise the care for patients with a major trauma. Major trauma centres (MTC) are hospitals that specialise in, and are designated for, the treatment of the major trauma patients. They admit such patients with sufficient frequency to gain expertise in their management. Although a majority of studies that investigate a volume–outcome relationship, find beneficial

results for higher-volume centres, the current evidence does, however, not allow to set an optimal volume-threshold above which there is an indisputable improvement in patient's survival [5–9].

In Europe, the establishment of volume-thresholds remains an issue of debate at the moment of the implementation of the MTC. The basis to set a minimal annual volume threshold of 250 major trauma cases was initially recommended in England [10], in line with most often cited volume-threshold of the American College of Surgeons (ACS) [10]. Other countries lowered this volume threshold to make it politically acceptable but also to ensure an adequate coverage of the territory. In The Netherlands and Germany, for instance, it is expected that MTCs treat a yearly minimum number of major trauma patients of 100 and 40, respectively [11, 12].

Although major trauma centres remain a cornerstone in a trauma network the emphasis moved from isolated institutions towards a collaboration between all relevant actors in the care process of major trauma patients. These major trauma networks (or systems) were pioneered in the USA but are now

---

**Electronic supplementary material** The online version of this article (<https://doi.org/10.1007/s00068-018-0932-9>) contains supplementary material, which is available to authorized users.

---

✉ Koen Van den Heede  
Koen.vandenheede@kce.fgov.be

<sup>1</sup> Belgian Healthcare Knowledge Centre, Kruidtuinlaan 55, 1000 Brussels, Belgium

also widely implemented elsewhere in the world [12–25]. The most important characteristic of these networks is that they are ‘inclusive’. This means that within a defined geographical area, all key actors, from prehospital emergency care services towards rehabilitation, play a clear role in trauma care [12, 20, 21, 26, 27].

Despite the international support for the trauma networks and the belief that they contribute to better patient outcomes (e.g. improved survival or reduced disabilities) the evidence base is less clear-cut. A main difficulty to assess the patients’ outcomes according to their severity grade is the definition of a major trauma or a severe trauma. In the scientific literature, the most reported definition of a ‘major trauma’ is a patient with an Injury Severity Score (ISS) above 15. However, this homogeneous definition hides a complex reality. For this reason, many authors prefer to split major trauma patients into subgroups, e.g. ISS (16–24) to ISS (25–75). Compared to lower-levels of care, admission to a MTC has been often, but not always, found to be beneficial for ‘major trauma patients’ [5]. A more in-depth analysis of studies with outcome measures reported for different subgroups of major trauma patients suggests that effects are most prominent for the most severely injured patients (e.g. ISS > 24) [28–33]. Likewise, there are indications that special provisions should be undertaken for specific subgroups such as paediatric and elderly patients and for specific injuries (e.g. burns, spinal cord injury) [18]. A key success factor for a trauma network is thus getting the patients with a major trauma, especially those with very severe or specific injuries, to the MTC. In addition, outcomes do not improve overnight. From the international examples it is clear that inclusive trauma systems require time to mature [34–40]. Moore et al. [41] reported that trauma systems could not be fully effective until up to 10 years after their implementation.

In Europe major trauma networks are nowadays dominant way to organise care for major trauma patients. Several countries (e.g. England, The Netherlands, Germany, Norway, Denmark) implemented major trauma networks, while other countries such as Switzerland, Scotland, Wales and Ireland plan to implement them in the near future [42–45]. Nevertheless, not all countries (e.g. France, Belgium, Spain) follow this pathway. In this study we will evaluate, for Belgium, if there is a need to organise the care for major trauma patients in light of these international reforms. More specifically, we addressed the following research question: What is the level of dispersion in the care for major trauma patients in Belgium?

## Materials and methods

### Setting

Belgium is the fifth smallest country in the EU (30.528 km<sup>2</sup>), highly developed and densely populated (11.3 million of

inhabitants) at the cross-roads of Western Europe. Its population density equals 369 per km<sup>2</sup>. The maximum distance between two points is around 280 km and its neighbouring countries are France, The Netherlands, Luxembourg and Germany.

In Belgium, there are 102 acute hospitals located on 198 different hospital sites [46, 47]. All hospitals have one or more emergency departments (ED) with a total of 139 hospital sites with an emergency department (ED). This results in approximately 2 hospital sites per 100,000 inhabitants with an ED, which is high in the international context [46]. It is well documented that Belgium has a large hospital capacity (e.g. high density of hospital services) and that most hospitals provide the broadest possible number of services with the latest technological innovations, resulting in a wide diffusion of technologies and heavy equipment [48]. The infrastructure and medical equipment to provide care for major trauma patients might thus be available in a large number of acute hospitals. Yet, this dense hospital landscape and more particularly the high density of ED have an important downside. It results in a dispersion of budgets (e.g. to provide 24/7 availability) and an insufficient caseload by hospital to maintain medical, nursing and paramedical expertise.

The Belgian Law stipulates that emergency medical services (EMS) should transport the victim to the nearest hospital with an ED. However, under specific circumstances the patient may be referred to the closest most adequate hospital’s site. In case of a major trauma, the ambulance which is staffed by an ambulance driver and a rescuer (non-medically trained staff who followed a short course in first aid assistance) is usually assisted by a Mobile Intensive Care Unit (MICU). MICUs are specially equipped cars staffed with an emergency physician specialised in emergency care and a nurse specialised in emergency and intensive-care medicine.

### Data sources to evaluate the Belgian context

Due to the absence of a trauma registry in Belgium, it is currently not possible to fully assess the incidence of life-altering and life-threatening trauma-related incidents in Belgium. Therefore, we used two data sources to assess the degree of dispersion of patients with major trauma: the MICU registry (each intervention of a MICU is mandatory registered in this registry) and the Belgian Hospital Discharge Dataset (B-HDDS) data.

In pre-hospital settings, a severe trauma can be registered in the MICU registry as one out of eight pathologies and conditions (severe trauma, cardiac arrest, respiratory distress, acute coronary syndrome, stroke, intoxication, suicide and other). The instructions included in the manual of the MICU registry stipulate that a severe trauma occurs when the patient has a Revised Trauma Score (RTS) of less or equal to five and whose International Classification of

Diseases-9th Revision-Clinical Modification, ICD-9-CM code is between 800 and 959.9 (these are injury and poisoning codes). Despite these instructions, in clinical practice this flag ‘severe trauma’ is ticked by the MICU-team based on their clinical assessment. Based on the registry data of the years 2009–2015 we identified the number of hospitals and hospital sites that admitted major trauma patients, the major trauma cause (e.g. fall, traffic accident), transport times, etc. Only MICU interventions for patients that were transported to a hospital were included (e.g. death at the scene were excluded from the database). The registry does not allow to monitor the major trauma patients throughout their care trajectory after being accepted to the hospital (e.g. mortality after trauma).

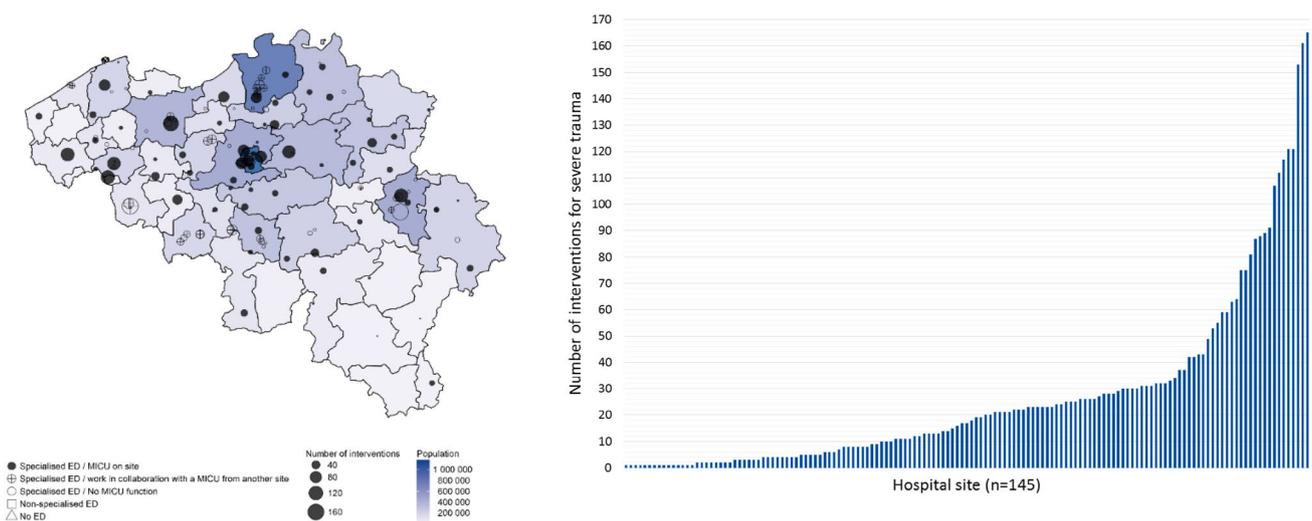
A second data source used in this study is the Belgian Hospital Discharge Dataset. This database is used to identify the number of hospitals that accept major trauma patients (at least the subgroup of patients with multiple significant trauma) as well as to study the number of patients that are transferred to another hospital as well as the time lag between admission and transfer. For each patient admitted in a Belgian acute hospital, hospitals have to send twice a year medical data (using the International Classification of Diseases-9th Revision-Clinical Modification, ICD-9-CM) to the Federal Ministry of Health. Each inpatient and day-care stay is assigned an APR-DRG-SOI (All Patient Refined Diagnosis Related Group-Severity of Illness) combination. The APR-DRG system is a patient classification system intended to define medically coherent and cost homogeneous groups. Each APR-DRG belongs to a ‘Major Diagnostic

Category’ (MDC). For the analysis of this study we selected in-patient stays for multiple significant trauma (MDC 25) in the B-HDSS of the years 2009–2014. The choice to restrict the patients with a ‘MDC 25’ was made in order to unambiguously identify patients with severe or major trauma, with the knowledge that this only concerns a subgroup of major trauma patients. Indeed, major trauma patients can be classified within an APR-DRG outside the MDC 25 (e.g. MDC 8 ‘Diseases and Disorders of the Musculoskeletal System and Connective Tissue’). Yet, it is unlikely that patients within MDC 25 ‘multiple significant trauma’ do not concern major trauma patients. This was confirmed by experts in the field as well as by experts specialised in the coding practice of this administrative database.

The two databases could not be linked because a primary key containing crucial information on the patient identification was missing. Nevertheless, the combination of both analyses allows to make statements about the level of dispersion of care for major trauma patients in Belgium. Although the data were analysed for several consecutive years, Fig. 1 illustrates the data from the most recent available year (MICU: 2015; B-HDSS: 2014).

### Ethical approval

As outlined in the Law of 24 December 2002 (articles 259–300), which regulates the foundation of the Belgian Healthcare Knowledge Centre (KCE), the access to and analysis of administrative databases such as the B-HDSS and the MICU-registry is approved.



**Fig. 1** Dispersion of major trauma care in Belgium: hospital site where the patient with a major trauma was sent to (MICU data 2015). Source: Federal Public Service (FPS) Health, Food Chain Safety and Environment: Mobile Intensive Care Units (MICU) Data 2015

## Results

### Belgium

#### MICU interventions for major trauma

During the period 2009–2015, the number of interventions for patients with a major trauma varied from 3295 to 3959 cases per year without a clear time trend (see Table 1). ‘Major trauma interventions’ represent 3.6–4.8% of all MICU-interventions. The proportion of severe trauma interventions for children (< 16 years) remained stable around 7%. The proportion of MICU interventions for elderly patients ( $\geq 75$  years) increased over the years from 11 to 14%. In 2015, there were 3856 interventions for major trauma cases of which falls at home or in public areas ( $n = 1\ 396$ ; 36%) and traffic accidents ( $n = 1\ 332$ ; 35%) were the two most common causes.

In 2015, 3856 severe trauma cases were transported to 145 different hospital sites resulting in a median of 17 cases per hospital site (IQR 4–30), with a minimum of 1 and maximum of 165 interventions per site. The majority of the severe trauma cases were transported to hospital

sites with an ED operating a MICU. The majority of the sites admitting patients with severe trauma have at least one CT-scan (98% of the sites) and a MRI (76%) (Table 2).

In 2015, for 17% of the interventions ( $n = 672$ ) for a severe trauma the closest hospital was bypassed for therapeutic reasons. Those trauma cases were sent to 76 different hospital sites but mainly to university hospitals (35%) or to larger (> 450 beds) hospitals (29%). The main therapeutic indication to bypass a hospital is a burn injury. In 71% of the burn-related severe trauma cases, the closest hospital was bypassed. From those cases, 80% were sent to one of the six acute hospital sites with a burn care service.

An important factor contributing to the successful management of major trauma patients is the time interval between the accident, the emergency call, the MICU intervention and the arrival to the hospital site. From the moment when the MICU receives the call until the arrival of the victim at the closest most adequate hospital’s site, the delay was less than 46 min in half of the cases (IQR 35–60 min). The time needed to provide care by the emergency physician on the scene is counted in this result. In general, for three cases on four, the full MICU intervention lasts less than 1 h. For interventions sent to another hospital for therapeutic reasons this time is stretched to 73 min. The median transport time

**Table 1** Description of data included in analyses (2009–2015). Source: Federal Public Service (FPS) Health, Food Chain Safety and Environment: Mobile Intensive Care Units (MICU) data 2009–2015

	2009	2010	2011	2012	2013	2014	2015	All
Number of MICU interventions with a transport to a hospital site	$N = 80,639$	$N = 82,056$	$N = 79,693$	$N = 85,990$	$N = 91,895$	$N = 95,262$	$N = 97,237$	$N = 612,772$
Number of interventions for severe trauma	3547	3959	3728	3792	3295	3649	3856	25826
% of severe trauma interventions	4.4	4.8	4.7	4.4	3.6	3.8	4.0	4.2

**Table 2** Interval of time between some specific actions (in min)—severe trauma intervention (2015) and severe trauma intervention sent to a site for therapeutic choice (Data 2015). Source: Federal Public

Service (FPS) Health, Food Chain Safety and Environment: Mobile Intensive Care Units (MICU) data 2015

	All severe trauma interventions				Severe trauma interventions sent to another hospital site for therapeutic reasons			
	On scene (1)	Travel time (2)	From scene to hosp. site (1+2)	From the MICU call to hosp. site (3)	On scene (1)	Travel time (2)	From scene to hosp. site (1+2)	From the MICU call to hosp. site (3)
Number of interventions	3423 <sup>a</sup>	3443 <sup>a</sup>	3473 <sup>a</sup>	3522 <sup>a</sup>	625 <sup>a</sup>	630 <sup>a</sup>	632 <sup>a</sup>	638 <sup>a</sup>
Median (Q1–Q3)	23 (16–33)	10 (6–16)	35 (25–48)	46 (35–60)	30 (21–40.6)	14.5 (10–22)	47 (35–61)	58 (45–73)
Min–max	0.01–146	0.01–607	0.01–631	0.03–642	0.01–139	0.03–145	0.05–213	1–237

(1) From arrival on scene to departure from scene; (2) from departure from scene to arrival to hospital site; (3) from call to arrival to hospital site. Records with an overall interval of time > 20 h were deleted from the analyses and considered as coding error

<sup>a</sup>Each interval of time is calculated on available time in our database. Difference between the number of interventions is due to missing time information for some of the records

(time from departure on the scene to the arrival to the ED) was 10 min (IQR 6–16 min). The median transport times rose to 14.5 min for the MICU interventions where the choice of the hospital site was made for therapeutic reasons.

### In-hospital data for patients with multiple significant trauma

The number of stays for multiple significant traumas varied around 2400 a year (from 2447 stays in 2009 to 2408 stays in 2014 without time trends) (see supplementary material). During this period (2009–2014), the proportion of stays was constant around 3.5% for children (< 16 years) while that for elderly patients ( $\geq 75$  years) increased from 19 to 25% over the years. In 2014, the median number of stays per hospital site was 11 per site (IQR 5–19) and with a minimum of 1 and maximum of 85 stays per site (Table 3).

The majority of patients with a severe multiple trauma are discharged back home (75%). Around 8% of the MDC 25 stays ( $n = 184$  cases) are transferred to 77 hospital sites for specialised care (other than rehabilitation or medical surveillance). Only for 9% of them, the transfer occurs within the day of arrival to the hospital site. The median length-of-stay in the hospital before transfer is 10 days (IQR 3.5–24) after admission. The in-hospital mortality rate per site over the

period 2009 to 2014 was, in median, of 9.6% [Q1–Q3 of (1.8; 13.5%)].

## Discussion

The purpose of this study was to evaluate, in light of the recent scientific evidence and the experience of other European countries [12–18], the need to reform the organisation of care for major trauma patients in Belgium. Based on this study it is clear that there are compelling arguments to reorganise the care for major trauma patients.

There is a high degree of dispersion in the care for major trauma patients in Belgium. Both datasets clearly indicated that major trauma patients are treated in a large number of hospitals resulting in low caseloads per hospital. In fact, median caseloads (i.e. 17 cases per centre) are far below the lowest international accepted caseloads (e.g. at least 40 major trauma patients per year in Germany). The dispersion of major trauma cases is obviously linked to the combination of the legal provisions (i.e. transport to the most adequate nearest hospital) and the high density of emergency departments. Taking into account these results, we may wonder whether, in the long-term, the dispersion of patients will allow to ensure the medical expertise of the teams while being financially viable. Recent studies indicate that there is a volume–outcome relationship, especially for the most severely injured [28–31, 33, 49]. In trauma systems, per definition, it is aimed to enhance the concentration of patients into the centres that are better adapted to respond to the complex care needs major trauma patients require. Achieving a critical mass of patients per centre is considered ‘a must’ to allow the multidisciplinary teams to acquire and maintain the required expertise.

Second, while in countries with a major trauma system in place, hospitals are bypassed to ensure that patients with a major trauma arrive at a MTC as soon as possible, bypassing a hospital during emergency transport in Belgium takes rarely place. This clearly has the advantage, together with the very dense acute hospital landscape on a small territory that transport times in Belgium are kept low. In fact, transport times are far below the international used targets [11, 12, 18, 50, 51].

The downside is that patients might not arrive in a hospital with sufficient expertise to deal with these major trauma cases. What is more, patients are after admission rarely transferred to another hospital and if they are, this happens rather late (median of 10 days). Improving the patient flow of major trauma patients by transporting them immediately to specialised centres seems, therefore, indicated. Nevertheless, when a trauma system is implemented it seems worthwhile to keep the time interval between activation of the call and getting to the scene as short as possible. The MICU

**Table 3** Number (%) of interventions according to hospital site characteristics—Data 2015. Source: Federal Public Service (FPS) Health, Food Chain Safety and Environment: Mobile Intensive Care Units (MICU) data 2015 ; Characteristics of the hospital site come from FOD-SPF public health

	All severe trauma
Number of interventions $N =$ (number of sites)	3856 (145)
Characteristics	
Missing	11 (0.3%)
Site capacity	
< 200 beds	518 (13.4%)
200–299 beds	529 (13.7%)
300–449 beds	1105 (28.7%)
450+ beds	913 (23.7%)
University	791 (20.5%)
Number of CT scanners	
0	93 (2.4%)
1	3457 (89.7%)
2	295 (7.7%)
Number of MRI	
0	940 (24.4%)
1	1468 (38.1%)
2	834 (21.6%)
3	496 (12.9%)
4	107 (2.8%)

teams which are staffed by an emergency physician and a nurse have the advantage that they can assess the severity of the injury at the scene of the accident and stabilise the patient when needed. This is a different starting point compared to other European systems that re-designed their trauma system (e.g. in England ambulances are staffed by paramedics). What needs to be done is to specify that the closest most appropriate hospital in case of a major trauma is a specialised centre like a MTC. This will undoubtedly prolong the current transport times. Nevertheless, it seems possible to achieve this in Belgium (given the small territory and the high density of MICU services) without exceeding the international targets [11, 12, 18, 50, 51]. By doing this, the time between the trauma and getting the most appropriate treatment is likely to shorten. After all, it was shown that transferring major trauma patients to better equipped hospitals is not a common practice in Belgium. Nevertheless, it seems feasible to bypass the closest acute hospital when MTCs are established and officially accredited to admit severe injured patients in priority. This practice is already adopted for severe burn injuries patients who are directly transported to one of the six accredited Belgian burn care centres [52].

There are several limitations to the current study. The evaluation of the Belgian situation was hampered by a lack of a trauma registry. The available administrative data did not allow to measure the performance of the system given the lack of information on patients' outcomes. Furthermore, the definitions for 'major trauma' used in this study only reflect an approximation of the internationally accepted definitions for major trauma. For the MICU registry we relied on 'flagged major trauma cases' based on the clinical assessment of the MICU staff, while for the B-HDDS we only included multiple significant trauma patients. This is a sub-group of major trauma patients and thus not suitable to estimate prevalence rates or minimal caseloads. The B-HDDS data were only used to check if a similar picture of dispersion takes place as that based on MICU-data and to study the time in hospital before patients are transferred to another hospital. Nevertheless, the definitions used were discussed with experts from the field. While they acknowledged that the data potentially did not reflect the true incidence of 'major trauma', the experts agreed that the choices made allow to have an appropriate view on the dispersion of patients throughout the country.

## Conclusion

To conclude, concentrating the care for major trauma patients in MTCs that are part of regionally organised trauma networks is not a sure-fire approach to improve outcomes. Nevertheless, the weight of evidence suggests that

major trauma patients—specifically those at highest risk—are better off when they are treated in MTCs that treat a critical mass of these patients and have specific equipment, protocols and staffing levels in place. Therefore, it is worthwhile that countries without such a system analyse the level of dispersion and caseloads per hospital for this patient group. This evaluation in Belgium, for sure, questions the accuracy of the current system and will help to launch a reform where these data, together with the best available evidence are discussed with stakeholders and professional organisations in order to improve the organisation of care for this patient group.

**Acknowledgements** This study was funded by the Belgian Health Care Knowledge Centre (KCE). The KCE is a federal institution which is financed by the National Institute for Health and Disability Insurance (NIHDI, RIZIV—INAMI), the Federal Public Service of health, food chain safety and environment, and the Federal Public Service of social security. The development of health services research studies is part of the legal mission of the KCE. Although the development of the studies is paid by the KCE budget, the sole mission of the KCE is providing scientifically valid information.

## Compliance with ethical standards

**Conflict of interest** All authors state that they have no conflicts of interest to disclose.

## References

1. WHO. Injuries and violence: the facts. 2010. [http://www.who.int/violence\\_injury\\_prevention/key\\_facts/en/](http://www.who.int/violence_injury_prevention/key_facts/en/). Accessed 2 Oct 2015.
2. European Association for Injury Prevention and Safety Promotion (EuroSafe). Injuries in the European Union: summary of injury statistics for the years 2008–2010. Amsterdam; 2011.
3. European Association for Injury Prevention and Safety Promotion (EuroSafe). Injuries in the European Union: summary of injury statistics for the years 2010–2012. Amsterdam; 2013.
4. European Association for Injury Prevention and Safety Promotion (EuroSafe). Injuries in the European Union: summary of injury statistics for the years 2012–2014. Amsterdam; 2016.
5. Kim YJ. Relationship of trauma centre characteristics and patient outcomes: a systematic review. *J Clin Nurs*. 2014;23(3–4):301–14.
6. Caputo LM, Salottolo KM, Slone DS, Mains CW, Bar-Or D. The relationship between patient volume and mortality in American trauma centres: a systematic review of the evidence. *Injury*. 2014;45(3):478–86.
7. Minei JP, Fabian TC, Guffey DM, Newgard CD, Bulger EM, Brasel KJ, et al. Increased trauma center volume is associated with improved survival after severe injury: results of a Resuscitation Outcomes Consortium study. *Ann Surg*. 2014;260(3):456–64 (**discussion 64**).
8. Zacher MT, Kanz KG, Hanschen M, Haberle S, van Griensven M, Lefering R, et al. Association between volume of severely injured patients and mortality in German trauma hospitals. *Br J Surg*. 2015;102(10):1213–9.
9. Clement RC, Carr BG, Kallan MJ, Wolff C, Reilly PM, Malhotra NR. Volume–outcome relationship in neurotrauma care. *J Neurosurg*. 2013;118(3):687–93.

10. The Royal College of Surgeons of England. Provision of Trauma Care Policy Briefing. London: RCSE, September 2007. <http://www.rcseng.ac.uk/rcseng/content/publications/docs/provision-of-trauma-care-1>.
11. Nederlandse Vereniging voor Traumachirurgie. Levelcriteria NVT. 2013. <http://www.trauma.nl/levelcriteria-nvt>. Accessed 5 Jan 2018.
12. German Society for Trauma Surgery, Professional Association of Orthopaedic and Trauma Specialists. Whitebook medical care of the severely injured. Berlin: Deutsche Gesellschaft für Unfallchirurgie; 2012.
13. Landelijk Netwerk Acute Zorg. Landelijke Traumaregistratie 2010–2014. Rapportage Nederland; 2015.
14. Landelijk Netwerk Acute Zorg. Landelijke Traumaregistratie 2009–2013. Rapportage Nederland; 2014.
15. Lansink KW, Gunning AC, Spijkers AT, Leenen LP. Evaluation of trauma care in a mature level I trauma center in the Netherlands: outcomes in a Dutch mature level I trauma center. *World J Surg.* 2013;37(10):2353–9.
16. TraumaRegister DGU. 20 years of trauma documentation in Germany—actual trends and developments. *Injury.* 2014;45(Supplement 3):S14–9.
17. Ruchholtz S, Mand C, Lewan U, Debus F, Dankowski C, Kühne C, et al. Regionalisation of trauma care in Germany: the “TraumaNetwork DGU®-Project”. *Eur J Trauma Emerg Surg.* 2011;38(1):11–7.
18. NHS England. NHS standard contract for Major Trauma Services (all ages). London: NHS England; 2013.
19. Alfred Health Caring for the severely injured in Australia. Inaugural report of the Australian Trauma Registry. Melbourne: Alfred Health; 2014.
20. Trauma Association of Canada, Association Canadienne de Traumatologie. Trauma system. Accreditation guidelines. 2011.
21. Committee on trauma American College of Surgeons. Resources for optimal care of the injured patient. American college of Surgeons: Chicago; 2014
22. Innledning: nasjonal traumeplan—Traumesystem i Norge 2015 [Introduction: national trauma plan—Trauma System in Norway 2015].
23. Dehli T, Gaarder T, Christensen BJ, Vinjevoll OP, Wisborg T. Implementation of a trauma system in Norway: a national survey. *Acta Anaesthesiol Scand.* 2015;59(3):384–91.
24. Kristiansen T, Ringdal KG, Skotheimsvik T, Salthammer HK, Gaarder C, Naess PA, et al. Implementation of recommended trauma system criteria in south-eastern Norway: a cross-sectional hospital survey. *Scand J Trauma Resusc Emerg Med.* 2012;20:5.
25. Kristiansen T, Soreide K, Ringdal KG, Rehn M, Kruger AJ, Reite A, et al. Trauma systems and early management of severe injuries in Scandinavia: review of the current state. *Injury.* 2010;41(5):444–52.
26. NHS Clinical Advisory Groups Report. Regional networks for major trauma. London: NHS England; 2010.
27. Australasian Trauma Verification Program Officer. The Australasian trauma verification program manual. Royal Australasian College of Surgeons: Melbourne; 2009.
28. Ashley DW, Pracht EE, Medeiros RS, Atkins EV, NeSmith EG, Johns TJ, et al. An analysis of the effectiveness of a state trauma system: treatment at designated trauma centers is associated with an increased probability of survival. *J Trauma Acute Care Surg.* 2015;78(4):706–12 (discussion 12).
29. Di Bartolomeo S, Marino M, Ventura C, De Palma R. Evaluation of the survival benefit of trauma-centre care in the Italian setting. *Injury.* 2014;45(1):299–303.
30. Glance LG, Osler TM, Mukamel DB, Dick AW. Impact of trauma center designation on outcomes: is there a difference between level I and level II trauma centers? *J Am Coll Surg.* 2012;215(3):372–8.
31. Kuimi BL, Moore L, Cisse B, Gagne M, Lavoie A, Bourgeois G, et al. Influence of access to an integrated trauma system on in-hospital mortality and length of stay. *Injury.* 2015;46(7):1257–61.
32. Matsushima K, Schaefer EW, Won EJ, Armen SB. The outcome of trauma patients with do-not-resuscitate orders. *J Surg Res.* 2016;200(2):631–6.
33. Vickers BP, Shi J, Lu B, Wheeler KK, Peng J, Groner JJ, et al. Comparative study of ED mortality risk of US trauma patients treated at level I and level II vs nontrauma centers. *Am J Emerg Med.* 2015;33(9):1158–65.
34. Dinh MM, Bein KJ, Gabbe BJ, Byrne CM, Petchell J, Lo S, et al. A trauma quality improvement programme associated with improved patient outcomes: 21 years of experience at an Australian Major Trauma Centre. *Injury.* 2014;45(5):830–4.
35. Dinh MM, Curtis K, Mitchell RJ, Bein KJ, Balogh ZJ, Seppelt I, et al. Major trauma mortality in rural and metropolitan NSW, 2009–2014: a retrospective analysis of trauma registry data. *Med J Aust.* 2016;205(9):403–7.
36. Moore L, Hanley JA, Turgeon AF, Lavoie A. Evaluation of the long-term trend in mortality from injury in a mature inclusive trauma system. *World J Surg.* 2010;34(9):2069–75.
37. Moore L, Turgeon AF, Lauzier F, Emond M, Berthelot S, Clement J, et al. Evolution of patient outcomes over 14 years in a mature, inclusive Canadian trauma system. *World J Surg.* 2015;39(6):1397–405.
38. Moore L, Stelfox HT, Evans D, Hameed SM, Yanchar NL, Simons R, et al. Trends in injury outcomes across Canadian trauma systems. *JAMA Surg.* 2016;152(2):168–74.
39. Dutton RP, Stansbury LG, Leone S, Kramer E, Hess JR, Scalea TM. Trauma mortality in mature trauma systems: are we doing better? An analysis of trauma mortality patterns, 1997–2008. *J Trauma.* 2010;69(3):620–6.
40. Sarkar B, Brunsvold ME, Cherry-Bukowcic JR, Hemmila MR, Park PK, Raghavendran K, et al. American College of Surgeons’ Committee on Trauma Performance Improvement and Patient Safety program: maximal impact in a mature trauma center. *J Trauma.* 2011;71(5):1447–53 (discussion 53–4).
41. Moore L, Champion H, Tardif PA, Kuimi BL, O’Reilly G, Lepaniemi A, et al. Impact of trauma system structure on injury outcomes: a systematic review and meta-analysis. *World J Surg.* 2017.
42. Jansen JO, Lendrum RA, Morrison JJ. Trauma care in Scotland: the role of major trauma centres, trauma units, and local emergency hospitals. *Surg J R Coll Surg Edinb Irel.* 2016;14(5).
43. Jansen JO, Morrison JJ, Wang H, He S, Lawrenson R, Hutchison JD, et al. Access to specialist care: optimizing the geographic configuration of trauma systems. *J Trauma Acute Care Surg.* 2015;79(5):756–65.
44. Deasy C, Cronin M, Cahill F, Geary U, Houlihan P, Woodford M, et al. Implementing major trauma audit in Ireland. *Injury.* 2016;47(1):166–72.
45. Décision concernant la planification de la médecine hautement spécialisée (MHS) dans le domaine de la prise en charge des blessés graves; 2015.
46. Van den Heede K, Dubois C, Devriese S, Baier N, Camaly O, Depuijdt E, et al. Organisation and payment of emergency care services in Belgium: current situation and options for reform. Health Services Research (HSR). Brussels: Belgian Health Care Knowledge Centre (KCE); 2016.
47. Koninklijk besluit van 27 april 1998 houdende vaststelling van de normen waaraan een functie “gespecialiseerde spoedgevallenzorg” moet voldoen om erkend te worden. B.S. 19 juni 1998.
48. Van de Voorde C, Van den Heede K, Obyn C, Quentin W, Geissler A, Wittenbecher F, Busse R, Magnussen J, Camaly O, Devriese S, Gerkens S, Mispion S, Neyt M, Mertens R. Conceptual framework for the reform of the Belgian hospital payment system. *Health*

- Services Research (HSR) Brussels: Belgian Health Care Knowledge Centre (KCE). 2014. KCE Reports 229. D/2014/10.273/68.
49. Matsushima K, Schaefer EW, Won EJ, Armen SB, Indeck MC, Soybel DI. Positive and negative volume-outcome relationships in the geriatric trauma population. *JAMA Surg.* 2014;149(4):319–26.
  50. Ambulancezorg Nederland, Nederlands Vereniging van Medisch Managers Ambulancezorg, V&NV Ambulancezorg. Landelijk Protocol Ambulancezorg; 2014.
  51. German Trauma Society, German Society of General and Visceral Surgery, German Society of Anesthesiology and Intensive Care Medicine, German Society of Endovascular and Vascular Surgery, German Society of Hand Surgery, German Society of Oto-Rhino-Laryngology HaNS, et al. S3—guideline on treatment of patients with severe and multiple injuries. English Version of the German Guideline S3—Leitlinie Polytrauma/Schwerverletzten-Behandlung. Berlin: German Trauma Society (DGU); 2012.
  52. Christiaens W, Van de Walle E, Devresse S, Van Halewyck D, Benahmed N, Paulus D, et al. The view of severely burned patients and healthcare professionals on the blind spots in the aftercare process: a qualitative study. *BMC Health Serv Res.* 2015;15:302.