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Original article

Care transitions in the first 6 months following traumatic brain injury: Lessons from the CENTER-TBI study

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ABSTRACT

Background: No large international studies have investigated care transitions during or after acute hospitalisations for traumatic brain injury (TBI).
Objectives: To characterise various TBI-care pathways and the number of associated transitions during the first 6 months after TBI and to assess the impact of these on functional TBI outcome controlled for demographic and injury-related factors.
Methods: This was a cohort study of patients with TBI admitted to various trauma centres enrolled in the Collaborative European NeuroTrauma Effectiveness Research in TBI (CENTER-TBI) study. Number of transitions and specific care pathways were identified. Multiple logistic regression analyses were used to assess the impact of number of transitions and care pathways on functional outcome at 6 months post-injury as assessed by the Glasgow Outcome Scale-Extended (GOSE).
Results: In total, 3133 patients survived the acute TBI-care pathway and had at least one documented in-hospital transition at 6-month follow-up. The median number of transitions was 3 (interquartile range 2–3). The number of transitions did not predict functional outcome at 6 months (odds ratio 1.08, 95% confidence interval 1.09–1.18; $P = 0.063$). A total of 378 different care pathways were identified; 8 were identical for at least 100 patients and characterized as "common pathways". Five of these common care pathways predicted better functional outcomes at 6 months, and the remaining 3 pathways were unrelated to outcome. In both models, increased age, violence as the cause of injury, pre-injury presence of systemic disease, both intracranial and overall injury severity, and regions of Southern/Eastern Europe were associated with unfavourable functional outcomes at 6 months.

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Conclusions: A high number of different and complex care pathways was found for patients with TBI, particularly those with severe injuries. This high number and variety of care pathway possibilities indicates a need for standardisation and development of "common data elements for TBI care pathways" for future studies.
Study registration: ClinicalTrials.gov NCT02210221.

1. Introduction

Traumatic brain injury (TBI) is a major cause of death and long-term disability worldwide [1]. Many patients with TBI are admitted to hospital in the acute phase, representing approximately 1.5 million hospitalisations in the European Union annually [2]. Guidelines for acute neurosurgical and intensive care have been widely adopted [3], but other healthcare and rehabilitation interventions following such hospitalisations are variable [4]. Transitions between inpatient and outpatient care are at risk for both quality and continuum of care in patients with TBI [5], and to exacerbate this, older patients with TBI have a higher risk of inappropriate discharge planning [6]. Previous Scandinavian studies have reported that direct transfers from hospitals to rehabilitation units improved outcomes and reduced length of hospital stay for patients with severe TBI [7–9], but the effect of a reduced number of transitions was not addressed. For TBI, no large international studies have investigated care transitions during and after acute hospitalisation.

The Collaborative European NeuroTrauma Effectiveness Research in Traumatic Brain Injury (CENTER-TBI) project has reported large variations in care structure among countries [10] in neurosurgical services [11], in-hospital acute rehabilitation, and referrals to post-acute rehabilitation services [12]. Even larger variations may be expected because the healthcare context can profoundly affect care pathways [13]. Hospital structure, organisation, and the training of staff can all affect care transitions between intensive care units (ICUs) and regular wards in addition to patient-related characteristics [14]. TBI severity and the presence of other injuries also affect outcomes [15] and may also affect length of stay and care pathways. Comorbidities are high, especially in older patients, and may have profound effects on both care pathways and discharges [16] and need to be considered when evaluating differences between countries.

Informed planning for care transitions is important to avoid adverse effects in patients with complex health care needs [17]. Transitions from hospitals to homes for patients with complex health care needs after TBI are especially vulnerable and require careful planning and support [18]. Acute-care hospitals are often under pressure to transfer patients from ICUs to regular wards or to discharge patients [19]. Consequently, rapid decisions may lead to inadequate healthcare assessments and inappropriate care transitions [17]. Planning discharges and future care for patients with cognitive impairment is particularly challenging and has not been studied in large international cohorts.

The present work addressed the burden of care transitions during the first 6 months after TBI, with a focus on various care pathways, number of care transitions, and assessments of their appropriate timing. The study also aimed to address the hypotheses that both the number of transitions and care pathways affect functional outcomes at 6 months.

2. Methods

2.1. Study design and participants

This paper adheres to the STROBE-guidelines for reporting cohort studies [20].

The study was conducted within the context of the Core study of the CENTER-TBI project. This was multi-centre, observational, longitudinal, cohort study of patients with TBI (registered at ClinicalTrials.gov: NCT02210221) who presented (between December 2014 and December 2017) to 59 medical and research centres from 19 European countries and Israel [21]. Appendix A provides a full list of the CENTER-TBI participants and investigators. The CENTER-TBI inclusion criteria were:

- clinical diagnosis of TBI;
- indication for CT imaging;
- presentation within 24 hr of injury;
- informed consent obtained.

Patients with severe pre-existing neurological disorders that could have confounded outcome assessments were excluded.

Enrolled patients were stratified into 3 groups according to initial clinical care pathway:

- emergency room (ER) stratum: evaluated in the ER, then discharged;
- admission (ADM) stratum: admitted to a hospital ward;
- ICU stratum: admitted directly to an ICU, from the emergency department or another hospital.

Initially, 4559 patients were enrolled, but 43 withdrew consent and 7 centres were excluded because of enrolment of < 5 patients. Thus, records for 4509 patients were available for analysis. See Steyerberg et al. [22] for the flowchart and specific details.

2.2. Ethical approval

The CENTER-TBI study was conducted in accordance with all relevant local and national ethical guidelines, regulatory requirements for recruiting human subjects, relevant data protection and privacy regulations. Informed consent was obtained from all patients or their legally acceptable representative. The study obtained ethical clearance from the institutions involved in the project (see https://www.center-tbi.eu/project/ethical-approval for details).

2.3. Data collection, handling and storage

Patient data were entered into a clinical database from an electronic Case Report Form with a Global Unique Patient Identifier used to ensure adequate de-identification. Data were stored at the International Neuroinformatics Coordinating Facility (INCF) in Stockholm, Sweden. The Neurobot data management tool was developed by the INCF for data extractions. Data curation was performed by a multidisciplinary data curation team.

This study used care-transition data from hospital admission to discharge home and post-acute care during the first 6 months. Care transitions were defined as points during a care pathway at which the patient was transferred from one treatment facility to another or discharged from organised TBI care. Seven categories were used to describe transitions from hospital ERs to an intensive or high care unit (CU), neurosurgical or neurological ward (WN), other ward (WO), rehabilitation unit (REHAB), nursing home (NH), home (HOME) and other hospital. Each patient was assigned a specific care pathway. Their last registered transition was designated as their post-acute discharge destination. The number of transitions between destinations was registered. Transitions to and from CT imaging, MRI, or surgery were excluded.

Treatment centres classified the timing of each transition as appropriate, premature, or delayed as follows: appropriate transition: a physician judged a patient's condition to be appropriate for transfer; premature transition: for example, a patient was discharged from an ICU due to limited bed capacity but would have remained longer if possible; delayed transition: for example, a patient remained on a ward because of lack of beds at the receiving rehabilitation unit. Geographical region was classifed by the Eurovoc classification scheme [23] as North/West (Austria, Belgium, Denmark, Finland, France, Germany, Latvia, Lithuania, Netherlands, Norway, Sweden, and the United Kingdom) or South/East and Israel (Hungary, Israel, Italy, Romania, Serbia, and Spain). Living arrangements were assessed by data collected on the number of co-habitants, using a yes or no designation for the patient living alone. Pre-injury somatic health problems were classified according to the American Society of Anesthesiologists Physical Status assessment system (ASAPS) [24] and were divided into 3 categories in the present study: healthy, mild systemic disease, and severe systemic disease. This classification was used to depict the functional impact of the medical comorbidity the patient had before the head injury (e.g., cardiovascular or endocrine disorders). Causes of injury were classified as a fall, road traffic accident (RTA), violence, suicide, or other. The Glasgow Coma Scale (GCS) score was used to evaluate injury severity (3–8, severe; 9–12, moderate; 13–15, mild). The Injury Severity Scale (ISS) was used to evaluate overall trauma severity. Whether or not cranial surgery was conducted was registered as yes or no. The Glasgow Outcome Scale-Extended (GOSE) score [25] was used to assess 6-month outcomes as favourable (5–8) or non-favourable (1–4), in accordance with Steyerberg et al. [22]. To evaluate transitions and outcome at 6 months, we excluded patients who had died. Hence, patients with a GOSE score of 1, signifying death, were excluded.

2.4. Statistical analysis

Data were retrieved from the CENTER-TBI Core 2.0 final sample (May 2019). Analyses were performed with R v3.6.2. Data are described with median (interquartile range [IQR]) or number (%). During descriptive data analyses, patients were classified by age groups: 0–15, 16–20, 21–40, 41–60, 61–70 and > 70 years. To investigate the predictive value of the number of transitions for a non-favourable GOSE classification and to adjust for covariates, we used multivariable logistic regression. The sample ($n = 3133$) included patients who:

- survived the acute TBI-care pathway;
- had been discharged by the time of their 6-month follow-up;
- had at least one documented in-hospital transition.

Analyses controlled for age, geographical region, living alone, pre-injury health status, cause of injury, GCS and ISS scores, and cranial surgery. Correlation analyses were used to determine possible multicollinearity between the covariates. Another multivariable logistic regression analysis was used to evaluate the impact of care pathway on non-favourable GOSE category and to adjust for covariates by using the same procedure as described above. Care pathways shared by < 100 patients were aggregated and termed "other" and used as a reference in the analyses ($n = 1197$). Odds ratios (ORs) > 1 increased the probability of a favourable functional outcome, and ORs < 1 decreased the probability of a favourable outcome.

Missing covariate values were imputed under the assumption of missing at random by using multiple imputations with IBM SPSS Statistics v25.0. For multiple imputations, all available data on variables used in the models and sex were used to generate 30 imputed data sets. The results from each complete dataset were combined to present single estimates. Sensitivity analyses were performed for the number of imputations for missing values. These multiple imputed models are presented in the results, with complete-case analyses in Appendix A.

3. Results

In total, 4029 patients were alive at 6 months and deemed eligible for study inclusion. Demographic and injury characteristics by patient strata are in Table 1. Median age overall was 48 years (IQR 29–64); most patients were male (67%), had mild TBI (71%), and showed favourable outcomes at 6 months (70%). Patients with mild TBI typically belonged to the ER and ADM strata, whereas the ICU stratum included mostly patients with more severe injuries and a non-favourable GOSE category. The median number of

Table 1
Patient characteristics across the emergency room (ER), admission (ADM) and intensive care unit (ICU) strata.

	Total ($n = 4029$)	ER ($n = 839$)	ADM ($n = 1451$)	ICU ($n = 1739$)
Age, years, median (IQR)	48 (29-64)	47 (29-64)	52 (31-67)	45 (27-61)
GCS category				
Mild	2864 (71%)	820 (98%)	1369 (94%)	675 (39%)
Moderate	315 (8%)	2 (~0%)	44 (3%)	269 (16%)
Severe	707 (18%)	1 (~0%)	6 (1%)	700 (40%)
NA	143 (3%)	16 (2%)	32 (2%)	95 (5%)
Sex				
Male	2681 (67%)	468 (56%)	947 (65%)	1266 (73%)
Female	1348 (33%)	371 (44%)	504 (35%)	473 (27%)
Region				
North/west	3031 (75%)	580 (69%)	1194 (82%)	1257 (72%)
South/east	998 (25%)	259 (31%)	257 (18%)	482 (28%)
GOSE at 6 months				
VS/lower severe disability	311 (8%)	3 (~0%)	28 (2%)	270 (15%)
Upper severe disability	158 (4%)	9 (1%)	42 (3%)	127 (7%)
Moderate disability	770 (19%)	55 (7%)	218 (15%)	497 (29%)
Good recovery	2066 (51%)	608 (73%)	904 (62%)	554 (32%)
NA	704 (18%)	154 (18%)	259 (18%)	291 (17%)

GCS: Glasgow Coma Scale; GOSE: Glasgow Outcome Scale-Extended; IQR: interquartile range; NA: not available; VS: vegetative state.

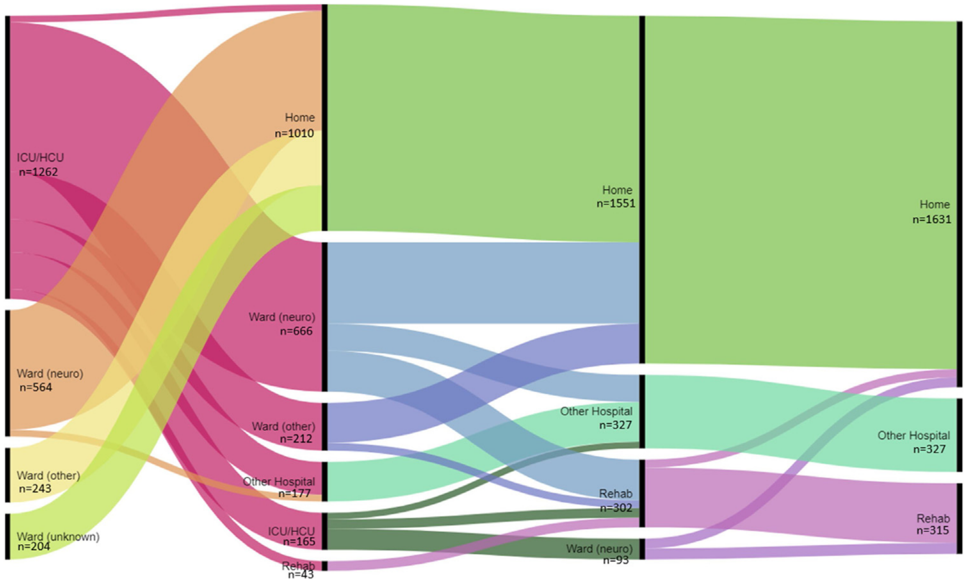

Fig. 1. Care trajectories with > 20 patients. ICU: intensive care unit; HCU: high-care unit.

Table 2
Strata, GOSE outcome, number of transitions and length of stay for patients in identified pathways and by registered post-acute discharge destination.

	All (n = 4029)	ER (n = 839)	ADM (n = 1451)	ICU (n = 1739)	GOSE favourable (n = 2836)	GOSE unfavourable (n = 489)	GOSE NA (n = 704)	Length of stay (n = 4021), days, median (IQR)	No. of transitions (n = 4017), median (IQR)
								4.5 (0.97-15.10)	**2 (2-3)**
Pathways									
HOME	783 (19%)	780 (93%)	3 (0%)	0 (0%)	627 (22%)	18 (4%)	138 (20%)	0.2 (0.1–0.6)	1 (1–1)
WN-HOME	534 (13%)	6 (1%)	528 (37%)	0 (0%)	399 (14%)	27 (5%)	108 (15%)	2.0 (1.1–4.3)	2 (2–2)
CU-WN-HOME	363 (9%)	0 (0%)	71 (5%)	292 (17%)	281 (10%)	26 (5%)	56 (8%)	7.7 (4.7–15.0)	3 (3–3)
WO-HOME	243 (6%)	10 (1%)	233 (16%)	0 (0%)	202 (7%)	8 (2%)	33 (5%)	1.8 (1.0–3.6)	2 (2–2)
WARD-HOME	204 (5%)	0 (0%)	204 (14%)	0 (0%)	167 (6%)	4 (1%)	33 (5%)	2.2 (1.1–4.2)	2 (2–2)
CU-WO-HOME	178 (4%)	1 (0%)	41 (3%)	136 (8%)	140 (5%)	16 (3%)	22 (3%)	8.0 (3.9–14.7)	3 (3–3)
CU-OTHER HOSPITAL	147 (4%)	0 (0%)	9 (1%)	138 (8%)	64 (2%)	43 (9%)	40 (6%)	10.5 (4.5–16.4)	2 (2–2)
CU-WN-REHAB	146 (4%)	0 (0%)	5 (0%)	141 (8%)	78 (3%)	46 (9%)	22 (3%)	25.34 (16.9–45.4)	3 (3–3)
CU-WN-OTHER HOSPITAL	121 (3%)	0 (0%)	1 (0%)	120 (7%)	77 (3%)	23 (5%)	21 (3%)	11.2 (6.6–19.5)	3 (3–3)
Other pathways	1197 (30%)	27 (3%)	351 (24%)	819 (47%)	751 (26%)	260 (53%)	186 (26%)	14.79 (5.3–31.9)	4 (3–4)
NA	113 (3%)	15 (2%)	5 (0%)	93 (5%)	50 (2%)	18 (4%)	45 (6%)	–	–
Post-acute discharge destination									
CU	10 (0%)	0 (0%)	0 (0%)	10 (1%)	5 (0%)	3 (0%)	2 (0%)	9.0 (7.8–14.4)	2 (2–2)
HOME	2876 (72%)	811 (97%)	1285 (89%)	780 (45%)	2253 (79%)	171 (35%)	452 (64%)	2.0 (0.7–7.3)	2 (1–3)
NURSING HOME	57 (1%)	4 (0%)	19 (1%)	34 (2%)	14 (1%)	34 (7%)	9 (2%)	20.6 (9.8–42.7)	3 (3–5)
OTHER HOSPITAL	484 (12%)	7 (1%)	85 (6%)	392 (23%)	258 (9%)	112 (23%)	114 (16%)	10.0 (4.3–19.5)	3 (2–3)
REHAB	476 (12%)	1 (0%)	54 (4%)	421 (24%)	248 (9%)	150 (31%)	78 (11%)	25.8 (15.4–46.3)	3 (3–4)
PSYCH	7 (0%)	1 (0%)	1 (0%)	5 (0%)	6 (0%)	0 (0%)	1 (0%)	14.6 (6.1–18.7)	3 (2.5–3)
WARD	6 (0%)	0 (0%)	2 (0%)	4 (0%)	2 (0%)	1 (0%)	3 (1%)	–	–
UNKNOWN	113 (3%)	15 (2%)	5 (0%)	93 (5%)	50 (2%)	18 (4%)	45 (6%)	–	–

ADM: admission; CU: intensive care unit/high care unit; ER: emergency room; GOSE: Glasgow Outcome Scale-Extended; IQR: interquartile range; NA: not available; PSYCH: psychiatric ward; WARD: undetermined hospital ward; WN: ward neurology/neurosurgery; WO: ward other.

transitions was 2 (IQR 2–3) (range 1–18). A total of 378 different care pathways were identified among surviving patients. Fig. 1 displays a visual representation of the care pathways that occurred for at least 20 patients.

Table 2 displays the distribution of the most common care pathways (≥ 100 patients) and post-acute discharge destinations by strata and GOSE category, including the length of stay and number of transitions. As expected, the most frequent care pathways varied by strata, as did the registered post-acute discharge destinations. Hospital length of stays were longest for the ICU-ward (neuro)-rehab pathway, which suggests that patients ending up in rehabilitation had the longest hospital stays. The "other pathways" had both the highest mean number of transitions and the highest frequency of non-favourable GOSE score at 6 months, with 45% of the total ICU strata belonging to this group.

For the 3133 patients with at least one documented in-hospital transition, the median age was 49 years (IQR 29–64). TBI severity was similar to the overall cohort (65% mild, 10% moderate, 21% severe, and 4% unknown), as was sex (69% male), geographical region (76% North/West), and GOSE category (9% vegetative/lower severe disability, 5% upper severe disability, 23% moderate disability, 46% good recovery, and 17% unknown). The median number of transitions among these patients was 3 (IQR 2–3). The median number of transitions did not vary across demographic subgroups except for patients > 70 years old (2 [IQR 2–3]). Of note, the median number of transitions was similar across the different

Table 3
Predictive value of number of transitions and covariates for unfavourable GOSE category at 180 days with multiple imputations ($n = 3133$).

Variable	Level/category	Adjusted OR	95% CI	P
Number of transitions	1 transition increase	1.08	0.99–1.18	0.063
Age	1 year older	1.02	1.02–1.3	< 0.001***
Region	North/West (reference)	1.00		
	South/East	1.33	1.03–1.74	0.029*
Living alone	No (reference)	1.00		
	Yes	0.99	0.74–1.32	0.953
ASAPS	Healthy (reference)	1.00		
	Mild systemic	1.57	1.18–2.08	0.002**
	Severe systemic	2.61	1.74–3.92	< 0.001***
Cause of injury	Fall (reference)	1.00		
	RTA	1.19	0.90–1.57	0.207
	Violence	2.04	1.10–3.79	0.024*
	Suicide	0.80	0.26–2.43	0.703
	Other	0.99	0.60–1.61	0.975
GCS severity	Mild (reference)	1.00		
	Moderate	1.88	1.27–2.77	0.001**
	Severe	4.12	3.02–5.62	< 0.001***
Total ISS score	1-point increase	1.03	1.02–1.04	< 0.001***
Cranial surgery	No (reference)	1.00		
	Yes	1.94	1.48–2.53	< 0.001***

ASAPS: American Society of Anesthesiologists Physical Status assessment system; CI: confidence interval; GCS: Glasgow Coma Scale; ISS: Injury Severity Scale; OR: odds ratio; RTA: road traffic accident.
* $P < 0.05$.
** $P < 0.01$.
*** $P < 0.001$.

Table 4
Predictive value of typical pathways of care and covariates for unfavourable GOSE category at 180 days with multiple imputation ($n = 3133$).

Variable	Level/Category	Adjusted OR	95% CI	P
Pathways	All other pathways (reference)	1.0		
	Ward (neuro)-Home	0.53	0.33–0.86	0.010*
	CU-Ward (neuro)-Home	0.34	0.21–0.56	< 0.001***
	Ward (other)-Home	0.33	0.15–0.72	0.005**
	Ward (unknown)-Home	0.24	0.08–0.68	0.008**
	CU-Ward (other)-Home	0.52	0.29–0.96	0.038*
	CU-Other hospital	1.45	0.91–2.32	0.113
	CU-Ward (neuro)-Rehab	1.07	0.68–1.66	0.762
	CU-Ward (neuro)-Other hospital	0.72	0.42–1.24	0.244
Age	1 year older	1.02	1.02–1.03	< 0.001***
Region	North/West (reference)	1.00		
	South/East	1.42	1.08–1.86	0.011*
Living alone	No (reference)	1.00		
	Yes	0.96	0.72–1.30	0.833
ASAPS	Healthy (reference)	1.00		
	Mild systemic	1.58	1.19–2.10	0.001**
	Severe systemic	2.49	1.65–3.74	< 0.001***
Cause of injury	Fall (reference)	1.00		
	RTA	1.18	0.89–1.57	0.226
	Violence	2.12	1.12–3.98	0.019*
	Suicide	0.83	0.27–2.53	0.756
	Other	1.00	0.61–1.63	0.998
GCS severity	Mild (reference)	1.00		
	Moderate	1.69	1.14–2.51	0.009**
	Severe	3.58	2.60–4.93	< 0.001***
Total ISS score	1-point increase	1.03	1.02–1.04	< 0.001***
Cranial surgery	No (reference)	1.00		
	Yes	1.68	1.28–2.21	< 0.001***

ASAPS: American Society of Anesthesiologists Physical Status assessment system; CI: confidence interval; CU: intensive care unit/high care unit; GCS: Glasgow Coma Scale; ISS: Injury Severity Scale; OR: odds ratio; RTA: road traffic accident.
* $P < 0.05$.
** $P < 0.01$.
*** $P < 0.001$.

pre-injury health categories and causes of injury (i.e., 3 [IQR 2–3]), except for those who attempted suicide (median 3 [IQR 3–4]). As expected, the number of transitions increased for patients with more severe GCS score, major trauma (ISS score >15), and cranial surgery.

Results of the imputed multivariable logistic regression analysis that assessed any influence of transition number on functional outcome are in Table 3. The number of transitions approached the threshold of statistical significance, with OR 1.08 (95% CI 0.99–1.18) after controlling for covariates. The complete-case analyses showed a very small but statistically significant predictive effect of number of transitions on unfavorable outcome (OR 1.10, 95% CI 1.01–1.21; Appendix A). With this exception, the complete-case analyses results were similar. Among the covariates, increased age, pre-injury presence of systemic disease, both intracranial and overall injury severity, injury caused by violence and regions of Southern/Eastern Europe were associated with unfavourable functional outcomes at 6 months.

Table 4 displays results of the imputed multivariable logistic regression analysis of the effect of 8 typical pathways on GOSE category. Complete-case results were similar (Appendix A). Five of these 8 most-common pathways showed decreased odds of non-favourable GOSE category as compared with all other pathways. The exception was the "CU-Other hospital" pathway, which showed a 45% increased likelihood of a non-favourable GOSE category. We found no association between the "CU-Ward (neuro)-Rehab" pathway and non-favourable GOSE category. This model also showed increased likelihood of non-favourable GOSE category with increased age, South/East region, premorbid systemic disease, injury caused by violence, and more severe intracranial and overall injuries.

Only 293 patients (~10%) were reported to have at least one premature or delayed transition. Of these, 244 (~8%) had at least one documented delay, and 57 (~2%) had documented premature transitions. Demographic and injury-severity characteristics of this group were similar to those for the full sample, except for higher percentages of severe TBI and major trauma. The median age was 51 years (IQR 32–64), 68% of patients were male, 87% were from the North/West region, 37% had severe TBI, 81% belonged to the ICU stratum and 85% had an ISS score $\geq$ 15. Significant differences between the premature/delayed transition group and the remaining patient group were confirmed for GCS and ISS scores, cranial surgery, and region of residence (data not shown). In the premature-transition subgroup, the main transitions were to home or other hospitals. In the delayed transition subgroup, we found a mixture of transitions from/to high CUs, other hospitals, neurosurgical wards and rehabilitation facilities.

4. Discussion

This is one of the first TBI studies to describe the care-transition burden at the patient level during the first 6 months after TBI. Transition number varied across patient strata and was highest in the ICU stratum. This finding may represent injury severity in patients admitted to the ICU (median GCS score 10), and their transitions related to prolonged care in hospital settings. However, 24% of patients with mild TBI were also admitted to ICUs [22] in line with a US study that reported 24% of mild-TBI patients requiring ICU admission at some stage after injury [26]. Other factors, such as extracranial injuries, might also play a role.

The median transition number showed little variation by demographic characteristics, including age. All age groups had medians of 3 transitions, except patients > 70 years, who had a median of 2. Pressure to free acute-care beds can lead to faster discharge of older patients [27].

Furthermore, patients with more severe TBIs and major trauma were transferred more often between different wards/facilities as compared with patients with less severe injuries. Patients with severe TBI and high disability levels often need prolonged stays in hospital [28].

Most transitions were rated appropriate, with only 9% considered delayed or premature, and the ICU stratum had the highest number of these. Premature transitions were to homes or other hospitals and may also reflect pressure to free acute-care beds [19]. In contrast, the delayed subgroup of patients was characterised by a mixture of care pathways. However, previous studies have reported that delayed transitions could be related to waiting times for destination beds or to other non-clinical care decisions [7].

The present study documented 378 care pathways. This finding may be a reflection of not only TBI complexity but also different care organisations and the decision-making processes involved in management in trauma hospitals involved in the CENTER-TBI project [10]. In the ADM stratum, approximately two-thirds of patients received treatment in wards before being discharged home, whereas one-quarter were in the heterogeneous other-pathways group. The ICU stratum was different: one-quarter of patients were transferred from CUs to hospital wards before discharge home, and almost half of these patients belonged to the other-pathways group. This finding may reflect that ICU stratum patients were more severely injured and thus needed more complex medical treatment and more frequent transitions; their median transition number was 4, and median length of stay was 15 days.

The hypothesis that number of transitions would influence functional outcome was not confirmed by the multivariate regression analysis; the number of transitions was not a significant predictor of non-favourable functional outcomes (GOSE) at 6 months in the imputed model. However, increased age, South/East regions, presence of premorbid disease, violence-related injuries, most-severe TBI and overall trauma were associated with non-favourable functional outcomes at 6 months. Yet, the complete-case analyses revealed a very small but statistically significant effect suggesting that increased number of transitions predicted unfavorable outcome at 6 months. The ORs were rather similar in both models. Previously, 3 factors were reported to influence transitions for individuals with brain injuries: personal/individual characteristics, family/caregiving factors, and professional/service factors [29].

The hypothesis that care pathways influence functional outcome was partly confirmed. The multivariable logistic regression analysis confirmed that 5 pathways significantly predicted favourable outcomes at 6 months. The 3 remaining pathways were unrelated to outcomes. Similarly, this model showed that the same covariates predicted outcomes at 6 months.

The better functional outcomes of the most frequent care pathway in both the ADM and ICU strata (transfer to wards and thereafter discharged home) are not surprising. This pathway reflects the patients with less severe TBI who recover faster. The present results suggest poorer functional outcomes for patients with severe TBI, major trauma, and increased age. They support previous findings that the burden of TBI-care pathways is determined by not only TBI severity but also overall injury severity and socio-biological factors such as age [30]. The management of severe TBI is lifelong, and a better understanding is needed of the impairments, available treatments, and optimal care, as highlighted in French guidelines for care pathways with adults with severe TBI [31].

In both multivariate regression models, we found more non-favourable outcomes for patients in South/East regions. Whether this finding is due to differences in TBI care is unclear, so our results should be interpreted with caution. However, variability in the number of hospital beds among European countries exists. For example, Germany has 2.5 times the number of curative-care beds and 50 times the number of rehabilitative-care beds (per 100,000 population) than Spain [32]. Both the contexts and systems of care assessed here were heterogeneous, and thus, the number of possible care pathways was high. Previous reports from this project highlighted substantial variations in the processes of TBI care [10] and suggested that these variations were opportunities to study specific aspects of TBI-care effectiveness. However, comparing 378 pathways across 59 institutions is a challenge. Thus, there is an urgent need for defining and standardising transitions and TBI-care pathways by integrating these into "common data elements" for future studies. For example, future studies should ensure that centres use a standardized definition of what constitutes delayed or premature transitions. Common TBI pathways could be identified for each country and data collected on both full care pathways and TBI-specific transitions and whether the patient was considered to receive standardized TBI care or not. This move would allow for identifying differences in care between patients but further provide a clearer picture of how transitions were affected by individual factors such as comorbid disorders, caregiving factors and service-related factors such as need to free beds or unavailability of rehabilitation services.

The strengths of the study are the large sample size and the number of participating countries, rendering a robust overview of care-pathway variations in Europe and Israel. However, local logistics and academic interests of participating centres as well as low numbers/non-consecutive enrolments in some centres may have resulted in selection bias for patient recruitment. Furthermore, differences in data registration among study sites and countries and organisational differences in discharge timing need to be taken into consideration when interpreting the present results. In addition, we did not analyse care transitions in patients who died within the 6 months ($n = 473$) nor those still in-hospital 6 months after TBI onset ($n = 7$) because the focus of the study was to evaluate the completed care trajectories of the patient group. Although the number of patients lost to follow-up was considered low, there was enough missing data to warrant imputed analyses, which is often an issue in longitudinal studies. In-depth studies across countries that follow care pathways in trauma hospitals are highly warranted.

5. Conclusions

The most important finding in this study was the highly diverse and complex TBI care pathways. The number of transitions, including delayed or premature, was highest in the ICU stratum and showed little variation by demographics. Patients with more severe TBI and major extracranial trauma were transferred more often between different wards and facilities than those with less severe injuries. The high number and variety of care pathway possibilities indicates a need for standardisation and development of "common data elements for TBI care pathways" for future studies.

Disclosure of interest

The authors declare that they have no competing interest.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.rehab.2020.10.009.

References

[1] Maas AI, Stocchetti N, Bullock R. Moderate and severe traumatic brain injury in adults. Lancet Neurol 2008;7:728–41. http://dx.doi.org/10.1016/S1474-4422(08)70164-9. S1474-4422(08)70164-9 [pii].

[2] Majdan M, Plancikova D, Brazinova A, et al. Epidemiology of Traumatic Brain Injuries in Europe: a cross-sectional analysis based on hospital discharge statistics and death certificates in 2012. Lancet Public Health 2016;1:e76–83.

[3] Groven S, Eken T, Skaga NO, Roise O, Naess PA, Gaarder C. Long-lasting performance improvement after formalization of a dedicated trauma service. J Trauma 2011;70:569–74. http://dx.doi.org/10.1097/TA.0b013e31820d1a9b. 00005373-201103000-00006 [pii].

[4] Leland NE, Roberts P, De Souza R, Hwa Chang S, Shah K, Robinson M. Care Transition processes to achieve a successful community discharge after postacute care: a scoping review. Am J Occup Ther 2019;73. http://dx.doi.org/10.5014/ajot.2019.005157. 7301205140p1-p9. Epub 2019/03/07. PubMed PMID: 30839269.

[5] Snow V, Beck D, Budnitz T, Miller DC, Potter J, Wears RL, et al. Transitions of Care Consensus policy statement: American College of Physicians, Society of General Internal Medicine, Society of Hospital Medicine, American Geriatrics Society, American College Of Emergency Physicians, and Society for Academic Emergency Medicine. J Hosp Med 2009;4:364–70. http://dx.doi.org/10.1002/jhm.510. PubMed PMID: 19479781.

[6] Gupta S, Perry JA, Kozar R. Transitions of care in geriatric medicine. Clin Geriatr Med 2019;35:45–52. http://dx.doi.org/10.1016/j.cger.2018.08.005. PubMed PMID: 30390983.

[7] Andelic N, Bautz-Holter E, Ronning PA, Olafsen K, Sigurdardottir S, Schanke AK, et al. Does an early onset and continuous chain of rehabilitation improve the long-term functional outcome of patients with severe traumatic brain injury? J Neurotrauma 2012;1:66–74.

[8] Sveen U, Roe C, Sigurdardottir S, Skandsen T, Andelic N, Manskow U, et al. Rehabilitation pathways and functional independence one year after severe traumatic brain injury. Eur J Phys Rehab Med 2016;52:650–61. PubMed PMID: 27050083.

[9] Borg J, Røe C, Nordenbo A, Andelic N, de Boussard C, af Geijerstam J-L. Trends and challenges in the early rehabilitation of patients with traumatic brain injury a Scandinavian perspective. Am J Phys Med Rehab 2011;90:65–73. http://dx.doi.org/10.1097/PHM.0b013e3181fc80e7.

[10] Cnossen MC, Polinder S, Lingsma HF, Maas AIR, Menon D, Steyerberg EW, 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;11. http://dx.doi.org/10.1371/journal.pone.0161367. e0161367(8).

[11] van Essen TA, den Boogert HF, Cnossen MC, de Ruiter GCW, Haitsma I, Polinder S, et al. Variation in neurosurgical management of traumatic brain injury: a survey in 68 centers participating in the CENTER-TBI study. Acta Neurochirur 2018. http://dx.doi.org/10.1007/s00701-018-3761-z. PubMed PMID: 30569224.

[12] Cnossen MC, Lingsma HF, Tenovuo O, Maas AIR, Menon D, Steyerberg EW, et al. Rehabilitation after traumatic brain injury: a survey in 70 European neurotrauma centres participating in the CENTER-TBI study. J Rehabil Med 2017;49:395–401. http://dx.doi.org/10.2340/16501977-2216. PubMed PMID: 28440841.

[13] Jourdan C, Bahrami S, Azouvi P, Tenovuo O. Practitioners' opinions on traumatic brain injury care pathways in Finland and France: different organizations, common issues. Brain Injury 2019;33:205–11. http://dx.doi.org/10.1080/02699052.2018.1539869. PubMed PMID: 30449182.

[14] Heidegger CP, Treggiari MM, Romand JA, Swiss ICUN. A nationwide survey of intensive care unit discharge practices. Intensive Care Med 2005;31:1676–82. http://dx.doi.org/10.1007/s00134-005-2831-x. Epub 2005/10/27. PubMed PMID: 16249927.

[15] Majdan M, Mauritz W, Brazinova A, Rusnak M, Leitgeb J, Janciak I, et al. Severity and outcome of traumatic brain injuries (TBI) with different causes of injury. Brain injury 2011;25:797–805. http://dx.doi.org/10.3109/02699052.2011.581642. Epub 2011/06/03. PubMed PMID: 21631184.

[16] Eum RS, Seel RT, Goldstein R, Brown AW, Watanabe TK, Zasler ND, et al. Predicting institutionalization after traumatic brain injury inpatient rehabilitation. J Neurotrauma 2015;32:280–6. http://dx.doi.org/10.1089/neu.2014.3351. Epub 2014/09/10. PubMed PMID: 25203001; PubMed Central PMCID: PMCPMC4322088..

[17] Tverdal CB, Howe EI, Roe C, Helseth E, Lu J, Tenovuo O, et al. Traumatic brain injury: patient experience and satisfaction with discharge from trauma hospital. J Rehabil Med 2018;50:505–13. http://dx.doi.org/10.2340/16501977-2332. PubMed PMID: 29620136..

[18] Turner BJ, Fleming J, Ownsworth T, Cornwell P. Perceived service and support needs during transition from hospital to home following acquired brain injury. Disabil Rehabil 2011;33:818–29. http://dx.doi.org/10.3109/09638288.2010.513422. PubMed PMID: 20812814.

[19] Cox JC, Sadiraj V, Schnier KE, Sweeney JF. Higher quality and lower cost from improving hospital discharge decision making. J Econ Behav Org 2016;131:1–16. http://dx.doi.org/10.1016/j.jebo.2015.03.017. Epub 2017/02/28. PubMed PMID: 28239219; PubMed Central PMCID: PMCPMC5319446.

[20] Von Elm E, Altman DG, Egger M, Pocock SJ, Gøtzsche PC, Vandenbroucke JP. Strobe Initiative. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement: guidelines for reporting observational studies. Int J Surg 2014;12:1495–9.

[21] Maas AI, Menon DK, Steyerberg EW, Citerio G, Lecky F, Manley GT, et al. Collaborative European NeuroTrauma Effectiveness Research in Traumatic Brain Injury (CENTER-TBI): a prospective longitudinal observational study. Neurosurgery 2015;76:67–80. http://dx.doi.org/10.1227/NEU.0000000000000575. 00006123-201501000-00008 [pii].

[22] Steyerberg EW, Wiegers E, Sewalt C, Buki A, Citerio G, De Keyser V, et al. Case-mix, care pathways, and outcomes in patients with traumatic brain injury in CENTER-TBI: a European prospective, multicentre, longitudinal, cohort study.

Lancet Neurol 2019;18:923–34. http://dx.doi.org/10.1016/S1474-4422(19)30232-7. Epub 2019/09/19. PubMed PMID: 31526754.
[23] Eurovoc. Thesaurus Eurovoc-Volume 2: Subject-Oriented Version. Ed. 3/English Language; 1995, Annex to the index of the Official Journal of the EC. Luxembourg, Office for Official Publications of the European Communities. URL accessed 06.07.20: http://eurovoc.europa.eu/100277.
[24] Mayhew D, Mendonca V, Murthy BV. A review of ASA physical status–historical perspectives and modern developments. Anaesthesia 2019;74:373–9.
[25] Wilson JT, Pettigrew LE, Teasdale GM. Structured interviews for the Glasgow Outcome Scale and the extended Glasgow Outcome Scale: guidelines for their use. J Neurotrauma 1998;15:573–85.
[26] Nelson LD, Temkin NR, Dikmen S, Barber J, Giacino JT, Yuh E, et al. Recovery after mild traumatic brain injury in patients presenting to US Level I Trauma Centers: a Transforming Research and Clinical Knowledge in Traumatic Brain Injury (TRACK-TBI) Study. JAMA Neurol 2019. http://dx.doi.org/10.1001/jamaneurol.2019.1313. Epub 2019/06/04. PubMed PMID: 31157856; PubMed Central PMCID: PMCPMC6547159..
[27] Ekdahl AW, Linderholm M, Hellstrom I, Andersson L, Friedrichsen M. 'Are decisions about discharge of elderly hospital patients mainly about freeing blocked beds?' A qualitative observational study. BMJ Open 2012;2. http://dx.doi.org/10.1136/bmjopen-2012-002027. Epub 2012/11/21. PubMed PMID: 23166138; PubMed Central PMCID: PMCPMC3533092..
[28] Tardif PA, Moore L, Boutin A, Dufresne P, Omar M, Bourgeois G, et al. Hospital length of stay following admission for traumatic brain injury in a Canadian integrated trauma system: a retrospective multicenter cohort study. Injury 2017;48:94–100. http://dx.doi.org/10.1016/j.injury.2016.10.042. Epub 2016/11/15. PubMed PMID: 27839794..
[29] Turner BJ, Fleming JM, Ownsworth TL, Cornwell PL. The transition from hospital to home for individuals with acquired brain injury: a literature review and research recommendations. Disabil Rehabil 2008;30:1153–76. http://dx.doi.org/10.1080/09638280701532854. Epub 2007/09/14. PubMed PMID: 17852241..
[30] Schumacher R, Walder B, Delhumeau C, Muri RM. Predictors of inpatient (neuro)rehabilitation after acute care of severe traumatic brain injury: an epidemiological study. Brain injury 2016;30:1186–93. http://dx.doi.org/10.1080/02699052.2016.1183821. Epub 2016/07/09. PubMed PMID: 27389772.
[31] Pradat-Diehl P, Joseph PA, Beuret-Blanquart F, Luaute J, Tasseau F, Remy-Neris O, et al. Physical and rehabilitation medicine (PRM) care pathways: adults with severe traumatic brain injury. Ann Phys Rehabil Med 2012;55:546–56. http://dx.doi.org/10.1016/j.rehab.2012.07.002. Epub 2012/10/04. PubMed PMID: 23031681.
[32] Figures EI. Eurostat Year Book. Publications Office Of The European Union; 2011, Accessed on 8th of July 2020, URL: https://ec.europa.eu/eurostat/documents/3217494/5728733/CH_03_2011-EN.PDF/ab5df803-d8d4-4714-babb-0da150c747da.