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RESEARCH PAPER

Epidemiology and clinical outcomes in a multicentre regional cohort of patients with severe acquired brain injury

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ABSTRACT

Purpose: To evaluate epidemiological and clinical data on patients with severe acquired brain injury (sABI) admitted to rehabilitation units in the first 6 years since the inception of a regional register (2005–2010) in the Emilia-Romagna region (Italy).
Method: Retrospective multicentre study of a regional cohort using data from an online regional register (Gravi Cerebrolesioni Emilia-Romagna – GRACER). The study included 318 patients who suffered sABI (defined by Glasgow Coma Scale score ≤8 recorded in the initial 24 h following injury), who were admitted to and subsequently discharged from rehabilitation units. Physical and cognitive functions were evaluated at admission and discharge. Other data recorded included aetiology, presence of secondary conditions and need for specific medical support.
Results: Three-quarters of patients displayed improvements in physical and/or cognitive function at discharge from rehabilitation units, with 71.4% of patients returning home. Better outcomes at discharge were associated in particular with younger age, traumatic brain injury (versus non-traumatic), or absence of tracheostomy at admission.
Conclusion: The GRACER register is a useful tool for the assessment of epidemiological and clinical information on sABI patients. In light of the positive impact on patient outcomes, rehabilitation in specialised units is highly encouraged and should occur as soon as possible.

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➤ IMPLICATIONS FOR REHABILITATION

- There is a need for more epidemiological and clinical data associated with severe acquired brain injury, particular regarding those of non-traumatic origin.
- In a retrospective multicentre study of a regional cohort using data from an online regional register in Italy (GRACER), more than three-quarters of patients displayed improvements in physical and/or cognitive function at discharge from the rehabilitation units. Better outcomes at discharge were associated in particular with younger age, traumatic brain injury (versus non-traumatic) or absence of tracheostomy at admission.
- Admission to a specialised rehabilitation unit is highly encouraged for patients with severe acquired brain injury, and should occur as soon as possible.
- Policy-makers and service planners should continue to develop strategies and allocate adequate resources for rehabilitation services due to their positive impact on patient outcomes. In particular, patients with conditions associated with increased likelihood of poor outcomes may require special attention during rehabilitation to improve outcomes at discharge.

Introduction

Acquired brain injury (ABI) encompasses an array of damages to the central nervous system, which may be of traumatic or non-traumatic origin.[1,2] Traumatic brain injury (TBI) is a major cause of death and long-term disability, being considered a major public health issue worldwide.[3] Common causes are motor vehicle accidents, falls and physical violence. Non-traumatic causes of ABI include anoxia, aneurysm and focal brain lesions, which are also associated with long-term impairments.[1,2]

There is a need for more epidemiological and clinical data associated with severe acquired brain injury (sABI), particularly regarding those of non-traumatic origin. Studies on sABI patients admitted to rehabilitation units have shown better outcomes in patients with TBI than

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those with non-traumatic injuries.[2,4,5] An observational prospective study of patients with sABI conducted from the Gruppo Italiano per lo Studio delle Gravi Cerebrolesioni Acquisite e Riabilitazione (Italian Group for the Study of sABI) has shown that the probability of home discharge from the rehabilitations centres was greater for patients with traumatic conditions than those of non-traumatic origin.[6] However, the benefits of rehabilitation programmes not only vary depending on the underlying causes of sABI, but also in relation to the interval between index event and admission to the rehabilitation clinic, type of medical intervention and demographic characteristics of the patient.[6]

The Emilia-Romagna region in Italy offers free universal health care, and since 2004 patients with sABI have been monitored through the Gravi Cerebrolesioni Emilia-Romagna (GRACER) register. GRACER was designed to prospectively collect data on incidence, rehabilitation, health care needs and outcomes of people living or treated in Emilia-Romagna who suffered sABI.

In this study, we aimed to evaluate epidemiological and clinical information on a regional cohort of sABI patients admitted to the regional reference rehabilitation units in the first 6 years since GRACER's inception (2005–2010).

Materials and methods

Ethics

Ethics approval for this study was provided by the Unique Ethical Committee of the Ferrara Province (Emilia-Romagna, Italy). All procedures followed were in accordance with the ethical standards of the responsible committees. Written or verbal informed consent from individual patients was not required, as this study involved an audit of routine clinical practise based on anonymised data.

GRACER

Care of patients with sABI in the Emilia-Romagna region is allocated based on a hub and spoke network, where the central hub is a highly specialised hospital (Neuroscience and Rehabilitation Department, Ferrara University Hospital, Ferrara) and the spokes are regional hospitals. These regional hospitals refer patients to the central hub when unable to take care of them locally. Data for each patient is entered into GRACER (an online database), which covers the entire population of the Emilia-Romagna region (4,432,430 inhabitants at the last census). Patients are followed by 55 physiatrists throughout the region, who are responsible for entering the data into GRACER. This registry and its respective clinical indicators were based on the users' manual developed by the Australasian Faculty of Rehabilitation Medicine of the Royal Australasian College of Physicians.[7] Importantly, GRACER has uniform rules for data entry, allowing meaningful interpretation of data obtained from this registry.

Patients

Patients were only included in this study if they had suffered sABI defined by Glasgow Coma Scale (GCS) score ≤ 8 recorded in the initial 24 h following injury. Inclusion criteria were also admission to a rehabilitation unit and subsequent discharge. Patients who died while in the rehabilitation unit ($n = 14$) were excluded from this study.

All patients were assessed at the rehabilitation unit for physical, cognitive and behavioural impairments. The rehabilitation programme was provided by a group of health care team (including physicians, psychologists, nurses, physiotherapists, speech therapists and health workers), who carried out rehabilitation programmes in the following areas: basic life functions; sensorimotor impairments; impairments of cognitive-behavioural function; independence in activities of daily living; social reintegration; prescription, supply, and instructions regarding the use of assistive devices; impairments in respiratory, cardiovascular, bladder-sphincter and gastrointestinal function; as well as education and training of patients and their families on the management of disabilities.

Parameters of interest

Data on a number of clinical parameters were obtained from the GRACER at admission to and at discharge from the rehabilitation unit. Data included length of stay at rehabilitation unit; aetiology of sABI (traumatic or non-traumatic); presence of secondary brain damage (mainly intracranial hypertension, ventricular enlargement, post-traumatic epilepsy, or infection); presence of musculoskeletal or internal lesion (mainly para-osteo-arthropathy, tendon retraction, infection, pressure ulcer, or deep vein thrombosis); need for feeding support; sphincter control and tracheostomy. Note also that data on musculoskeletal or internal lesions at discharge were incomplete, and only the respective admission data are considered in this study.

At admission to the rehabilitation unit, severity of the injury was assessed using the GCS [8] during the first 24 h post-injury. GCS scores can be classified as mild (GCS 13–15), moderate (9–12) or severe (3–8) [9], but all participants had severe scores as per inclusion criteria.

At both admission to and discharge from rehabilitation unit, physical and cognitive functions were clinically assessed. Physical disability was evaluated using the Barthel Index [10,11] and the Disability Rating Scale (DRS).[12] The Barthel Index, proposed by Mahoney and Barthel [10], is a reliable and sensitive measure of activities of daily living to assess physical disability.[11] The Barthel Index vary from 0 (most disabled) to 100 (normal function), and scores were also classified into mild (90–100), moderate (60–85) and severe (0–55) disability as per Goldstein et al.[13] The DRS provides a quantitative evaluation of patient recovery following injury.[12] DRS scores range from 0 to 29, and were categorised into nine levels according to the level of disability: no disability, mild, partial, moderate, moderately severe, severe, extremely severe, vegetative state and extreme vegetative state.[14] In this study, we categorised DRS scores into a binary outcome: good (none to partial) and poor (moderate to extreme vegetative state).

Responsiveness and cognitive function of patients were assessed by the Rancho Los Amigos Level of Cognitive Functioning Scale (LCFS).[15] This scale records gradual levels of recovery: level I (no response), II (generalised response), III (localised), IV (confused, agitated), V (confused, inappropriate, non-agitated), VI (confused, appropriate), VII (automatic, appropriate) and VIII (purposeful, appropriate).[15] Here, the cognitive function of patients was categorised as poor-moderate (LCFS levels I–V) and good (levels VI–VIII).

Statistical analyses

Proportions of patients with particular outcomes were compared with Fisher's exact tests. Associations with time spent in rehabilitation unit were evaluated with Spearman's rank correlations and non-parametric Kruskal–Wallis tests. Comparisons with the length of stay and rates from previous studies were done with two-sample *t*-tests and Fisher's exact tests. Likelihood of adverse outcomes among patients was assessed with binary logistic regressions. In addition, three binary logistic regressions were used to examine a number of factors at admission as predictors of better cognitive and functional outcomes at discharge, specifically discharge home, a good DRS score and a Barthel Index >60. The factors included in these models were the following parameters recorded at admission to rehabilitation unit: age, sex, GCS score, aetiology of injury, as well as the presence of cerebral damage, musculoskeletal/internal damage, tracheostomy, entero/parenteral nutrition and sphincter control problems. Analyses were performed in Minitab version 16 (Pennsylvania State University, State College, PA). All statistical tests were two-tailed and maintained at a 5% significance level. Where appropriate, data are mean ± standard deviation, with medians in square brackets.

Results

Cohort

A total of 1474 patients were recorded in GRACER over the study period, but only 318 subjects met the inclusion criteria for this study. Compared to those who were excluded, study participants were slightly younger (−2.8 years; $p = 0.019$), but of similar sex ratio ($p = 0.69$), GCS at admission ($p = 0.85$) and injury aetiology ($p = 0.30$).

Study patients were aged 48.4 ± 19.3 years (range 2.9–85.5 years), including 14 participants aged less than 18 years, and most were males (66.4%). Half of the population (50.5%) suffered TBI, with the remainder of patients suffering non-traumatic injuries encompassing haemorrhagic/ischemic apoplexy, anoxic brain injury and other causes.

Length of stay in rehabilitation unit

There was considerable variation in the length of stay at the rehabilitation unit, with a mean stay of 105 ± 81 [82] d, ranging from 4 to 362 d. As it would be expected, increasing length of time spent at the rehabilitation unit was correlated with more severe Barthel Index scores ($\rho = -0.42$; $p < 0.0001$), poorer DRS scores ($\rho = 0.45$; $p < 0.0001$) and poorer LCFS scores ($\rho = -0.43$; $p < 0.0001$) at admission. Importantly, the presence of any form of physical impairment at admission was associated with a considerable increase in the length of stay (Table 1).

Admission versus discharge

At admission, almost all patients had severe physical disability as per Barthel Index and DRS scores (Table 2), but most showed improvements in both scales over the course of rehabilitation (73.3 and 76.1%, respectively). Thus, at discharge the rate of patients with severe Barthel Index had fallen to 51.9% ($p < 0.0001$) (Table 2). Similarly, 80.8% of the study population had poor-moderate LCFS scores at admission (Table 2); 76.4% of patients showed improvement, so that only 38.1% had poor cognitive function at discharge ($p < 0.0001$; Table 2).

There were also considerable reductions in the incidence of tracheostomy ($p < 0.0001$), enteral and/or

Table 1. The length of stay at the rehabilitation units (in days) according to the presence (yes) or absence (no) of a particular impairment at admission. Data are means ± standard deviations, with medians in brackets.

	Yes	No	*p* Value
Severe Barthel Index (0–55)	110 ± 81 [90]	32 ± 19 [31]	<0.0001
Poor Disability Rating Scale scores	106 ± 81 [83]	20 ± 10 [20]	0.001
Poor-moderate Level of Cognitive Function Scale scores	116 ± 83 [100]	60 ± 57 [46]	<0.0001
Secondary cerebral lesion	136 ± 87 [114]	99 ± 79 [73]	0.002
Secondary musculoskeletal or internal lesion	123 ± 85 [104]	93 ± 76 [64]	0.001
Tracheostomy	120 ± 85 [100]	73 ± 64 [52]	<0.0001
Enteral and/or parenteral nutrition	126 ± 84 [104]	69 ± 61 [50]	<0.0001
Problem with sphincter control	112 ± 82 [91]	49 ± 41 [41]	<0.0001

Table 2. Clinical parameters among the 318 patients at admission and discharge.

	Admission (%)	Discharge (%)	*p* Value
Severe Barthel Index (0–55)	93.7	51.9	<0.0001
Poor Disability Rating Scale scores	98.4	81.1	<0.0001
Poor-moderate Level of Cognitive Function Scale scores	80.8	38.1	<0.0001
Secondary cerebral lesion	17.0	19.2	0.54
Secondary musculoskeletal or internal lesion	39.6	–	–
Tracheostomy	66.7	19.6	<0.0001
Enteral and/or parenteral nutrition	64.5	25.2	<0.0001
Problem with sphincter control	89.6	51.3	<0.0001

parenteral nutrition ($p < 0.0001$) and of problems with sphincter control ($p < 0.0001$) at discharge (Table 2). However, the overall rate of secondary cerebral lesions was relatively unchanged (Table 2).

Note that 71.4% of patients went home following discharge from the rehabilitation unit. The remaining 28.6% were moved to other healthcare units (mostly nursing facilities for patients whose families were unable to care for them), with some of these patients being readmitted to acute care units following worsening of clinical conditions.

Glasgow Coma Scale

The more severe the injury as per GCS scores, the longer was the length of stay at the rehabilitation unit ($\rho = -0.33$; $p < 0.0001$). Lower GCS scores (i.e. greater impairment) were correlated with more severe Barthel Index ($\rho = 0.33$; $p < 0.0001$), poorer DRS scores ($\rho = -0.33$; $p < 0.0001$) and poorer LCFS scores ($\rho = 0.29$; $p < 0.0001$) at admission. Lower GCS scores were also associated with increased likelihood of tracheostomy ($p < 0.0001$), enteral and/or parenteral nutrition ($p < 0.0001$), musculoskeletal or internal lesions ($p = 0.039$) and problems with sphincter control ($p < 0.0001$) at admission. However, GCS scores were not associated with the likelihood of having secondary cerebral lesion ($p = 0.88$).

The same above associations with post-injury GCS were observed regarding outcomes at discharge. In addition, lower GCS scores were associated with increased likelihood of the patient being moved into another health care facility rather than going home ($p = 0.002$).

Aetiology

Median GCS scores post-injury were similar in TBI and non-traumatic groups ($p = 0.17$), and there were no differences in length of stay at rehabilitation unit (102 ± 85 [64] versus 108 ± 78 [89] d, respectively; $p = 0.20$). At admission, patients with TBI were on average 12.6 years younger than those with non-traumatic injuries (42.3 ± 20.5 versus 54.9 ± 15.6 years; $p < 0.0001$). Most clinical parameters were also similar between the two groups, except that there were more TBI patients with poor to moderate LCFS scores (85.5 versus 75.8%; $p = 0.033$) (Table 3).

At discharge, better outcomes were seen in both groups, with improvements in physical function, nutrition and sphincter control (Table 3). However, more TBI patients showed improvements in physical function, so that the proportions of traumatic patients with severe Barthel Index and poor DRS scores were lower than in the non-traumatic group ($p = 0.003$ and $p < 0.001$, respectively; Table 3). In addition, there was a greater rate of respiratory improvement among those with TBI, so that tracheostomy was more common among non-traumatic patients at discharge ($p = 0.001$), as was the prevalence of problems with sphincter control ($p = 0.007$; Table 3). Further, TBI patients were more likely to return home after discharge than non-traumatic patients, with respective rates of 78.1% and 64.3% ($p = 0.009$).

Sex

Males had greater odds of experiencing TBI than females (odds ratio 2.68 (95% CI: 1.61–4.48)), making up 78.1%

Table 3. Clinical parameters at admission and discharge among patients who suffered traumatic (TBI; $n = 160$) or non-traumatic ($n = 157$) severe acquired brain injury.

	TBI		Non-traumatic	
	Admission (%)	Discharge (%)	Admission (%)	Discharge (%)
Sex ratio (males)	78.1		54.1††††	
Severe Barthel Index (0–55)	95.0	43.8****	92.4	60.5****††
Poor Disability Rating Scale scores	98.8	73.8****	98.1	88.5**†††
Poor-moderate Level of Cognitive Function Scale scores	85.5	37.1****	75.8†	39.5****
Secondary cerebral lesion	15.0	16.9	19.1	21.7
Secondary musculoskeletal or internal lesion	38.1	–	40.8	–
Tracheostomy	68.2	12.3****	64.9	27.2****††
Enteral and/or parenteral nutrition	61.3	23.1****	67.5	27.4****
Problem with sphincter control	88.1	43.8****	91.1	59.2****††

**$p < 0.01$ and
****$p < 0.0001$ for admission versus discharge within aetiology group;
††$p < 0.01$,
†††$p < 0.001$ and ††††$p < 0.0001$ for TBI versus non-traumatic patients within a given time point. Note that there was no information on aetiology for one patient.

Table 4. Clinical parameters at admission and discharge among males ($n = 211$) and females ($n = 107$) who suffered severe acquired brain injury.

	Males		Females	
	Admission (%)	Discharge (%)	Admission (%)	Discharge (%)
Severe Barthel Index (0–55)	93.8	51.7****	93.5	52.3****
Poor Disability Rating Scale scores	98.6	79.6****	98.1	84.1***
Poor-moderate Level of Cognitive Function Scale scores	81.5	38.9****	79.3	36.8****
Secondary cerebral lesion	16.2	18.5	18.7	20.6
Secondary musculoskeletal or internal lesion	37.0	–	44.9	–
Tracheostomy	64.2	19.4****	71.7	20.0****
Enteral and/or parenteral nutrition	63.5	26.5****	66.4	22.4****
Problem with sphincter control	89.1	52.1****	90.7	49.5****

***$p < 0.001$ and
****$p < 0.0001$ for admission versus discharge.

and 54.1% of the traumatic and non-traumatic groups, respectively ($p < 0.0001$; Table 3). However, there were no differences between males and females regarding length of stay at rehabilitation unit (106 ± 84 [80] versus 102 ± 78 [86], respectively; $p = 0.90$) or post-injury GCS ($p = 0.79$).

At admission, males were on average 6.5 years younger than females (46.3 ± 19.3 versus 52.8 ± 18.6; $p = 0.004$), but there were no significant differences in clinical parameters between males and females (Table 4). At discharge, the changes observed mirrored those displayed by the group as a whole, with similar rates of improvement seen in men and women (Table 4).

Age

Increasing age at admission was slightly correlated with longer stay at rehabilitation unit ($\rho = 0.15$; $p = 0.011$), and was also associated with greater odds of enteral/parenteral nutrition (+1% per year; $p = 0.037$). Subgroup analyses were carried excluding children and adolescents, i.e. comparing adults aged 18–64 ($n = 220$) years versus elderly patients aged ≥ 65 years ($n = 84$).

The prevalence of TBI was greater in younger adults than in the elderly group (52.5% versus 39.3%, respectively; $p = 0.041$). At admission, there were no significant differences between groups in any parameters of physical and cognitive function, or presence of impairments (Table 5).

There were no significant differences between younger and elderly adults in length of stay (106 ± 84 [83] versus 110 ± 77 [84], respectively; $p = 0.34$). Both age groups displayed improvements in the physical and cognitive functions at discharge, with the exception of the presence of secondary cerebral lesion (Table 5). However, in contrast to what was observed at admission, there was a greater prevalence of poor outcomes amongst elderly patients at discharge compared to younger adults (Table 5). This was observed for all parameters assessed, with older patients also tending to have a greater prevalence of secondary cerebral lesions at discharge ($p = 0.052$). However, age was not a factor determining the likelihood of a patient returning home ($p = 0.61$), with relatively similar rates observed among younger and elderly adults (71.4% versus 66.7%; $p = 0.48$).

Table 5. Clinical parameters at admission and discharge among adult patients who suffered severe acquired brain injury according to age: 18–64 years ($n = 220$) versus ≥65 years ($n = 84$).

	18–64 years		≥65 years	
	Admission (%)	Discharge (%)	Admission (%)	Discharge (%)
Severe Barthel Index (0–55)	93.6	47.3****	96.4	70.2****†††
Poor Disability Rating Scale scores	98.2	78.2****	100	91.7*††
Poor-moderate Level of Cognitive Function Scale scores	80.0	34.1****	86.8	54.2****††
Secondary cerebral lesion	15.9	16.8	20.2	27.4
Secondary musculoskeletal or internal lesion	40.5	–	41.2	–
Tracheostomy	68.1	16.0****	68.8	30.9****††
Enteral and/or parenteral nutrition	65.0	21.4****	69.1	38.1****††
Problem with sphincter control	90.0	47.7****	92.9	65.5****††

*$p < 0.05$ and
****$p < 0.0001$ for admission versus discharge.
††$p < 0.01$ and
†††$p < 0.001$ for younger versus elderly patients within a given time point.

Table 6. Parameters recorded at admission to rehabilitation unit as prognostic factors of better outcomes at discharge. Each of the three binary logistic regression models included all parameters listed. Data are p values and odds ratios (with 95% CI).

	Outcomes at discharge					
Parameters at admission	Discharge home		Good DRS score		Barthel Index >60	
Sex (male)	0.316	0.73 (0.40–1.35)	0.962	1.02 (0.49–2.11)	0.050	0.52 (0.27–1.00)
Age (years)	0.082	0.99 (0.97–1.00)	0.156	0.99 (0.97–1.00)	<0.001	0.96 (0.94–0.98)
Glasgow Coma Scale score	0.085	1.14 (0.98–1.33)	0.175	1.14 (0.94–1.37)	0.001	1.32 (1.12–1.54)
Traumatic brain injury	0.007	2.69 (1.25–4.26)	0.020	2.33 (1.14–4.73)	0.053	1.87 (0.99–3.54)
Cerebral damage	0.247	1.55 (0.74–3.26)	0.634	0.79 (0.30–2.10)	0.134	0.55 (0.25–1.20)
Musculoskeletal/internal damage	0.162	0.67 (0.38–1.18)	0.668	0.86 (0.43–1.71)	0.002	0.39 (0.21–0.71)
Tracheostomy	<0.001	0.13 (0.05–0.35)	0.259	0.61 (0.26–1.43)	0.012	0.35 (0.16–0.79)
Enteral/parenteral nutrition	0.679	0.41 (0.52–2.71)	0.018	0.35 (0.15–0.83)	0.053	0.47 (0.22–1.01)
Sphincter control problems	0.767	0.78 (0.15–4.13)	0.337	0.64 (0.26–1.59)	0.046	0.11 (0.01–0.97)

DRS: disability rating scale.

Prognostic factors

The usefulness of a number of parameters as prognostic factors of better outcomes at discharge is summarised in Table 6. Greater odds of being discharged home were independently associated with TBI (as opposed to non-traumatic injury) and absence of tracheostomy at admission (Table 6).

Most health parameters recorded at admission to the rehabilitation unit were associated with the level of physical disability at discharge, as measured by the Barthel Index (Table 6). Specifically, greater odds of a Barthel Index >60 were associated with younger age and higher GCS scores (Table 6). In contrast, lower odds of a better outcome as per Barthel Index were associated with musculoskeletal/internal damage, sphincter control problems, tracheostomy, with similar trends observed for non-TBI, entero/parenteral nutrition and male sex (Table 6).

For DRS, non-TBI and enteral/parenteral nutrition were predictive of lower odds of good DRS scores at discharge (Table 6). Note the only aetiology was an independent predictor of outcomes in all three domains assessed, with patients with TBI having greater odds of a better outcome at discharge compared to those with non-traumatic injury (Table 6).

Discussion

Our audit of a population with sABI shows that more than three-quarters of patients displayed improvements in physical and/or cognitive function at discharge from the rehabilitation units. Better outcomes at discharge were associated in particular with younger age, TBI (versus non-traumatic) or absence of tracheostomy at admission.

As it would be expected, poor physical or cognitive function at arrival was associated with a longer stay in rehabilitation. Further, the presence of any one form of impairment at the time of admission (e.g. secondary cerebral lesion, tracheostomy, enteral and/or parenteral nutrition, or problem with sphincter control) was almost invariably associated with a major increase in the length of stay. Although most patients displayed considerable improvements in clinical parameters, 81% of patients still had moderate or worse levels of disability as per DRS scores at discharge. Nonetheless, nearly three-quarters of patients returned home following discharge from the rehabilitation unit.

Similarly to other studies [2,4,5,16], TBI patients were younger and had better outcomes at discharge than non-traumatic patients. Among our TBI patients, 78.4% returned home after discharge (rather than being admitted to other healthcare facilities). This rate is similar to that of 74.4% ($p = 0.32$) reported by Zampolini et al. [17], but significantly higher than the 67.6% ($p = 0.007$) reported in Avesani et al. [2] (both nationwide Italian studies on sABI patients). Further, our observed rate of patients with non-traumatic sABI returning home (64.3%) was also considerably higher than the national figure of 42.3% ($p < 0.0001$).[2]

The identification of prognostic factors at admission for those patients who experience sABI is important for risk-profiling patients and estimating later health outcomes. In our study, being discharged home and better functional outcomes at discharge were independently predicted by having suffered TBI (as opposed to non-traumatic injury) and absence of tracheostomy at admission. Similarly, previous studies have shown worse outcomes in young patients with non-TBI (ischemic or hypoxic) than in those with TBI [18,19]. There is also existing evidence that the respiratory status is a relevant prognostic factor in those who suffered sABI [20], with a prospective study of 110 patients with severe head injury showing that the vast majority of those hypoxic at admission had unfavourable outcomes (82.6%).[21]

We have also found that enteral/parenteral nutrition, sphincter control problems and musculoskeletal/internal damage at admission were all predictors of worse cognitive and/or functional outcomes at rehabilitation unit discharge. Patients with brain injury often require alternative forms of feeding due to impaired cognition, dysphagia, assisted ventilation and other conditions that can delay oral feeding.[22] Sphincter control problems represent a common functional deficit after brain injury, particularly in those with frontal TBI due to the involvement of the frontal lobe locus of continence.[23] It is worth noting that being discharged home may be delayed in patients with faecal incontinence, and a large multicentre study involving 1013 patients after acute brain injury showed that those with bowel incontinence stayed 53 more days in inpatient rehabilitation than continent patients.[23] There is also evidence that patients with TBI and multiple traumas may have worse functional outcomes as a result of impaired cognitive function and/or permanent disability.[24]

GCS scores at admission were predictive of health outcomes at both admission and discharge. However, the more comprehensive regression models showed that higher GCS scores at admission were associated in particular with better physical outcomes at discharge. Previously, Heather et al. showed that severe GCS scores (3–8) were predictive of long-term (one year or more after injury) neurological disability and the need for educational support at school.[25] In this study, we expand on those results showing that within a cohort of patients only with severe scores, there is a continuous worsening of physical and cognitive outcomes with decreasing GCS scores over the course of rehabilitation and at discharge.

Our data also suggest that more men experienced sABI than women, with the male proportion of patients (66.5%) being very similar to the national figure (67.5%).[2] These findings are in accordance with numerous previous studies showing higher rates of TBI amongst males [2,26–28], which was three-fold higher than that of females. Unfortunately, our records do not provide information on specific causes of trauma, but the likely higher incidence of TBI amongst men may be associated with more risk-taking activities, occupational hazards and increased rates of violence compared to women.[29] In regards to outcomes at discharge, a number of studies have shown that females have poorer outcomes than males following TBI.[30–32] In our study, males and females displayed similar outcomes at discharge.

We observed that, both younger and elderly adults displayed improvements in physical and cognitive functions at discharge, although the prevalence of poor outcomes was greater amongst elderly patients compared to younger adults. Similarly, Chan et al. have found that younger (19–64 years) and older (≥65 years) adults discharged from rehabilitation made similar gains, despite younger adults having higher total function scores at admission and at discharge.[33] These findings have been speculated to reflect less neuronal plasticity in elderly than younger adults.[34] However, a systematic review of the literature covering the years 1980–2005 has reported that there is still limited evidence suggesting a higher rate of change on functional outcomes in younger (18–54 years) than older patients (≥55 years).[35] We have also observed that, although younger age at admission was a prognostic factor of better functional outcomes, age was not a factor determining the likelihood of a patient returning home, with similar rates observed among younger and elderly adults. Thus, based on the available evidence age does not necessarily limit recovery so that age should not determine the level of access to rehabilitation programmes following sABI, as younger and older patients can potentially respond and improve their functional status.[33]

We acknowledge that the number of patients that had to be excluded due to missing data is a limitation of our study. However, this was necessary to ensure the inclusion only of those patients with comprehensive data. Nonetheless, as described in the results, our study participants were likely representative of the overall cohort.

In conclusion, the GRACER register is a useful tool allowing for the assessment of epidemiological and clinical information on sABI patients. We showed that a number of prognostic factors obtained at admission to rehabilitation unit are useful predictors of outcomes at discharge. In addition, based on the improvements in physical and cognitive function at discharge and the high rate of reintegration into home life compared to national averages (especially for those with TBI), admission to a specialised rehabilitation unit following discharge from acute care is highly encouraged for patients with sABI, and should occur as soon as possible.

Declaration of interest

The authors report no declarations of interest.

References

1. Teasell R, Bayona N, Marshall S, et al. A systematic review of the rehabilitation of moderate to severe acquired brain injuries. Brain Inj. 2007;21:107–112.
2. Avesani R, Roncari L, Khansefid M, et al. The Italian National Registry of severe acquired brain injury: epidemiological, clinical and functional data of 1469 patients. Eur J Phys Rehabil Med. 2013;49:611–618.
3. Roozenbeek B, Maas AIR, Menon DK. Changing patterns in the epidemiology of traumatic brain injury. Nat Rev Neurol. 2013;9:231–236.
4. Colantonio A, Gerber G, Bayley M, et al. Differential profiles for patients with traumatic and non-traumatic brain injury. J Rehabil Med. 2011;43:311–315.
5. Cullen NK, Park YG, Bayley MT. Functional recovery following traumatic vs non-traumatic brain injury: a case-controlled study. Brain Inj. 2008;22:1013–1020.
6. Zampolini M, Corea F, Avesani R, et al. Rehabilitation of acquired brain injuries: a multicentric prospective survey. Eur J Phys Rehabil Med. 2013;49:365–372.
7. The Australian Council on Healthcare Standards. Rehabilitation Medicine Version 4. ACHS Clinical Indicator Users' Manual 2008. Sydney; 2008.
8. Teasdale G, Jennett B. Assessment of coma and impaired consciousness. A practical scale. Lancet. 1974;2:81–84.
9. Rimel RW, Giordani B, Barth JT, et al. Moderate head injury: completing the clinical spectrum of brain trauma. Neurosurgery. 1982;11:344–351.
10. Mahoney FI, Barthel DW. Functional evaluation: the Barthel Index. Md State Med J. 1965;14:61–65.
11. Wade DT, Collin C. The Barthel ADL Index: a standard measure of physical disability? Int Disabil Stud. 1988;10:64–67.
12. Rappaport M, Hall KM, Hopkins K, et al. Disability rating scale for severe head trauma: coma to community. Arch Phys Med Rehabil. 1982;63:118–123.
13. Goldstein LB, Lyden P, Mathias SD, et al. Telephone assessment of functioning and well-being following stroke: is it feasible? J Stroke Cerebrovasc Dis. 2002;11:80–87.
14. Rappaport M, Herrero-Backe C, Rappaport ML, et al. Head injury outcome up to ten years later. Arch Phys Med Rehabil. 1989;70:885–892.
15. Hagen C, Malkmus D, Durham P. Levels of cognitive functioning. Rehabilitation of the head injured adult: comprehensive physical management. Professional Staff Association of Rancho Los Amigos National Rehabilitation Center. Downey; 1979. p. 87–88.
16. Cullen NK, Weisz K. Cognitive correlates with functional outcomes after anoxic brain injury: a case-controlled comparison with traumatic brain injury. Brain Inj. 2011;25:35–43.
17. Zampolini M, Zaccaria B, Tolli V, et al. Rehabilitation of traumatic brain injury in Italy: a multi-centred study. Brain Inj. 2012;26:27–35.
18. Johnson AR, DeMatt E, Salorio CF. Predictors of outcome following acquired brain injury in children. Dev Disabil Res Rev. 2009;15:124–132.
19. Brenner T, Freier MC, Holshouser BA, et al. Predicting neuropsychologic outcome after traumatic brain injury in children. Pediatr Neurol. 2003;28:104–114.
20. Abdennour L, Zeghal C, Deme M, et al. [Interaction brain-lungs]. Ann Fr Anesth Reanim. 2012;31:e101–e107.
21. Saini NS, Rampal V, Dewan Y, et al. Factors predicting outcome in patients with severe head injury: multivariate analysis. Indian J Neurotrauma. 2012;9:45–48.
22. Cook AM, Peppard A, Magnuson B. Nutrition considerations in traumatic brain injury. Nutr Clin Pract 2008;23:608–620.
23. Foxx-Orenstein A, Kolakowsky-Hayner S, Marwitz JH, et al. Incidence, risk factors, and outcomes of fecal incontinence after acute brain injury: findings from the Traumatic Brain Injury Model Systems national database. Arch Phys Med Rehabil. 2003;84:231–237.
24. Andruszkow H, Probst C, Grün O, et al. Does additional head trauma affect the long-term outcome after upper extremity trauma in multiple traumatized patients: is there an additional effect of traumatic brain injury? Clin Orthop Relat Res. 2013;471:2899–2905.
25. Heather NL, Derraik JG, Beca J, et al. Glasgow Coma Scale and outcomes after structural traumatic head injury in early childhood. PLoS One. 2013;8:e82245.
26. Greenwald BD, Burnett DM, Miller MA. Congenital and acquired brain injury. 1. Brain injury: epidemiology and pathophysiology. Arch Phys Med Rehabil. 2003;84:S3–S7.
27. Crandon IW, Harding-Goldson HE, McDonald A, et al. The aetiology of head injury in admitted patients in Jamaica. West Indian Med J. 2007;56:223–225.
28. Canadian Institute for Health Information. Head Injuries in Canada: A Decade of Change (1994-1995 to 2003-2004) 2006. [cited 2015 Oct 13] Available from: https://secure.cihi.ca/free_products/ntr_head_injuries_2006_e.pdf.

29. Teasell R, Aubut JA, Bayley M, et al. Evidence-based review of moderate to severe acquired brain injury. London: ABIEBR; 2013.
30. Kraus JF, Peek-Asa C, McArthur D. The independent effect of gender on outcomes following traumatic brain injury: a preliminary investigation. Neurosurg Focus. 2000;8:e5.
31. Kirkness CJ, Burr RL, Mitchell PH, et al. Is there a sex difference in the course following traumatic brain injury? Biol Res Nurs. 2004;5:299–310.
32. Bazarian JJ, Blyth B, Mookerjee S, et al. Sex differences in outcome after mild traumatic brain injury. J Neurotrauma. 2010;27:527–539.
33. Chan V, Zagorski B, Parsons D, et al. Older adults with acquired brain injury: outcomes after inpatient rehabilitation. Can J Aging. 2013;32:278–286.
34. Bayona NA, Bitensky J, Teasell R. Plasticity and reorganization of the uninjured brain. Topics Stroke Rehabil. 2005;12:1–10.
35. Cullen N, Chundamala J, Bayley M, et al. The efficacy of acquired brain injury rehabilitation. Brain Inj. 2007;21:113–132.