ORIGINAL ARTICLE

Early predictors of long-term participation in patients with severe acquired traumatic injury discharged from Intensive Rehabilitation Unit

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ABSTRACT

BACKGROUND: Participation represents the most relevant indicator of successful functioning after a severe traumatic brain injury (sTBI), since it correlates with a higher perceived quality of life by patients, their families, and healthcare professionals. Nevertheless, studies on Italian population are lacking.
AIM: The aim of this study was to evaluate the long-term participation and its early predictors in patients after a sTBI.
DESIGN: This paper is an observational retrospective single-site study with long-term follow-up.
SETTING: The Intensive Rehabilitation Units (IRU) of the IRCCS Don Gnocchi Foundation, Florence, Italy.
POPULATION: The population included adults who were admitted to the IRU after a sTBI from August 2012 to May 2020 and who underwent a longitudinal follow-up between September 2021 and April 2022.
METHODS: Patients were contacted by a phone interview including participation assessment using the Community Integration Questionnaire (CIQ). When the patients were unable to respond, the caregiver was interviewed. Early predictors of long-term participation at admission and discharge from the IRU were assessed by a univariate and a multivariate analysis.
RESULTS: Among one hundred and forty-nine eligible patients, 3 died during their IRU stay, 35 patients were lost at the follow-up, 5 refused to participate in the interview and 46 died between discharge and follow-up. Sixty patients (men: 48 [80%]; age: 53.8 [IQR: 34.1] years; time postonset [TPO]: 36.5 [IQR: 22] days; education level: 8 [IQR: 5] years; mean time event-follow-up: 5.8 [IQR: 3.5] years) were included. The total CIQ Score was 11 (0-28): Home integration score 4 (0-10), Social integration 6 (0-12) and Productive activity 0 (0-6). Among 33 patients who worked or studied before the event, 19 (57.6%) returned to their previous activities. Only a younger age was associated with a better long-term participation both at admission (B=-0.210, P<0.001, R^2=0.307) and at discharge (B=-0.173, P<0.001, R^2=0.398).
CONCLUSIONS: This study reveals that under the same umbrella label of sTBI there are patients whose trajectories of long-term participation recovery are extremely heterogeneous. Further studies on larger samples are needed to identify patients with better participation recovery profiles, to customize their rehabilitation pathway.
CLINICAL REHABILITATION IMPACT: The present study provides relevant information to help clinicians in giving accurate information to caregivers and drawing adequate rehabilitation pathways.

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KEY WORDS: Brain injuries, traumatic; Patient participation; Community integration.

Traumatic brain injury (TBI) is the first cause of disability in young adults worldwide,[1] leading to impairment in physical, cognitive, emotional, and social functioning, that disrupt the individual's ability to return to preinjury roles and activities. As the increase in the incidence of TBI[1] has been accompanied by significant advances in emergency medicine and neurosurgery during the last decades, the number of TBI survivors carrying different sequelae is increasing to the point that it has been described as a "silent epidemic."[2] TBI is an acute catastrophic event, that triggers a cascade of neurologic and psychosocial sequelae generating a chronic disease process, that may contribute to permanent disability and premature death, months to years later.[3] Based on published data,[4, 5] in Italy between 200 and 300 patients per 100,000 inhabitants admitted to hospital every year as a result of this kind of injury, resulting in a death rate of 10 people per 100,000 inhabitants. Road accidents were the most frequent cause (about 80% of cases), especially among young people (medium age: 22 years). The disability rate varies from 2% to 45%, depending on the severity of the trauma. One of the most challenging aims of rehabilitating TBI survivors is to promote their return to pretraumatic activities and participation. Participation – defined by the World Health Organization in the International Classification of Functioning, Disability, and Health as the involvement in a life situation – is considered the most meaningful indicator of successful functioning after TBI.[6] Higher participation is associated with a higher perceived quality of life by individuals with TBI, their families, and healthcare professionals.[7, 8] Several studies have shown the global adverse effect of TBI on functional independence, disability burden, subjective well-being, and participation.[9-11] Some social and emotional aspects have been identified as predictors of better participation by Larsson et al. in a study investigating long-term participation in TBI survivors four years after traumatic event.[9] Age, educational level, depression, substance abuse, loss of consciousness during the acute event, and post-traumatic amnesia (PTA) duration[12] were identified as predictors of long-term participation after a median time of 8 years after acute event. More recently, a higher Functional Independence Measure motor score at discharge from inpatient rehabilitation was associated with a higher participation level five years after a TBI.[13] Nevertheless, most of the studies investigating predictors of long-term recovery of participation in TBI included persons with mild to very high severity[9-13] creating a very heterogeneous group. Severe acquired brain injuries, including those of traumatic etiology, are defined as a brain damage related to a pathological event of a non-congenital, perinatal, or degenerative nature determining a coma condition, with Glasgow Coma Scale Score-acute phase between 3 and 8, lasting more than 24 hours, in presence of brain imaging abnormalities and PTA>7. These patients should be considered deeply different from those with mild or moderate TBI. First, because of the more severe brain damage itself as demonstrated by the clinical and instrumental evaluations during the acute phase. Second, because of a high associated clinical complexity related to the concomitant presence of a disorders of consciousness, of multiple comorbidities and high care burden with multiple medical devices (percutaneous endoscopic gastrostomy [PEG], tracheal tube, mechanical ventilation) at discharge from intensive care unit. For all these reasons, those patients, after a period in the intensive care unit often referred to high specialty Intensive Rehabilitation Units (IRUs)[14] where the length of stay (LoS) is up to 180 days according to the national regulation.[15] During the early rehabilitation phase, the interdisciplinary rehabilitation team working in the IRUs are called to develop the individual rehabilitation project at admission and to inform, as soon as possible, the patients' families about the prognosis. Indeed, longitudinal studies focusing on long-term participation of patients surviving a severe TBI (sTBI) are lacking. This observational longitudinal study aimed to evaluate the long-term participation and its early predictors in patients with sequelae of sTBI, discharged from a high specialty Italian IRU.

Materials and methods

A non-concurrent cohort study was conducted, following STROBE guidelines; this study is an observational retrospective single-site analysis with long-term follow-up. We followed the principles of the Declaration of Helsinki, and the study was approved by the Institutional Ethics Committee (N. 17505_oss).

Participants

Subjects were selected from a database of patients admitted to the IRU of the IRCCS Don Gnocchi Foundation-Florence-Italy from August 2012 to May 2020 following a sTBI. Patients (or their caregivers) were contacted by telephone between September 2021 and April 2022 and underwent the Community Integration Questionnaire (CIQ).[16] The CIQ was administered to the caregiver when the patient's conditions were not compatible with the interview. Written consent was obtained from the patients

or their legal guardians. Inclusion criteria were: 1) first admission to the IRU after a sTBI related to a pathological event of a non-congenital, perinatal, or degenerative nature determining a coma condition, with Glasgow Coma Scale Score-acute phase between 3 and 8, lasting more than 24 hours, presence of brain imaging abnormalities and PTA >7 days; 2) 18+ years; and 3) absence of previous brain trauma, neurological disease, or cognitive disorders.

Interdisciplinary functional assessment and rehabilitation intervention

At admission to the IRU, all patients underwent a multidimensional interdisciplinary assessment, performed by a team of professionals (neurologist, internist, physiotherapist, speech therapist, nurse, and neuropsychologist) including demographics variables (age, sex, country of origine race, education), data concerning the pretraumatic clinical history (history of alcohol or drug abuse, psychiatric history), Cognitive Reserve Index Questionnaire (CRIq)[17] (referring to the pre-event conditions and administered to the caregiver) and the clinical data including time between the acute event and the admission in the IRU. The following functional scales, chosen on the basis of the Physical Medicine and Rehabilitation Italian Society (SIMFER) minimal protocol for the evaluation of patients with sABI,[14] were administered at admission and discharge: the level of cognitive functioning (LCF),[18] the Galveston Orientation and Amnesia Test (GOAT)[19] and the Disability Rating Scale (DRS).[20] At discharge, the Glasgow Outcome Scale (GOS)[21] was also administered.

Individual rehabilitation project

Based on individual assessments, the individual rehabilitation project was planned by an interdisciplinary team of neurorehabilitation professionals in agreement with patient and or family/proxies, delivering an average of 3 h of specific treatment per day. In addition, the pharmacologic interventions were carried out according to the patient's needs. Discharge was planned and carried out upon the decision of the interdisciplinary team, including the patient's family and caregivers, in agreement with the local health authority, either when the patient reached a plateau or when the patient achieved a functional improvement characterized by a consistent reduction of the care burden, the complete recovery of consciousness and the decannulation all conditions that allowed a transfer to a less specialized rehabilitation setting.

Follow-up assessment

All sTBI patients discharged from the IRU (or their caregivers) were contacted by phone and asked to complete an interview to assess their functional disability by the phone Glasgow Outcome Scale Expanded (pGOSE)[22] and their participation using the CIQ which is the most widely used community integration measurement tool utilized in research for people with TBI. The Telephone Montreal Cognitive Assessment (T-MoCA)[23] was also administered based on the patient's cognitive conditions.[14]

Endpoints

The primary endpoint was the level of community integration, assessed by the CIQ, in the long-term of patients surviving a sTBI and discharged from the IRU. The secondary endpoint was to identify early predictors of long-term participation after sTBI as measured by the CIQ.

Statistical analysis

Categorical and dichotomous variables were summarized using frequencies and percentages, continuous variables using median and interquartile range (IQR) due to the non-normality of the distributions assessed using the Shapiro-Wilk Test. The association of individual predictors with the possible recovery of follow-up participation was assessed using univariate linear regression models. Variables found to be significantly associated with recovery of participation were included as independent variables in two multivariate linear regression models. The first model (model A) included socio-demographic variables and clinical data collected at baseline; the second model (model B) included socio-demographic variables and clinical data at discharge. In both models, the CIQ Score at follow-up was included as a dependent variable. In all analyses, a P value <0.05 was considered significant. Software used: SPSS v27 (IBM Corp., Armonk, NY, USA).

Results

One hundred and forty-nine patients with sTBI were admitted to the IRU between August 2012 and May 2020. Three patients died during their IRU stay. Thirty-five patients were lost at the follow-up and 5 refused to participate in the phone interview. Forty-six patients died between discharge and follow-up. Of this 46 subjects: 1) 48 were men (73.8%) and 12 women (26.2%); 2) the age of the whole sample was 74.1 (IQR: 24.5) years, in which women's age was 70.0 (IQR: 41; min-max: 22-84), while men's age was
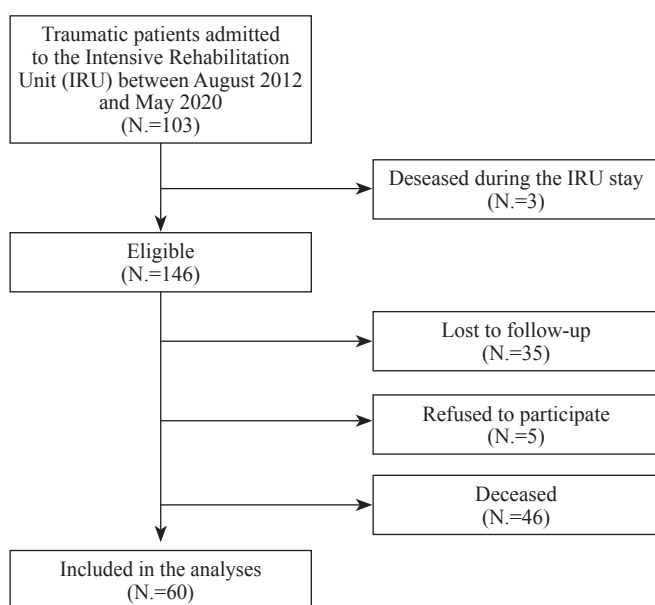
Figure 1.—Flow chart of patients' inclusion.

51.0 (IQR: 29; min-max: 17-85); 3) time postonset (TPO) was 48 (IQR: 38) days; and 4) education level was 8 (IQR: 9) years. Median time from event to death was 7 months (IQR: 13) for 36 patients, while 4 patients survived more than 50 months (range 53-117 months). Sixty patients (men: 48 [80%]; age: 53.8 [IQR: 34.1] years; TPO: 36.5 [IQR: 22] days; education level: 8 [IQR: 5] years) were still alive at the follow-up and were included in this retrospective and longitudinal analysis. (Figure 1). The included patients had a median LoS of 109.5 (IQR: 88) days and were discharged from the IRU with a median GOS was 3 (IQR: 1; min-max: 2-5). The median time between the event and the phone follow-up was 5.8 (IQR: 3.5) years; (range: 1.8-10.4). The total CIQ Score of recruited patients was 11 (IQR: 14; min-max: 0-28) distributed as follows: 1) home integration score 4 (IQR: 5; min-max: 0-10); 2) social integration 6 (IQR: 8; min-max: 0-12); and 3) productive activity 0 (IQR: 3; min-max: 0-6). Focusing on the working activities, it has been observed that among 33 patients who had a productive activity (work or study) before the event 19 (57.6%) returned to work/study. Demographic and clinical characteristics at admission, discharge and follow-up are summarized in Table I. To identify early predictors of long-term participation, a univariate linear regression was performed including CIQ as the dependent variable and the following independent variables: age, sex, education, CRIq, TPO, psychiatric and abuse history, DRS category at admission and discharge, LCF at admission

TABLE I.—*Characteristics of the study sample at admission and discharge.*

Variables	Median [IQR] (min-max) or N. (%)
Age (years)	53.8 [34.1]; (18-84.9)
Women	70.0 [IQR: 41]; (22-84)
Men	51.0 [IQR: 29]; (17-85)
Sex	
Male	48 (80.0%)
Education (years)	8 [5]; (3-23)
Country of birth	
Eastern Europe	2 (3.3%)
Western Europe	58 (96.7%)
TPO (days)	36.5 [22]; (13-501)
CRIq tot	91 [14]; (76-167)
Abuse history	
Yes	9 (15.0%)
Psychiatric history	
Yes	7 (11.7%)
LCF at admission	4 [1]; (1-7)
DRS at admission	7 [3]; (3-9)
GOAT at admission	10 [36]; (0-100)
LCF at discharge	6 [2]; (2-8)
DRS at discharge	5 [2]; (0-8)
GOS at discharge	3 [1]; (2-5)
GOAT at discharge	67 [67]; (0-100)
LoS in the IRU (days)	109.5 [88]; (22-324)
Time between event and follow-up (years)	5.8 [3.5]; (22-324)
CIQ – home integration	4 [5]; (0-10)
CIQ – social integration	6 [8]; (0-12)
CIQ – productive activity	0 [3]; (0-6)
Total CIQ Score at follow-up	11 [14]; (0-28)
Total CIQ Score = 0	2 (3.3%)
pGOSE at follow-up	4 [5]; (3-8)
T-MoCA*	18 [4]; (0-22)

IQR: interquartile range; TPO: time postonset; CRIq: Cognitive Reserve Index Questionnaire; LoS: length of stay; LCF: levels of cognitive functioning; DRS: Disability Rating Scale; GOS: Glasgow Outcome Scale; GOAT: Galveston Orientation and Amnesia Test; CIQ: Community Integration Questionnaire; pGOS-E: Phone Glasgow Outcome Scale-Expanded; T-MoCA: Telephone-Montreal Cognitive Assessment.
*Administered only to 10 people.

and discharge, GOS at discharge, and time between event and phone follow-up (Table II). All enrolled patients were born in a European country (Eastern Europe 2 [3.3%] and Western Europe 58 [96.7%]) thus this variable was not included in subsequent analyses. Significant variables both at admission to the IRU (Table III, model A) and discharge (Table III, model B) were then included in a multivariate linear regression analysis to predict long-term participation. In model A including demographic characteristics and clinical data at admission, a higher CIQ Score at follow-up remained significantly associated with younger age (B=-0.210, P<0.001, R^2=0.307). Similarly, in model B including demographic characteristics and clinical data at discharge, a higher CIQ Score at follow-up remained sig-

TABLE II.—*Univariate linear regressions.*

Variables	B	SE	Beta	T	P value	95% CI lower	95% CI upper
Age (years)	-0.222	0.046	-0.538	-4.860	0.000	-0.314	-0.131
Sex	2.771	2.687	0.134	1.031	0.307	-2.608	8.150
Education (years)	0.379	0.270	0.183	1.404	0.166	-0.162	0.920
TPO (days)	-0.015	0.012	-0.157	-1.212	0.230	-0.040	0.010
CRIq tot	-0.077	0.061	-0.165	-1.271	0.209	-0.198	0.044
Abuse history	3.307	3.006	0.143	1.100	0.276	-2.711	9.325
Psychiatric history	-1.580	3.372	-0.061	-0.468	0.641	-8.330	5.171
LCF at admission	1.945	0.881	0.279	2.209	0.031	0.182	3.708
DRS at admission	-1.353	0.707	-0.244	-1.915	0.060	-2.768	0.061
LCF at discharge	3.611	0.785	0.517	4.600	0.000	2.040	5.182
DRS at discharge	-1.497	0.593	-0.315	-2.526	0.014	-2.684	-0.311
GOS at discharge	4.707	1.483	0.385	3.173	0.002	1.738	7.677
Time between event and follow-up (years)	0.312	0.518	0.079	0.603	0.549	-0.725	1.350

Dependent variable: total CIQ Score at follow-up; independent variables: demographic characteristics and clinical data at admission and discharge.
SE: standard error; CI: confidence interval; CIQ: Community Integration Questionnaire; TPO: time postonset; CRIq: Cognitive Reserve Index Questionnaire; LCF: levels of cognitive functioning; DRS: Disability Rating Scale; GOS: Glasgow Outcome Scale.

TABLE III.—*Multivariate linear regression.*

Model	B	SE	Beta	T	P value	95% CI lower	95% CI upper
Model A (R^2=0.307)							
Age (years)	-0.210	0.045	-0.508	-4.635	0.000	-0.301	-0.119
LCF at admission	1.423	0.766	0.204	1.859	0.068	-0.110	2.956
Model B (R^2=0.398)							
Age (years)	-0.173	0.046	-0.419	-3.766	0.000	-0.266	-0.081
LCF at discharge	1.948	1.060	0.279	1.837	0.072	-0.177	4.073
DRS at discharge	-0.460	0.651	-0.097	-0.707	0.483	-1.766	0.845
GOS at discharge	1.223	1.425	0.100	0.858	0.394	-1.633	4.079

Dependent variable: total Community Integration Questionnaire (CIQ) Score at follow-up; independent variables: demographic characteristics and clinical data at admission (model A) and discharge (model B).
SE: standard error; CI: confidence interval; CIQ: Community Integration Questionnaire; LCF: levels of cognitive functioning; DRS: Disability Rating Scale; GOS: Glasgow Outcome Scale.

nificantly associated only with a younger age (B=-0.173, P<0.001, R^2=0.398). Finally, a comparative analysis of demographic and clinical characteristics at both admission and discharge of included and excluded patients has been performed (Supplementary Digital Material 1: Supplementary Table I). These two groups were comparable in terms of clinical scales at admission (LCF and DRS), they significantly differ in age (included/excluded: 53.8 [34.1] *vs.* 73.4 [24]; P<0.001), and in all the functional scales performed at discharge: LCF 6 (IQR: 2) *vs.* 4 (IQR: 3), P<0.001; DRS: p5 (IQR: 2) *vs.* 7 (IQR: 3); P<0.001 and GOS: 3 (IQR: 1; min-max: 2-5) *vs.* 3 (IQR: 1; min-max: 1-5); P<0.001.

Discussion

Six years after the acute event, about half of sTBI patients referred to our IRU died between discharge and follow-up, one-third of the survivors showed a very low participation if compared with previous studies explor-

ing moderate to severe TBI long-term participation[23] and two-thirds of the survivors presented a moderate to good participation level. In this last group, about 60% of the patients returned to their previous productive activity (work or study) at the follow-up time. Younger age was the only early predictor of higher long-term participation both considering admission and discharge time points. These results, the firsts on the Italian population for the best of our knowledge, are hardly comparable with other studies including both moderate and severe TBI[12] since these populations are consistently different and reveal the complexity of sTBI patients. Indeed, under the same umbrella label of sTBI, one finds extremely heterogeneous patients' profiles with rehabilitation trajectories that veer toward very different "community integration" outcomes. The importance of long-term studies in this specific population to identify those patients with a profile of better "community integration" stands out consequently. Alongside the strictly functional-related aspects of participation, the definition of "community integration" also embraces

basic elements, including interpersonal relationships, independence, and the possibility to participate actively in meaningful daily life activities.[24] Thus, the importance of an accurate assessment of the "community integration", in addition to its deep relationship with the Quality of Life[25] is closely related to the rehabilitation pathway starting from the admission in the IRU. Indeed, the World Health Organization released Guidelines for Essential Trauma Care emphasizing the importance of surveillance data to reduce the global burden of death and disability from injuries.[26] Specifically, data collection on long-term participation state in patients with sTBI would enable clinical teams to determine the full extent of physical, mental, and socioeconomic post-trauma sequelae[27] allowing accurate communication with patients' families. In addition, such data collection enables the personalization and the planning of territorial rehabilitation pathways. Finally, long-term data collection is a valuable tool for monitoring the use of National Health System resources, to investigate the effects of treatment and management decisions for patients,[28, 29] enabling continuous quality improvement projects and trials; and forming registries that can, in turn, be incorporated into care pathways, injury prevention strategies, and policies.[30] However, this important goal of rehabilitation is scarcely covered by rehabilitation community and health policies, as demonstrated by the limited number of published studies involving this specific population surviving a sTBI.[31] This lack of interest is hardly conceivable, since TBI of all severities are the main cause of disability in young adults, generating non-negligible costs for national health systems.[3, 32] Despite improvements in injury surveillance data, studies on disability and long-term functional outcomes remain poorly recorded[33] and very little has been published on the challenges faced in facilitating long-term follow-up and collection of outcomes.[31] Among existing research, clinic-level data collection efforts have been hampered by factors such as weak health care and long-term support infrastructure, resulting in a lack of regular follow-up of trauma patients.[28] The present study, by using a phone interview of patients or caregivers of patients discharged from an IRU after a sTBI, provides valuable information to help clinicians in drawing the rehabilitation pathway. The CIQ[34] was chosen in the present work to measure participation, evaluating three related but distinct areas of integration: home integration, social integration, and integration into productive activities[34]. Several reasons have motivated this choice. First, the Italian version of the CIQ has been used referring to the minimum assessment

protocol for the rehabilitation of patients with severe acquired brain injury outcomes.[14] Second, although it presents some critical issues, the CIQ has good face validity for measuring community integration post-TBI and shows good predictive validity. Third, it presents several advantages over other measures of participation, such as shortness, ability to focus on recent life events, good test-retest reliability, and internal consistency.[34] Fourth, the CIQ is easily administrable to caregivers since relatively similar results are obtained regardless of whether the respondent is the individual with TBI or a family member.[34] Indeed, it has adequate to excellent reliability for use with proxies, with kappa coefficients that ranged from 0.42 (shopping) to 0.94 (school).[35] Fifth, the CIQ provides a quantitative index of community integration that is sensitive to living situations (institutional setting or home), thus providing applicability in the different life context of the assessed patients.

Limitations of the study

This study has some limitations that warrant discussion. First, this study is a retrospective analysis of data collected in a single center and with a relatively small sample size, thus limiting the statistical power of the reported associations, in particular for the few patients who reached a good level of participation. Thus, the generalization of these results should be done with caution. However, data concerning the long-term status of patients discharged from an IRU after a sTBI are extremely rare, at least in the Italian setting, and in this context, this work takes on a certain translational value. Second, the participation level before the event is not documented by the CIQ. Nevertheless, data concerning the pre-event work ability was available, and the CRIq, partially reporting the patient's lifestyle before the traumatic event, has been included in the analysis. To obtain the compliance of interviewees and make the follow-up feasible, we built a short questionnaire to be easily administered by phone. For these reasons, only some aspects such as disability (pGOSE), participation (CIQ) and cognitive evaluation (T-MoCA) were investigated while others like self-sufficiency in activities of daily leaving were omitted, although we acknowledge that we may have missed some relevant information. Another limitation worth discussing is the relatively high rate of excluded patients (26.8%). For this purpose, demographic and clinical data at admission and discharge were compared between included and excluded patients. From this analysis (Supplementary Table I), we can observe that excluded patients were older and more severe both at admis-

sion and discharge as measured by all the clinical scales. Although it is well documented that traumatic brain injuries are more frequent in younger male patients,[36] this difference is also partially responsible for the very young median age of our population. Third, we did not include any imaging parameter among the variables at the IRU admission. The importance of the pathological heterogeneity of focal and diffuse TBI on determining the long-term outcome has been suggested[37, 38] and further longitudinal studies should be performed to explore their effects on long term participation. Finally, further rehabilitation administered after the IRU discharge was not investigated in this study, that might have a relevant impact on this outcome. Indeed, the accuracy of our predictive models was rather low, suggesting that some relevant potential predictors were not included in our analysis. Nevertheless, we do provide some preliminary models to allow clinicians to estimate the long-term participation outcome during the early rehabilitation phase.

Conclusions

In conclusion, sTBI includes a heterogeneous population that presents different rehabilitation trajectories. Assessing their long-term "community integration" may be a good way to better identify patients with higher rehabilitation perspectives and act accordingly from the subacute phase. Further studies are needed to better define the profiles related with a better participation outcome and consolidate the shift toward precision rehabilitation.

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