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Evaluation of the Berlin polytrauma definition: A Dutch nationwide observational study

Mitchell L.S. Driessen, MD, Leontien M. Sturms, PhD, Erik W. van Zwet, PhD, Frank W. Bloemers, MD, PhD, Henk Jan ten Duis, PhD, Michael J.R. Edwards, MD, PhD, Dennis den Hartog, MD, PhD, Mariska A.C. de Jongh, PhD, Peter A. Leenhouts, MD, Martijn Poeze, MD, PhD, Inger B. Schipper, MD, PhD, FACS, Richard Spanjersberg, MD, Klaus W. Wendt, MD, PhD, Ralph J. de Wit, MD, Stefan W.A.M. van Zutphen, MD, *and* **Luke P.H. Leenen, MD, PhD, FACS, FEBS (Emergency Surgery)**, *Gelderland, the Netherlands*

BACKGROUND: The Berlin polytrauma definition (BPD) was established to identify multiple injury patients with a high risk of mortality. The definition includes injuries with an Abbreviated Injury Scale score of ≥3 in ≥2 body regions (2AIS ≥3) combined with the presence of ≥1 physiological risk factors (PRFs). The PRFs are based on age, Glasgow Coma Scale, hypotension, acidosis, and coagulopathy at specific cutoff values. This study evaluates and compares the BPD with two other multiple injury definitions used to identify patients with high resource utilization and mortality risk, using data from the Dutch National Trauma Register (DNTR).

METHODS: The evaluation was performed based on 2015 to 2018 DNTR data. First, patient characteristics for 2AIS ≥3, Injury Severity Score (ISS) of ≥16, and BPD patients were compared. Second, the PRFs prevalence and odds ratios of mortality for 2AIS ≥3 patients were compared with those from the Deutsche Gesellschaft für Unfallchirurgie Trauma Register. Subsequently, the association between PRF and mortality was assessed for 2AIS ≥3–DNTR patients and compared with those with an ISS of ≥16.

RESULTS: The DNTR recorded 300,649 acute trauma admissions. A total of 15,711 patients sustained an ISS of ≥16, and 6,263 patients had suffered a 2AIS ≥3 injury. All individual PRFs were associated with a mortality of >30% in 2AIS ≥3–DNTR patients. The increase in PRFs was associated with a significant increase in mortality for both 2AIS ≥3 and ISS ≥16 patients. A total of 4,264 patients met the BPDs criteria. Overall mortality (27.2%), intensive care unit admission (71.2%), and length of stay were the highest for the BPD group.

CONCLUSION: This study confirms that the BPD identifies high-risk patients in a population-based registry. The addition of PRFs to the anatomical injury scores improves the identification of severely injured patients with a high risk of mortality. Compared with the ISS ≥16 and 2AIS ≥3 multiple injury definitions, the BPD showed to improve the accuracy of capturing patients with a high medical resource need and mortality rate. (*J Trauma Acute Care Surg.* 2021;90: 694–699. Copyright © 2021 Wolters Kluwer Health, Inc. All rights reserved.)

LEVEL OF EVIDENCE: Epidemiological study, level III.

KEY WORDS: Dutch national trauma registry; multiple injury; Berlin polytrauma definition; injury severity; severity evaluation.

The structured and reproducible denomination of severely injured patients is complex and has been the subject of discussion for decades.[1] Almost 50 different multiple injury definitions have been described.[1] The most widely used definition is the Injury Severity Score (ISS).[2] The ISS is based on an anatomical injury severity classification, the Abbreviated Injury Scale (AIS).[3] Thirty years ago, an ISS cutoff of ≥16 points was chosen to describe the severely injured because these patients had an expected mortality rate of more than 20%.[4] Because of the introduction of trauma systems[5–9] and enhanced medical care, mortality is currently considerably lower for ISS ≥16 patients and ranges between 9.0% and 12.3%.[10] These observations reopened the discussion on the ISS ≥16 definition's usability to identify severely injured patients. Butcher and Balogh[11] reported that patients with an AIS score of ≥3 in at least two different AIS body regions captured more clinically defined multiple injury patients with a worse outcome than the definition of an ISS of ≥16 or ISS of ≥18. The physiological derangement characteristics following trauma have been described in multiple studies; however, the application within a trauma definition was proven to be questionable, mostly because of practical limitations.[12–15]

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From the Dutch Network for Emergency Care (M.L.S.D., L.M.S.), Utrecht; Department of Medical Statistics (E.W.v.Z.), Leiden University Medical Center, Leiden; Department of Surgery (F.W.B.), Amsterdam University Medical Center, VU, Amsterdam; Department of Trauma Surgery (M.J.R.E.), Radboud University Medical Center, Nijmegen; Trauma Research Unit, Department of Surgery (D.d.H.), Erasmus MC, University Medical Center Rotterdam, Rotterdam; Brabant Trauma Registry (M.A.C.d.J.), Network Emergency Care Brabant, Tilburg; Department of Surgery (P.A.L.), Amsterdam University Medical Center, AMC, Amsterdam; Department of Surgery (M.P.), Maastricht University Medical Center, Maastricht; Department of Trauma Surgery (I.B.S.), Leiden University Medical Center, Leiden; Department of Trauma Surgery (R.S.), Isala Hospitals, Zwolle; Department of Trauma Surgery (K.W.W.), University Medical Center Groningen, Groningen; Department of Trauma Surgery (R.J.d.W.), Medical Spectrum Twente, Enschede; Department of Surgery Elisabeth Two Cities Hospital (S.W.A.M.v.Z.), Tilburg; and Department of Surgery (L.P.H.L.), University Medical Center Utrecht, Utrecht, the Netherlands.

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Address for reprints: Mitchell L.S. Driessen, MD, Dutch Network Emergency Care, Newtonlaan 115, 3584 BH Utrecht, the Netherlands; email: mls.driessen@lnaz.nl.

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Going forward from there, an expert panel introduced the Berlin polytrauma definition (BPD) in 2014, presented in an article by Pape et al.[16] This definition combines the anatomical classification of injury, that is, the AIS, with the physiological response. For the development of the BPD, the mortality cutoff value was set at a minimum of 30%. According to the BPD, critically injured patient (multiple injury) patients have sustained injuries with an AIS score of ≥3 in at least two different AIS body regions and have one or more of the following five physiologic parameters: hypotension (systolic blood pressure, ≤90 mm Hg), unconsciousness (Glasgow Coma Scale score, ≤8), acidosis (base excess [BE], ≤−6.0), coagulopathy (partial thromboplastin time of ≥40 seconds or an international normalized ratio [INR] of ≥1.4), and age (≥70 years).[16]

The BPD differs from the ISS ≥16 definition in that it includes physiological parameters, and it requires trauma patients to have sustained at least two significant injuries (AIS score, ≥3) in separate body regions. Thus, severe mono trauma patients and patients with an ISS of <18 do not meet the BPD.

The BPD aims to identify critically ill patients who require multidisciplinary care and overarching management by trauma specialists. The definition was developed and tested on data recorded in the Deutsche Gesellschaft für Unfallchirurgie Trauma Register (DGU-TR). The DGU-TR focuses on patients with multiple injuries admitted to intensive care facilities. External validation of the definition in a broader trauma population has yet to be performed. The Dutch National Trauma Register (DNTR) provides this opportunity because it has national coverage and includes all acute trauma admissions.[17] The purpose of this study was to reassess the BPD on the Dutch trauma registry data, including all acute trauma admissions, and to compare results with those previously reported by the expert consensus study on intensive care admissions in Germany.[16] Moreover, we aimed to compare patient characteristics, resource use, and outcomes for patients with an ISS of >15, patients with an AIS score of ≥3 in at least two body regions, and patients that meet the BPD (i.e., patients with not only two AIS scores of ≥3 in at least two body regions but also at least one physiological risk factor [PRF]). Finally, we explored the value of adding PRFs to anatomical injury definitions of both the ISS >15 patients and patients with at least two AIS scores of ≥3 for identifying patients with high mortality risk.

PATIENTS AND METHODS

Patients

The DNTR includes all injured patients directly admitted to the hospital through the emergency department (ED) within 48 hours after trauma. Patients without vital signs upon arrival at the ED were excluded. Since 2015, 100% of trauma-receiving hospitals in the Netherlands have participated in the DNTR.[17] For this study, all patients recorded in the DNTR between January 1, 2015, and December 31, 2018, were included. According to the inclusion criteria, patients transferred within 48 hours after the incident are registered twice. Therefore, patients who were secondarily transferred to the hospital after ED treatment at another hospital were excluded.

For this study, we defined the following patient subgroups: (1) all patients with an AIS score of ≥3 in at least two body regions (2AIS ≥3–DNTR); this group matches the population that was used in the expert consensus study by Pape et al.[16] (2AIS ≥3–DGU-TR); (2) patients corresponding to the BPD's criteria, that is, patients with an AIS score of ≥3 in at least two body regions and the presence of at least one of the five PRFs (BPD-DNTR); and (3) patients with an ISS of ≥16 (ISS16-DNTR).

Statistical Analysis

We compared the patient characteristics of 2AIS ≥3–DNTR patients with those of the 2AIS ≥3–DGU-TR patients. In addition, we described these characteristics for the BPD-DNTR and the ISS16-DNTR patients. The prevalence, in-hospital mortality rate, and odds ratio (OR) for mortality were calculated for each PRF in the 2AIS ≥3–DNTR patient group and compared with those reported in the 2AIS ≥3–DGU-TR population. Furthermore, to investigate the additional value of including PRFs within a trauma definition, we graphically assessed the association between the number of PRFs and in-hospital mortality within the 2AIS ≥3–DNTR and the ISS16-DNTR patient group.

Missing Data

In this study, we assumed that risk factors were absent if the data were missing. In particular, values for coagulopathy (INR) and BE were often not recorded. The exact number of missing values for the variables used in this study is listed in Table 1 of Supplemental Digital Content (http://links.lww.com/TA/B889). Unfortunately, the DNTR does not capture variables such as thromboplastin or lactate that are positively correlated with INR and BE.[16] Therefore, multiple imputations on missing values could not be performed. To assess if there were any differences between patients for whom risk factor values were missing versus nonmissing, we compared these groups on age, ISS, intensive care units (ICUs) admission, and Maximum Abbreviated Injury Scale and body region from the AIS scores of ≥3. These comparisons show that patients with missing values for INR and BE tended to be elderly, less severely injured, less often admitted to the ICU, and were less likely to die from their injuries (Supplemental Digital Content, Supplementary Tables 2–5, http://links.lww.com/TA/B889). These findings support our data handling assumption that risk factors were absent if missing.

RESULTS

From January 1, 2015, to December 31, 2018, a total of 323,106 cases were recorded in the DNTR. After the exclusion of patients transferred to another hospital, 300,649 acute trauma admissions were included. For 3,912 patients (1.3%), the AIS specification was missing, and these patients were excluded.

Comparison of the Dutch and German Multiple Injury Patients

Application of the anatomical criteria of the BPD to the DNTR, that is, selecting patients with an AIS score of ≥3 in at least two AIS separate body regions (2AIS ≥3–DNTR), resulted in 6,263 patients (2.1%). Table 1 shows patient characteristics, resource use, and in-hospital mortality of these patients versus their counterparts from the DGU-TR.

Both the 2AIS ≥3–DGU-TR and the 2AIS ≥3–DNTR group consisted mainly of men (72.4% vs. 67.5%) and predominantly sustained blunt injuries (96.9% vs. 97.9%). For both the

TABLE 1. Characteristics of BPD Patients in the DGU-TR and DNTR Data Sets, and for DNTR Trauma Patients With an AIS Score of ≥3 in Two Body Regions and for Patients With an ISS of ≥16

	2AIS ≥3–DGU-TR (n = 28,211)	2AIS ≥3–DNTR (n = 6,267)	BPD-DNTR (n = 4,264)	ISS ≥16–DNTR (n = 15,711)
Male	72.4% (n = 20,433)	67.5% (n = 4,231)	65.5% (n = 1,470)	66.0% (n = 10,377)
Age, mean (SD), y	42.9 (20.2)	50.0 (24.8)	55.1 (25.1)	54.5 (22.6)
Penetrating injury	3.1% (n = 886)	2.1% (n = 130)	1.7% (n = 74)	3.0% (n = 467)
ISS, mean (SD)	30.5 (12.2)	26.6 (12.1)	28.8 (12.4)	23.8 (9.5)
ICU admission	92.9% (n = 26,130)	63.2% (n = 3,963)	71.2% (n = 3,030)	53.6% (n = 8,419)
ICU LOS, mean (SD), d	NA	4 (2–9)	4 (2–11)	3 (2–6)
Overall LOS, mean (SD), d	NA	8 (3–18)	10 (3–20)	9 (4–18)
MAIS				
3 Points	29.1% (n = 8,212)	48.7% (n = 3,050)	49.4% (n = 1,722)	28,9% (n = 4,527)
4 Points	40.2% (n = 11,362)	25.9% (n = 1,628)	27.7% (n = 1,181)	43.4% (n = 6,812)
5 Points	29.1% (n = 8,207)	24.2% (n = 1,517)	30.4% (n = 1,298)	25.9% (n = 4,072)
6 Points	1.5% (n = 430)	1.1% (n = 72)	1.5% (n = 63)	1.1% (n = 166)
AIS score, ≥3				
Head injuries	54.1% (n = 15,279)	53.8% (n = 3,374)	66.3% (n = 2,826)	58.7% (n = 9,221)
Thoracic injuries	66.7% (n = 18,824)	65.9% (n = 4,134)	68.2% (n = 2,949)	47.1% (n = 7,405)
Abdominal injuries	24.8% (n = 7,005)	16.5% (n = 1,036)	15.9% (n = 680)	10.7% (n = 1,683)
Extremity injuries	43.5% (n = 12,290)	52.2% (n = 3,273)	51.5% (n = 2,196)	20.7% (n = 3,260)
Mortality	18.7% (n = 5,277)	19.9% (n = 1,251)	27.2% (n = 1,161)	17.1% (n = 2,679)
Level 1 trauma center care	NA	71.6% (n = 4,486)	76.4% (n = 3,256)	65.8% (n = 10,338)

LOS, length of stay; MAIS, Maximum Abbreviated Injury Scale; NA, not available.

2AIS ≥3–DGU-TR and 2AIS ≥3–DNTR group, the majority of injuries involved the AIS regions of the thorax and head, closely followed by extremity injuries. Compared with their DGU-TR counterparts, the 2AIS ≥3–DNTR patients had a higher mean age (42.9 vs. 50.0), a lower mean ISS score (30.5 vs. 26.6), a lower ICU admission rate (92.9% vs. 63.2%), and a lower percentage of patients with a Maximum Abbreviated Injury Scale of four or higher (70.8% vs. 51.2%). The overall in-hospital mortality was comparable between the Dutch and German groups of 2AIS ≥3 patients.

Table 2 describes the prevalence of the five PRFs, the mortality rate, and the ORs of death per risk factor for the 2AIS ≥3–DNTR and the 2AIS ≥3–DGU-TR data sets. Except for age, the prevalence of the risk factors was higher in the 2AIS ≥3–DGU-TR group. In the German and the Dutch 2AIS ≥3 groups, mortality for the PRFs was well above 30%. In general, 2AIS ≥3–DNTR patients showed higher mortality rates in the presence of each individual risk factor except for older age (38.0% vs. 31.0%). The OR of death for the unconscious patients was notably higher in the DNTR data set (4.90 vs. 7.09).

Of the 6,263 2AIS ≥3–DNTR patients, 4,265 (1.4%) also had PRF(s) and met the Berlin polytrauma definition criteria (BPD-DNTR). The overall mortality in the BPD-DNTR was 27.2%, which is significantly higher compared with the 18.7% and 19.9% for respectively the 2AIS ≥3 groups.

Comparison of Dutch 2AIS ≥3, ISS ≥16, and the Berlin Polytrauma Patients

Compared with the 2AIS ≥3–DNTR patients, ISS16-DNTR patients were relatively older (50.0 vs. 54.5) and had a lower mean

TABLE 2. Prevalence of PRFs and In-hospital Mortality for German and Dutch Patients With an AIS of ≥3 in Two or More Body Regions

PRF	Registry Population	Prevalence, %	Mortality, %	OR	(95% CI)
≥70 y	2AIS ≥3–DGU-TR	13.00	38.00	2.99	
	2AIS ≥3–DNTR	26.40	31.05	2.36	(2.06–2.69)
GCS score of ≤8	2AIS ≥3–DGU-TR	34.60	38.30	4.90	
	2AIS ≥3–DNTR	31.50	42.70	7.09	(6.19–8.11)
SBP of ≤90 mm Hg	2AIS ≥3–DGU-TR	29.50	35.30	4.90	
	2AIS ≥3–DNTR	9.62	42.60	3.49	(2.92–4.15)
BE ≤−6	2AIS ≥3–DGU-TR	24.90	38.30	3.32	
	2AIS ≥3–DNTR	13.00	43.66	3.94	(3.37–4.60)
INR ≥1.4	2AIS ≥3–DGU-TR	26.20	38.40	5.81	
	2AIS ≥3–DNTR	10.30	44.96	3.96	(3.34–4.69)

CI, confidence interval; GCS, Glasgow Coma Scale; SBP, systolic blood pressure.

ISS (26.6 vs. 23.8) (Table 1). Moreover, ISS16-DNTR patients were less often admitted to the ICU (63.2% vs. 53.6%) and had a slightly lower mortality rate (19.9% vs. 17.1%). The most affected body region in the ISS16-DNTR group was the head, followed by the thorax, whereas for 2AIS ≥3–DNTR patients, thoracic injuries were the most common.

The patients included in the BPD-DNTR group were older (55.1 years) and more severely injured (ISS, 28.8) than the ISS16-DNTR and 2AIS ≥3–DNTR group (Table 1). Resource use based on ICU admission, ICU length of stay, and overall length of stay was higher for every parameter for the BPD-DNTR group compared with 2AIS ≥3 and ISS ≥16 patients. Approximately 71.2% of patients were ICU admitted for a median period of 4 days (interquartile range, 2–11 days), and 76.4% of patients received level 1 trauma center care. The BPD-DNTR group also recorded the highest mortality rate (27.2%) compared with 2AIS ≥3–DNTR and the ISS16-DNTR group with 19.9% and 17.1%, respectively.

Adding PRFs to the Injury Definition

Figure 1 presents the association of the number of PRFs with mortality for the 2AIS ≥3–DGU-TR, the 2AIS ≥3–DNTR, and the ISS16-DNTR groups. Because of the low number of 2AIS ≥3– and ISS16-DNTR patients with all five risk factors present (n = 138 and n = 72, respectively), mortality for the presence of four and five risk factors is combined in the chart. Unlike the 2AIS ≥3–DGU-TR, the highest prevalence for the 2AIS ≥3–DNTR-TR and ISS ≥16–DNTR was found when one risk factor was involved (ranging from 40.0% to 40.5%). The lowest prevalence occurred when all five risk factors were present (ranging from 0.9% to 1.7%). Moreover, both data sets show that mortality is almost negligible without any risk factors (2.9% vs. 4.5%). Patients with an increasing number of risk factors had an increased risk of mortality. In general, mortality was lower in the 2AIS ≥3–DNTR group compared with the 2AIS ≥3–DGU-TR group. The 2AIS ≥3–DNTR showed similar mortality rates as the ISS ≥16–DNTR group, except if four or five risk factors were present, then the slightly higher mortality rates were found for the ISS ≥16–DNTR group. The 2AIS ≥3–DGU-TR showed better discriminative performance with higher prevalence rates of patients with one or more risk factors.

DISCUSSION

This is the first study that evaluated the BPD in an extensive population-based trauma registry that includes all acute trauma admissions. Our research shows that the BPD also performs well for a broader trauma population. Moreover, our study confirms the additional value of adding physiological variables on top of the anatomical injury classification in identifying severely injured individuals with a high risk of mortality. The presence of each PRF used in the BPD showed a positive association with in-hospital mortality. The BPD gives an adequate reflection of resource utilization and observed death rate compared to multiple injury definitions based on the definition ISS ≥16 or even with at least two injuries with an AIS score of ≥3.

The Dutch 2AIS ≥3 patients' characteristics have a considerable number of similarities to their German counterparts. However, except for age, we found lower prevalence rates of the Dutch 2AIS ≥3 patients' PRFs. Furthermore, the Dutch 2AIS ≥3 patients with PRFs had slightly higher mortality rates than German patients with similar injuries. One of the differences stems from the different inclusion criteria of the trauma registries. The primary inclusion criteria for the German register are ICU admission.

In contrast, in the Netherlands, all acute trauma admissions are registered, which translates to only 8% ICU admissions in the DNTR population. Furthermore, the German register excludes, for instance, patients with hip fractures, these concern

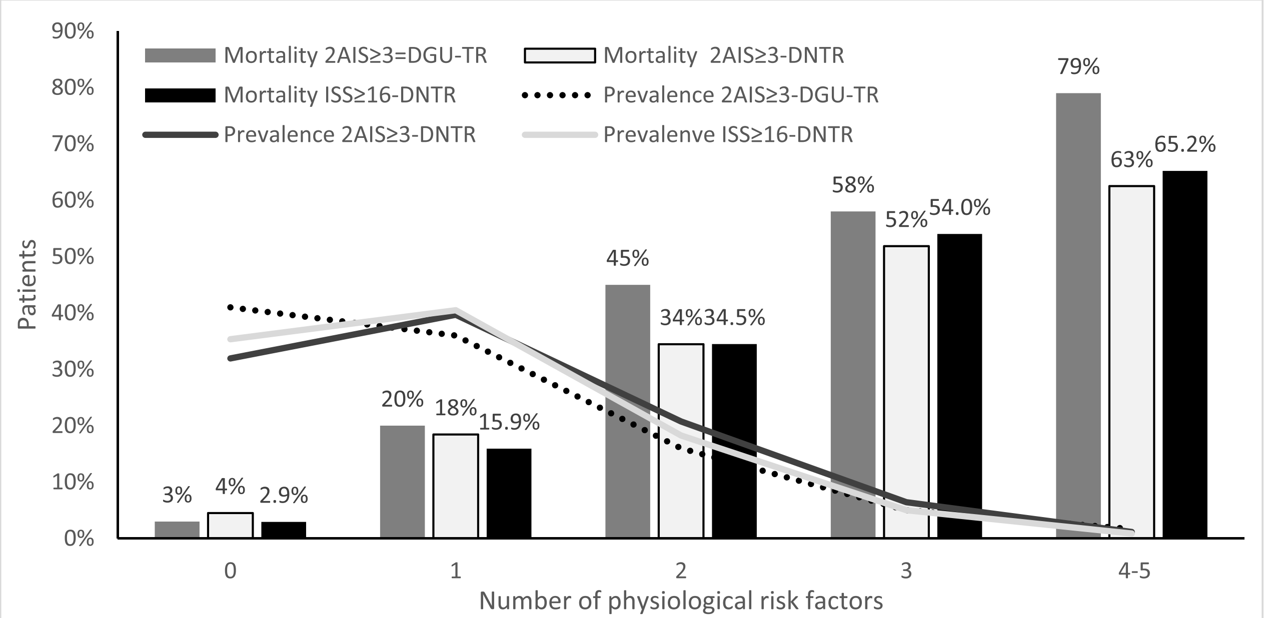

Figure 1. Prevalence and mortality rates for the 2AIS ≥3–DGU-TR, 2AIS ≥3–DNTR, and ISS ≥16–DNTR patients versus the number of PRFs.

about 4% of DNTR patients with an ISS of ≥16. These broader inclusion criteria may explain the higher number of elderly patients and less physiologically impaired patients in the DNTR.

Furthermore, differences in prehospital management, urbanization within trauma systems, and distances to trauma receiving hospitals may also play a role. On average, the total prehospital times are shorter in the Netherlands (55 minutes) than in Germany (68 minutes).[18] This time interval difference was smaller for patients with an ISS of ≥16, with 61 minutes for the Dutch group and 66 minutes for their German counterparts.[19] However, Timm et al.[19] did not find clinically relevant differences in outcome parameters of severely injured patients that could be accounted for this 5-minute advantage in favor of the Dutch.

Another notable difference is the higher mortality rate of the unconscious (GCS, ≤8) patients in the DNTR population. A possible explanation for this difference could be the number of patients who sustained traumatic brain injuries for which life-sustaining treatment was withdrawn; this mostly concerns elderly patients and can be initiated if there is little anticipated chance of recovery to an acceptable quality of life. A single-center study in the Netherlands showed that life-sustaining treatment was withdrawn in 82% of traumatic brain injury patients who died during admission.[20] It is unclear whether German policies on withdrawal of life-sustaining treatment differ from the Dutch policies. However, an international comparison study by Timm et al.[19] reported that 3.8% of German patients surviving a severe injury (ISS, ≥16) had a "persistent vegetative state" as an outcome, whereas this was only 0.7% in the Netherlands. An international comparison study is needed to assess these national dissimilarities fully.

The early identification of trauma patients with a high risk of mortality is essential in getting the patient to the right place at the right time. The applicability of the BPD, for this reason, has several limitations. First, it is important to note that some form of hospital diagnostics is needed for an accurate assessment of the injury severity, and the ISS is most often scored after admission. Second, the BE and coagulation risk factors are based on laboratory values that are not assessed before hospitalization; moreover, they take some time to evaluate and are not necessarily analyzed in all settings. Currently, the BPD can only reach its full potential in secondary triage. However, the PRFs have shown to be an excellent determinant for predicting mortality in trauma patients, conceivably better than the anatomical criteria of ISS ≥16. Studies by Brown et al.[21] and Fukuma et al.[22] showed promising results in prehospital management; the addition of on-scene lactate measurement significantly improved the predictive value for trauma activation algorithms and immediate intervention in hemorrhagic trauma patients. These findings can be useful in the development of new and enhanced prehospital triage protocols. At which point, the BPD can be used as the criterion standard for the evaluation of these prehospital triage protocols.

An important strength of our study is the fact that the Dutch trauma registry has national coverage and records all acute trauma admissions.[13] The original German derivation data set included a specific subgroup of the entire trauma population. These interinstitutional differences make definition validation difficult.

Our analysis also has several limitations, including the retrospective design and missing data. If a specific risk factor was not available because of missing values, we assumed that this factor was not present. This assumption may have led to an underestimation of the risk factor prevalence. Moreover, risk factors were not individually analyzed; thus, the estimated mortality for the individual risk factors could, to some degree, be the confluence of multiple risk factors. Another limitation is that, although we included more than 300,000 patients in this study, a relatively limited number of patients with four or more PRFs were found, weakening the conclusions for this specific subgroup.

CONCLUSION

Application of the BPD in the DNTR shows similar results regarding those with application in the DGU-TR development set. The addition of PRFs to anatomical injury scores contributes to the identification of severely injured patients with a high risk of mortality. The individual PRFs for age, unconsciousness, hypotension, acidosis, and coagulopathy all showed mortality rates of ≥30% in the DNTR population. Compared with the definitions that require an ISS of ≥16 or two injuries with an AIS score of ≥3, the BPD showed to improve the accuracy of capturing patients with the worst clinical outcomes and highest medical resource utilization.

AUTHORSHIP

M.L.S.D., L.M.S., and E.W.v.Z. performed the data analysis. M.L.S.D., L.M.S., E.W.v.Z., and L.P.H.L. contributed in the interpretation of the data and drafting of the article. All authors participated in critically reviewing the final article.

DISCLOSURE

The authors declare no conflicts of interest.

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