



## Intensive care admission criteria for traumatic brain injury patients across Europe



Victor Volovici<sup>a,b,\*</sup>, Ari Ercole<sup>c</sup>, Giuseppe Citerio<sup>d,e</sup>, Nino Stocchetti<sup>f,g</sup>, Iain K. Haitsma<sup>a</sup>, Jilske A. Huijben<sup>b</sup>, Clemens M.F. Dirven<sup>a</sup>, Mathieu van der Jagt<sup>h</sup>, Ewout W. Steyerberg<sup>b,i</sup>, David Nelson<sup>j</sup>, Maryse C. Crossen<sup>b</sup>, Andrew I.R. Maas<sup>k</sup>, Suzanne Polinder<sup>b</sup>, David K. Menon<sup>c</sup>, Hester F. Lingsma<sup>b</sup>

<sup>a</sup> Department of Neurosurgery, Erasmus MC, Rotterdam, the Netherlands

<sup>b</sup> Center for Medical Decision Making, Department of Public Health, Erasmus MC, Rotterdam, the Netherlands

<sup>c</sup> Division of Anesthesia, University of Cambridge, Addenbrooke's Hospital, Cambridge, UK

<sup>d</sup> School of Medicine and Surgery, University of Milano Bicocca, Milan, Italy

<sup>e</sup> Neurointensive Care Unit, San Gerardo Hospital, ASST-Monza, Monza, Italy

<sup>f</sup> Department of Pathophysiology and Transplants, University of Milan, Milan, Italy

<sup>g</sup> Fondazione IRCCS Ca' Granda - Ospedale Maggiore Policlinico, Department of Anesthesia and Critical Care, Neuroscience Intensive Care Unit, Milan, Italy

<sup>h</sup> Department of Intensive Care Adults, Erasmus MC, Rotterdam, the Netherlands

<sup>i</sup> Department of Medical Statistics and Bioinformatics, Leiden University Medical Center, Leiden, the Netherlands

<sup>j</sup> Department of Physiology and Pharmacology, Section of Perioperative Medicine and Intensive Care, Karolinska Institutet, Stockholm, Sweden

<sup>k</sup> Department of Neurosurgery, Antwerp University Hospital and University of Antwerp, Edegem, Belgium

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### ABSTRACT

Within a prospective, observational, multi-center cohort study 68 hospitals (of which 66 responded), mostly academic ( $n = 60, 91\%$ ) level I trauma centers ( $n = 44, 67\%$ ) in 20 countries were asked to complete questionnaires regarding the “standard of care” for severe neurotrauma patients in their hospitals. From the questionnaire pertaining to ICU management, 12 questions related to admission criteria were selected for this analysis. The questionnaires were completed by 66 centers. The median number of TBI patients admitted to the ICU was 92 [interquartile range (IQR): 52–160] annually. Admission policy varied; in 45 (68%) centers, patients with a Glasgow Coma Score (GCS) between 13 and 15 without CT abnormalities but with other risk factors would be admitted to the ICU while the rest indicated that they would not admit these patients routinely to the ICU. We found no association between ICU admission policy and the presence of a dedicated neuro ICU, the discipline in charge of rounds, the presence of step down beds or geographic location (North- Western Europe vs. South – Eastern Europe and Israel). Variation in admission policy, primarily of mild TBI patients to ICU exists, even among high-volume academic centers and seems to be largely independent of other center characteristics. The observed variation suggests a role for comparative effectiveness research to investigate the potential benefit and cost-effectiveness of a liberal versus more restrictive admission policies.

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### 1. Introduction

Intensive care unit (ICU) beds are a costly and limited resource. Admission is clearly justified for more severely injured patients needing acute life-sustaining physiological support. For the less severely injured, ICU admission could be justified by the notion that a proportion of these patients subsequently deteriorate or because of care needs that are still too intense to be adequately provided at the ward. However, accurate

and broadly applicable admission criteria for such less severely ill patients are lacking and may be subject to service-configuration, other institutional, or clinician-specific determinants. Admission of patients to the ICU who have a low risk of subsequently requiring physiological support or emergent surgical intervention, as a result of the severity of their traumatic brain injury (TBI) or extra-cranial injuries, is undesirable and may have adverse financial consequences.

In the United States, 20% of patients with mild TBI, defined as those with a Glasgow Coma Scale (GCS) of 13–15, presenting to the Emergency Department are admitted to the ICU [1]. Even though admitting a patient with a ‘mild’ traumatic brain injury (TBI) to the ICU might be the appropriate decision to ensure proper interventions in the case of secondary neurological worsening, existing data do not support this

\* Corresponding author at: Erasmus MC University Medical Center, Erasmus MC Stroke Center, Department of Neurosurgery and Medical Decision Making, Doctor Molenvaterplein 40, 3015, GD, Rotterdam, the Netherlands.  
E-mail address: [v.volovici@erasmusmc.nl](mailto:v.volovici@erasmusmc.nl) (V. Volovici).

[2,3]. In Europe, a recent survey demonstrated large variation in the number of critical care beds across countries. Moreover, no clear central policies to facilitate planning to meet the demand and optimal utilization in the future exist [4].

In this study we aim to describe the variation in policy of European neurotrauma centers regarding admission of TBI patients to the ICU.

## 2. Materials and methods

### 2.1. Data

Between 2014 and 2015, 68 centers from 20 European countries, participating in the CENTER-TBI prospective longitudinal observational study [5], were approached to complete a set of questionnaires about structure and process of care: The Provider Profiling (PP) questionnaires. These were developed according to best practice. In the item generation phase we have gathered experts together within the CENTER-TBI team and proceeded with item generation and item reduction in a second phase. The questionnaires were then pre-tested with a group of participating centers and face validity was discussed with the participants and the experts involved in item generation. The pilot testing evaluated flow and time required to complete [6].

We have measured reliability and concordance rates of the questionnaire. To estimate reliability of the questionnaires, we included 17 (5%) duplicate questions, including all question formats. We equally included structure and process questions in the duplicate questions. Concordance rates were estimated by calculating the percentage of overlap between duplicate questions, and presented as mean, median and range. For open questions (e.g. what is the number of intensivist in your center), a differences that were 10% or less were considered concordant. Questionnaires were disseminated during presentations, workshops and email conversations. More information is available at length in one of our group's previous publications [6,7].

The questionnaire on ICU care contained 3 items and 7 sub-questions on admission criteria which were selected for this analysis (Appendix A). In most questions the 'general policy' at each center was requested, which was defined as 'routine policy', i.e. what the standard treatment or policy would be in a particular case. In others, we asked for quantitative estimations, whereby the frequency of a treatment strategy could be indicated (never 0–10%, rarely 10–30%, sometimes 30–70%, frequently 70–90%, always 90–100%). The options 'frequently' and 'always' were interpreted as representing the general policy, in line with previous provider profiling studies [7].

### 2.2. Statistical analyses

To identify possible factors that are associated with admission policy to the ICU, we compared admission policy between different ICU organizations: dedicated neuro- ICU present (yes/no); high or low volume (according to number of beds and according to number of patients admitted, 'high' designating all centers with a number of beds above the median and 'low' centers the centers with number of beds lower than the median); presence of step-down beds (yes/no); healthcare expenditure as % of Gross Domestic Product (GDP; dichotomized in relatively lower and higher % of expenditure); number of ICU beds per 100,000 inhabitants (dichotomized to countries with relatively high vs low numbers of beds); and health expenditure (countries with a higher % expenditure than the median being classified as relatively high and the others classified as relatively low). For analysis of the geographic location, countries were divided into Northern and Western Europe and Southern and Eastern Europe. Differences were tested with chi-square tests, and if appropriate Fisher's exact test. This approach dichotomized hospitals based on admission of mild TBI patients to the ICU into those with a liberal admission policy, versus those with a more conservative policy. A liberal admission policy was defined as the admission of mild TBI patients to the ICU as 'general policy'.

Analyses were performed using the Statistical Package for Social Sciences (SPSS) version 21.

## 3. Results

### 3.1. General characteristics

Among the 68 eligible centers, 66 (97%) completed the questions regarding ICU admission policy. Sixty (91%) of these centers had an academic affiliation and 44 (67%) were designated as level I trauma centers. Experts that completed these questionnaires were primarily intensivists ( $n = 35$ , 53%) and neurosurgeons ( $n = 23$ , 35%) but also included administrative staff.

The median number of ICU beds was 33 (interquartile range (IQR): 22–44), more than half of the centers had a dedicated neuro ICU ( $n = 39$ , 59%) with a median admission rate of 92 (IQR 52–160) TBI patients annually. The median number of all annual ICU admissions (across all diagnoses) in 2013 was 1214 (IQR 554–1950). TBI admissions therefore represented 7% (IQR 5–8) of all admissions. The majority of these ICUs had a closed organization (the intensivist is primarily responsible for the care of patients), with intensivists that are either physically present 24/7, or can reach the hospital within 30 min ( $n = 63$ , 93%) (Table 1).

### 3.2. Admission criteria

Patients with severe TBI (GCS  $\leq 8$ ) would be admitted to the ICU as a general policy in 65 (98%) of the 66 centers. One center would not admit a patient to the ICU based on GCS score alone, but a only after looking at the patient 'as a whole'.

Moderate TBI patients with GCS of 9–12 and CT abnormalities would be admitted to the ICU as a general policy in 42 (63%) of the centers. The remainder stated that they would admit such patients to the ICU only in the presence of other risk factors. The risk factors were not explicitly indicated in the provider profiling questionnaire.

However, patients with initial GCS of 9–12 and no CT abnormalities would be admitted to the ICU as a general policy only in 17 centers (25%), and in another 43 centers (64%) only if other risk factors were present (Fig. 1).

Fourteen centers (21%) would admit a mild TBI patient with initial GCS of 13 to 15 to the ICU with prior anticoagulant therapy. Another 53 centers (80%) would admit such a patient to the ICU routinely if there were additional risk factors present. Patients with mild TBI who also had either a small epidural hematoma (EDH) or acute subdural hematoma (ASDH) would be admitted to the ICU as a general policy in 15 (22%) centers. Fourteen (21%) centers would always admit a mild TBI patient to the ICU if he or she had contusional lesions present on the CT Scan. (Fig. 1).

Most centers ( $n = 50$ , or 76%) indicated that they admit TBI patients postoperatively to the ICU as a general policy regardless of their GCS. 64 centers (97%) would admit such patients in the presence of other risk factors. Only 6 centers (9%) would admit a patient with mild TBI and concomitant extracranial injuries to the ICU if these, taken in isolation, would not necessitate ICU observation. This number increases to 60 (91%) if other risk factors were present.

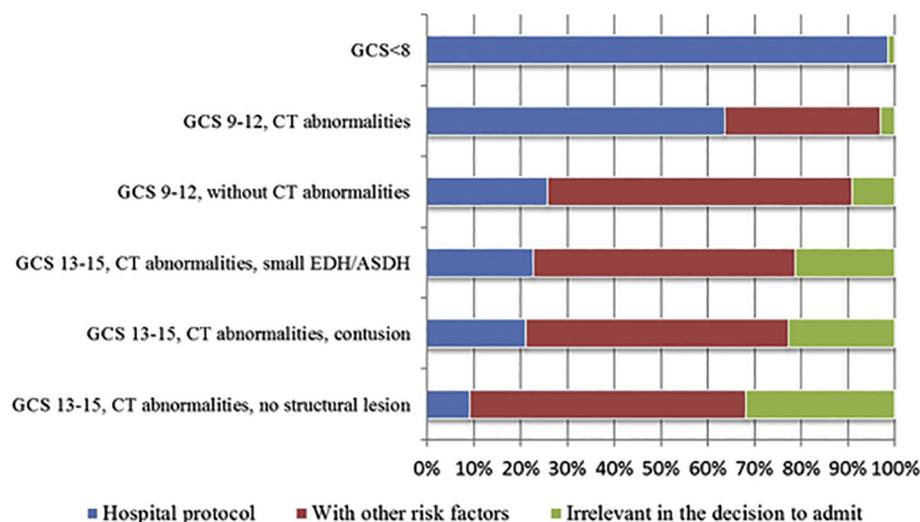
### 3.3. Characteristics of centers with a liberal admission policy

The centers were dichotomized into two categories; those who had responded 'general policy' to any of the questions regarding the admission of GCS 13–15 patients to the ICU ( $n = 23$ , 34.9%) and those who did not ( $n = 43$ , 65.1%). Number of ICU beds per 100,000 inhabitants and healthcare expenditure as % of GDP were not associated with a higher tendency to admit mild TBI patients to the ICU. However, these data were only available for 58 and 55 centers, respectively. The specialist deciding to transfer a TBI patient to the hospital did not influence a more liberal or more conservative approach to patient admission either:

**Table 1**  
Association between factors that may influence admission policy and centers that have a liberal policy of ICU admission and those that do not.

Factor	Total (% of total respondents)	Centers admitting mild TBI to ICU as a general policy (n = 23)	Centers not admitting mild TBI to ICU as a general policy (n = 43)	p-value
ICU Volume (no of beds)				0.53
High-volume	31 (47%)	12 (39%)	19 (61%)	
Low-volume	35 (53%)	11 (31%)	24 (69%)	
ICU Volume according to number of patients admitted				0.43
High- volume	31 (47%)	13 (42%)	18 (58%)	
Low- volume	31 (47%)	10 (32%)	21 (68%)	
Dedicated neuro ICU				0.45
Available	39 (59%)	15 (38%)	24 (62%)	
Not available	27 (41%)	8 (30%)	19 (70%)	
Following any severe TBI treatment guidelines				0.05
Yes	55 (83%)	22 (40%)	33 (60%)	
No	11 (16%)	1 (9%)	10 (91%)	
Having step down beds				0.67
Yes	48 (73%)	16 (33%)	32 (67%)	
No	18 (27%)	7 (39%)	11 (61%)	
Discipline in charge of rounds				0.72
Neurosurgeons, Neurologists	16 (24%)	5 (31%)	11 (69%)	
Intensivists, Anesthesiologists	50 (76%)	18 (36%)	32 (64%)	
Geographic location*				0.27
North Western Europe	43 (65%)	17 (39%)	26 (61%)	
South Eastern Europe	23 (35%)	6 (26%)	17 (74%)	
Number of ICU beds/100000 inhabitants				1.0
Relatively low number of beds	25 (47%)	9 (36%)	16 (64%)	
Relatively high number of beds	28 (53%)	11 (39%)	17 (61%)	
Health expenditure as % of GDP				0.59
Relatively lower expenditure	25 (43%)	8 (32%)	17 (68%)	
Relatively higher expenditure	33 (57%)	13 (39%)	20 (61%)	
Decision of transfer of TBI patients to the hospital made by intensivists				1.0
Intensivists	8 (12%)	3 (37%)	5 (63%)	
Other specialties	57 (88%)	13 (23%)	20 (77%)	
Decision of transfer of TBI patients to the hospital made by neurosurgeons				0.11
Neurosurgeons	41 (62%)	11 (27%)	30 (73%)	
Other specialties	25 (38%)	12 (48%)	13 (52%)	
TBI patients always admitted to the same ICU				0.28
Yes	41 (62%)	12 (29%)	29 (71%)	
No	25 (38%)	11 (44%)	14 (56%)	
TBI and polytrauma patients admitted to the same ICU				0.25
Yes	47 (71%)	14 (30%)	33 (70%)	
No	19 (29%)	9 (47%)	10 (53%)	

\* = The subdivision into geographic location was based on the classification by the United Nations. Austria, Belgium, Denmark, Finland, France, Germany, Lithuania, the Netherlands, Norway, Sweden and the United Kingdom (UK) were subsequently classified as countries from West and North Europe, while all other countries were classified as countries from South and East Europe and Israel, in line with our other publications on this matter.



**Fig. 1.** Indications for the admission of patients to the ICU among the interviewed centers (N = 66). GCS = Glasgow Coma Scale; EDH = epidural hematoma; ASDH = acute subdural hematoma. Irrelevant in the decision to admit designates a criterion that does not influence the decision to admit someone to the ICU or not.

when looking at intensivists versus other specialties or neurosurgeons, the majority ( $n = 41$ ; 62%), versus other specialties (Table 1).

The only statistically significant difference between these two categories was the fact that ICUs that reported a more liberal admission policy for mild TBI were less likely to follow formal guidelines for severe TBI management ( $p = .05$ ). In absolute numbers, 22 of the 55 centers (less than half, 40%) that follow severe TBI guidelines also have a liberal admission policy. Several other center characteristics were compared between these groups but we did not find any clear differences in internal organization of ICUs and hospital, the specialty that oversees patient care, or the geographical region where the center is located. (Table 1).

#### 4. Discussion

Among the 66 centers that responded to our provider profiling questionnaire, mostly academic, level I trauma centers, about a third ( $n = 23$ , 35%) reported that they always admitted mild TBI patients to the ICU in the presence of risk factors. Severe and moderate TBI patients are mostly admitted to the ICU as a general policy, especially in the presence of risk factors. Having a liberal admission policy regarding mild TBI patients did not correlate with other center characteristics except following TBI guidelines, suggesting that the variability is mainly caused by (random) variability of admission policies.

Higher-volume or specialized neuro-ICUs did not appear to be more likely to admit mild TBI patients. Unexpectedly, presence of a step-down unit from ICU did not have an impact in this regard either. This suggests that regardless of the resources available or of the organization, clinicians apply a more liberal or more conservative admission policy according to their personal preference, based on their knowledge and experience. This applies to the presence of step down beds as well, even though our questionnaire did not specifically aim to explore the exact processes of care with regards to the use of these beds and the admission policy surrounding them. Nonetheless, even in centers without step-down beds ( $n = 18$ ), 7 centers (39%) would still admit mild TBI patients to the ICU. Centers that follow severe TBI guidelines are less likely to have a liberal admission policy for mild TBI.

This apparent variation in policy has important implications for both research and processes of care, in two separate areas. ICU admission policy for TBI is ill-supported by high-quality evidence, and from a healthcare expenditure viewpoint, a day in the ICU can incur costs as high as 1597 euro [8]. Given that TBI costs are steeply on the rise [9], avoiding ICU admissions for uncomplicated mild TBI might be a cost-efficient alternative to current policy. Further research is needed to establish whether this alternative is not associated with worse clinical outcomes.

The observed variation provides support for comparative effectiveness research and prognostic modelling, in order to predict neuro-worsening and pinpoint who would indeed benefit from more intensive monitoring. Scarce literature suggests that observation of isolated mild TBI patients on the ICU is seldom necessary [2,3], but the evidence is of low quality.

Despite the ideal occupancy rate being estimated at 70–75% and higher occupancy rates being linked to more morbidity and mortality [10], many ICUs, especially in academic and larger hospitals routinely operate at far higher occupancy rates [11,12]. As a result, high opportunity costs arise from admitting patients who may not require ICU level care.

Our study was underpowered to detect subtle associations. Another limitation is that ‘risk factors’ in the response ‘when other risk factors are present’ were not specified. In practice, TBI is often associated with extra-cranial lesions (as major bleedings, chest injuries, spinal lesions, limb fractures etc.), other surgical or medical comorbidities, advanced age, mechanism of injury, duration of loss of consciousness, which

may, in themselves, be an indication for ICU admission. Our questionnaire was not specifically designed to detect the interplay of these factors in the decision to admit a patient to the ICU. Also, given that the respondents were mostly academic centers and mild TBI is often seen in a non-academic setting, the generalizability of the data is limited. Further research is needed to establish best practice for both academic and non-academic settings.

The issue of cost-efficiency of liberal admission policy for patients with mild TBI to the ICU motivates further investigation to support organizational decision-making and policy making. Moreover, high-quality comparative studies and prognostic models to aid the clinicians in tailoring the admission policy to the needs of the individual patient are necessary.

#### 5. Conclusions

There is considerable variation regarding the admission policy of (mild) TBI patients to the ICU in Europe. It is unclear if a liberal admission policy is beneficial for the patients and what the impact is on healthcare costs or whether there is a possible tendency to over-treat at play. Further investigation in this topic is needed, and includes, but is not limited to, on-going large-scale prospective studies, such as CENTER-TBI and TRACK-TBI.

#### Conflict of interest

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#### Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.jcrc.2018.11.002>.

#### References

- [1] Ratcliff JJ, Adeoyo O, Lindsell CJ, et al. ED disposition of the Glasgow Coma Scale 13 to 15 traumatic brain injury patient: analysis of the Transforming Research and Clinical Knowledge in TBI study. *Am J Emerg Med* 2014;32:844–50.
- [2] Nishijima DK, Sena MJ, Holmes JF. Identification of low-risk patients with traumatic brain injury and intracranial hemorrhage who do not need intensive care unit admission. *The Journal of trauma* 2011;70:E101–7.
- [3] Washington CW, Grubb Jr RL. Are routine repeat imaging and intensive care unit admission necessary in mild traumatic brain injury? *Journal of neurosurgery* 2012; 116:549–57.
- [4] Rhodes A, Ferdinande P, Flaatten H, et al. The variability of critical care bed numbers in Europe. *Intensive care medicine* 2012;38:1647–53.
- [5] Maas AI, Menon DK, Steyerberg EW, et al. Collaborative European NeuroTrauma Effectiveness Research in Traumatic Brain Injury (CENTER-TBI): a prospective longitudinal observational study. *Neurosurgery* 2015;76:67–80.
- [6] Burns KE, Duffett M, Kho ME, et al. A guide for the design and conduct of self-administered surveys of clinicians. *Cmaj* 2008;179:245–52.
- [7] Cnossen MC, Polinder S, Lingsma HF, et al. Variation in Structure and Process of Care in Traumatic Brain Injury: Provider Profiles of European Neurotrauma Centers Participating in the CENTER-TBI Study. *PLoS one* 2016;e0161367:11.
- [8] Grieve R, Sadique Z, Gomes M, et al. An evaluation of the clinical and cost-effectiveness of alternative care locations for critically ill adult patients with acute traumatic brain injury. *Br J Neurosurg* 2016;30:388–96.
- [9] Tuominen R, Joensuu P, Tenovuo O. Treatment costs and productivity losses caused by traumatic brain injuries. *Brain Inj* 2012;26:1697–701.
- [10] Chrusch CA, Olafson KP, McMillan PM, et al. High occupancy increases the risk of early death or readmission after transfer from intensive care. *Critical care medicine* 2009;37:2753–8.
- [11] Halpern NA, Pastores SM. Critical care medicine in the United States 2000–2005: an analysis of bed numbers, occupancy rates, payer mix, and costs. *Critical care medicine* 2010;38:65–71.
- [12] Thattil R, Klepzig D, Schuster M. Intensive care capacities in Germany: provision and usage between 1991 and 2009. *Intensivkapazitäten in Deutschland: Vorhaltung und Nutzung zwischen 1991 und 2009. Anaesthesist* 61:56–62, 2012