Measuring early predictors for recovery of walking ability in patients with moderate and severe traumatic brain injury. A feasibility study.

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Contents

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Nederlandse samenvatting

Achtergrond Patiënten met traumatisch hersenletsel (THL) blijven op langere termijn vaak beperkt door motorische stoornissen, zoals een verminderde zelfstandige loopvaardigheid. Inzicht in de predictoren voor loopvaardigheid in de klinische fase geeft de fysiotherapeut de mogelijkheid eerder risicopatiënten te identificeren en het revalidatietraject te verbeteren door 'op maat' gemaakte interventies te starten die gericht zijn op het optimaliseren van de zelfstandige loopvaardigheid.

Doel Toetsen of het praktisch haalbaar is om functionele uitkomstmaten tijdens de klinische fase te meten bij patiënten met middelzwaar- (MTHL) en ernstig traumatisch hersenletsel (ETHL).

Design Een prospectieve observationele pilotstudy.

Methode Twaalf patiënten, opgenomen in het de Radboud Universiteit Nijmegen Medisch Centrum, werden binnen 72 uur na het ontstaan van THL geïncludeerd. Een set van 12 functionele uitkomstmaten werd gemeten, met een follow-up van 1 en 2 weken na het THL. Per functionele variabele werd gekeken of deze voldeed aan de volgende haalbaarheidscriteria: T0: 50%, T1: 50-75% en T2: 75%. Beperkende factoren voor het meten van functionele uitkomstmaten werden gerapporteerd.

Resultaten De hoogste haalbaarheidscores werden gevonden op de Brunnstrom stadia (T1=87,5%, T2=83,3%) en de Modified Ashworth Scale (MAS) (T1=75%, T2=83,3%). Functionele uitkomstmaten op activiteitenniveau, scoorden laag (T0=16,7%, T1=7,5%, T2=50%). Tijdens de eerste 2 weken na THL waren patiënten niet in staat om een looptest uit te voeren (T0, T1, T2=0%). Het meten van functionele uitkomstmaten werd beperkt door factoren zoals sedatie, slechte instrueerbaarheid, bedrust, beperkte belastbaarheid of afwezigheid van loopvaardigheid.

Beperkingen De generaliseerbaarheid is laag vanwege de kleine steekproefgrootte (n=12), het design van een single-center studie in een academisch ziekenhuis en de consequentie dat patiënten die het ziekenhuis verlieten, uitvielen (50%).

Conclusie Het is haalbaar om de Brunnstrom stadia en de MAS te meten tijdens de klinische fase bij patiënten met MTHL en ETHL. Andere functionele uitkomstmaten zijn beperkt meetbaar binnen de eerste 2 weken na THL.

Woorden: 292

Abstract

Background Survivors after traumatic brain injury (TBI) often suffer from long-term disability in motor functions including gait. Predicting motor recovery in the first clinical phase after traumatic brain injury is important to choose the most appropriate rehabilitation setting.

Objective The purpose of this study was to examine the feasibility of measuring functional outcomes in patients with moderate (MTBI) and severe traumatic brain injury (STBI) at the clinical phase.

Design A prospective observational pilot study was conducted.

Methods Twelve patients were included at the Radboud University Nijmegen Medical Centre within 72 hours after onset of TBI. A set of 12 functional outcomes was measured, with a follow up at one and two weeks after TBI. Each functional variable was examined whether these met the following feasibility criteria: T0: 50%, T1: 50-75% and T2: 75%. Barriers hampering the assessment of functional outcomes, were reported.

Results The highest feasibility scores were found at the Brunnstrom stages (T1=87.5%, T2=83.3%) and the Modified Ashworth Scale (MAS) (T1=75%, T2=83,3%). Functional outcomes at the level of activities, scored low (T0=16.7%, T1=37.5%, T2=50%). During the first 2 weeks after trauma none of the patients was able to perform a walking test (T0, T1, T2=0%). Assessments were hampered by barriers like sedation, not able to follow instructions, bed rest, reduced physical capacity or no walking ability.

Limitations A single-center study in an university hospital, with a small sample (n=12) and a large number of lost to follow two weeks after trauma (50%), reduced the generalizability.

Conclusions The measurements Brunnstrom stages and MAS were feasible to measure in the clinical phase in patients with MTBI and STBI. Other functional outcomes were limited to assess within two weeks after TBI.

Words: 272

Introduction

Traumatic brain injury (TBI), by definition, is any damage to the brain occurring after birth and not related to congenital disorders, developmental disabilities or progressive processes.[1] In the Netherlands, annually 10,000 to 50,000 adults are diagnosed with TBI.[2] After brain injury, patients with moderate (MTBI) to severe traumatic brain injury (STBI) suffer from cognitive problems and limited physical functioning, such as reduced independent walking ability. The level of physical constraints depends on the amount of structural damage, type and severity of trauma.[3,4,5] Decreased independent walking ability leads to an increased risk of falling, reduced physical capacity, limited participation in society and decreased quality of life.[6,7] Therefore, optimizing walking ability is one of the core treatment goals for physical therapy in patients with MTBI and STBI, during their rehabilitation period.[8,9]

Studies have shown that 73-85% of the patients with STBI reached an independent walking ability within six months.[3,10] Most recovery takes place during the first three months after the onset of brain damage.[8] Therefore it is recommended that physical therapy focusing on improved walking ability, starts as early as possible after trauma.[3]

Existing research focused on the severity and type of brain damage, coma duration, age and level of ambulation to predict the recovery of independent walking ability.[10,11,12] Although these outcomes are useful in predicting the outcome, they cannot be influenced or modified by physical therapy interventions. Prospective cohort studies have shown that the existence of trunk control during sitting and muscle strength, measured during the rehabilitation phase, are important prognostic outcomes of the outcome for the recovery of independent walking ability after MTBI and STBI.[10,13] Unfortunately, most previous studies did not investigate these functional outcomes in relation to recovery of walking ability in the very early stages of recovery. Such findings raise the possibility that simple bedside tests (e.g. sensibility, muscle strength, trunk control, postural control), measured by physical therapists in the clinical phase, might predict the recovery of independent walking ability in patients with MTBI and STBI.

Early prediction of final functional outcome for recovery of independent walking ability is crucial for trauma management. To reduce the increasing health care costs, discharge planning should immediately start within the first days after trauma.

As yet, the feasibility of testing early in the course of TBI recovery, particularly for those who are severely injured, has not been adequately shown. In the pilot study presented here, we propose to test the feasibility of measuring functional outcomes in the clinical phase in patients with MTBI and STBI. We expect that it is difficult to assess functional outcomes by a physical therapist within 72 hours after TBI because of acute life threatening situations or complications. However, it is probably a perfect moment to identify and monitor the patient's health status. Probably, one week after TBI will be more feasible to assess functional outcomes, although outcomes like standing and walking performance will be limited by the poor physical capacity of the patient and Red Flags for mobilization. Overall, assessing functional outcomes will be restricted when patients are not able to follow instructions due to cognitive impairments.
In this pilot study we want to explore the feasibility of measuring functional outcomes in the clinical phase. Subsequently, we want to perform a large multi-centre prospective cohort study. That study will focus on whether functional outcomes might be predictors for recovery of independent walking ability six months after onset of TBI.

Methods

Study design and setting

A prospective observational pilot study was performed at the Radboud University Nijmegen Medical Centre (RUNMC) from February 2012 till May 23rd 2012. The involved departments of the RUNMC were the Intensive Care Unit (ICU), Medium Care Unit (MCU), Neurology, Neurosurgery and Rehabilitation. Patients with MTBI and STBI were evaluated within 72 hours after onset of the TBI, with a follow up at one and two weeks after TBI.

Participants

Adult patients were eligible when they met the following criteria: MTBI (Glasgow Coma Scale (GCS) score 9-12) and STBI (GCS score 3-8)[14], age between 18 to 85

years, command of the Dutch language and a normal premorbid cognition (at least primary education).[15]

Patients were excluded if the following criteria were present premorbid: a terminal illness[16,17], neurological disorders[18] and a limited walking ability (Functional Ambulation Categories (FAC) <4). Comorbid exclusion criteria were: traumatic spinal cord injury[16,17,19] and presence of fractures of the pelvis or lower extremities which hamper the start of mobilization.[18]

Outcomes

All study outcomes are presented in Table 1 and explained in detail below. These outcomes were measured at the level of the patient, the disease and function according to the International Classification of Functioning, Disability and Health (ICF).[20]

Walking ability – ICF level of activities

The ambulatory level of independency of walking was assessed with the FAC. This instrument distinguishes between six levels ranging from 'unable to walk' (i.e. score 0) to 'able to walk independently anywhere' (i.e. score 5).[21,22] To measure mobility, the Rivermead Mobility Index (RMI) was used. The RMI comprises a series of 14 questions and one direct observation. The questions cover a range of activities from for instance turning over in bed to running.[23] The Ten-Meter Walking Test (10MWT) was used to assess walking speed (m/s).[24,25] The Timed Up and Go test (TUG) was used to measure, in seconds, the time taken by an individual to stand up from a standard arm chair, walk a distance of three meters, turn, walk back to the chair, and sit down again.[26]

Furthermore the Six Minutes Walking Distance (6MWD) was performed to estimate functional exercise capacity. This test measures the distance that a patient can walk as fast as possible on a flat, hard surface during a period of six minutes.[27,28] In this study, the 6MWD was always examined at the same 20-meter corridor of the hospital department.

Potential functional predictors - ICF level of body function

To evaluate motor impairment, the Brunnstrom stages were used.[29] When Brunnstrom stage >3 was present, the muscle strength was measured with the

Medical Research Council Scale (MRC).[30] Furthermore sensible impairment (tactile and proprioception) was noted by the (modified) Nottingham Sensory Assessment ((m)NSA). The Modified Ashworth Scale (MAS) was used to evaluate the presence of spasticity.[31]

Potential functional predictors - ICF level of activities

The Trunk Control Test (TCT) was used to evaluate the trunk control, particularly in terms of balance during sitting.[32] Transfers in and out of the bed were examined with the Transfer Intensive Care scale (TIC). Furthermore, the Berg Balance Scale (BBS) was used to assess postural control during body transfers and static and dynamic 'standing balance' tasks.[33,34] This scale comprises 14 tasks (score range 0-4) yielding a maximal total sum score of 56 points.

Prognostic outcomes - ICF level of disease

Inter Cranial Pressure (ICP)[35] (only available when the patient had an ICP-meter during Intensive Care Unit (ICU) stay) and the Glasgow Coma Scale (GCS) to record the state of consciousness[14] were measured.

To describe the population and taking account of potential confounders, the following outcomes were assessed at baseline or calculated after two weeks follow up: date and kind of accident, cerebral computer tomography (CT) scan to detect type and localization of brain damage and the presence of hematoma, pupillary reactivity, hypertension, hypoxia, Post Traumatic Amnesia (PTA) duration,[36] if the patient was intubated, the Mechanically Ventilation (MV) time, type of remaining injuries, complications or operations, if the patient needed resuscitation, duration of ICU stay and if there were any Red Flags for mobilization of the patient.

Population outcomes - ICF level of patient

Finally, the following population outcomes were asked at baseline: age, gender, body weight, length, BMI and level of education.

Study procedure

Inclusion took place within 72 hours after the TBI by a physical therapist who screened the hospital admission list for inclusion criteria using the Electronic Patient

File (EBF) of the RUNMC. After inclusion, data was collected by using a Case Record Form (CRF). By incomplete data a (hetero) anamnesis was used. Physiotherapy started within 72 hours after TBI upon approval of the physician. Clinical rating scales, according to the first physiotherapy consultation, were measured if possible. Approval depended on the hemodynamic function, consciousness and capacity of the patient. If there were no restrictions, the first physiotherapy consultation took place at the ICU, MCU, neurology or neurochirurgical department. Clinical rating scales were measured beside the hospital bed.

Study size

Because some measurements that we propose have not been included in previous studies and it is therefore unknown whether these measurements are measurable in such an early stage, we decide to explore feasibility among a small subset of patients (n=12) first. This was preferred above a sample size calculation to avoid that a large number of subjects (often needed in rehabilitation studies because of small effect sizes) will be unnecessarily exposed to measurement procedures that appear to be invalid at the end of the study.

Statistical Analysis

Data were analysed by using SPSS (version 18). Cohort demographics, mean or number and percentage were described. Feasibility scores of the functional outcomes were prescribed in percentages. The primary objective was determined according to the feasibility criteria, based on our hypothesis[37]:

- ✓ Within 72 hours after TBI (T0), 50% of all eligible patients, functional outcomes can be measured.
- ✓ One week after TBI (T1), at least 75% of all eligible patients, all functional outcomes at the ICF level of function can be measured.
- ✓ One week after TBI (T1), at least 50% of all eligible patients, all functional outcomes at the ICF level of activities can be measured.
- ✓ Two weeks after TBI (T2), at least 75% of all eligible patients, all functional outcomes can be measured.

Results

Participants

Figure 1 provides an overview of the patients assessed. Of the 27 patients with STBI and MTBI who were admitted to the RUNMC, a total of 12 (44.4%) patients were included. All of these patients were measured within 72 hours after TBI (T0). Two patients died within the first week after TBI. Another two patients were transferred to a local hospital. Thus, a total of eight (66.7%) patients participated in the first follow-up, one week after TBI (T1). Because of transferring to a local hospital or rehabilitation clinic, two patients were lost to follow up within the second week after TBI. At least, a total of six (50%) patients were eligible to participate two weeks after TBI (T2).

Descriptive data

Table 2 presents the medical and demographical data of all (n=12) TBI patients included in the study. The average age of the participants was 52,7 (range 22-73) years, including seven (58.3%) men and five (41.7%) women. In seven patients trauma was caused by traffic accident; in one patient during motorsports; and four patients had fallen from a height. Eleven patients (91.7%) suffered from STBI and one patient had MTBI. Most patients had a combination of type of trauma, although it was usually a hemorrhage (68.2%) located in the right hemisphere (75%).

Feasibility scores

Table 3 presents the feasibility scores of each functional variable at T0, T1 and T2. The highest feasibility scores were found at the Brunnstrom stages (T1=87.5%, T2=83.3%) and the MAS (T1=75%, T2=83.3%). Functional outcomes at the ICF level of activities, including postural control during body transfers and standing balance tasks, seem to have scored low (T0=16.7%, T1=37.5%, T2=50%). During the first two weeks after trauma none of the patients was able to perform a walking test (T0, T1, T2=0%).

Barriers

Furthermore, we analyzed the different barriers hampering the assessment of functional outcomes at T0 (table 4a), T1 (table 4b) and T2 (table 4c).

In six out of the 12 patients (50%), sedation was a major barrier (50-100%) for the assessment of all of the functional outcomes at T0. One week after trauma one of the eight patients was sedated. This hampered the assessment of all functional outcomes for 12.5% to 100%. Two weeks after trauma this patient was still sedated, making the assessment of all functional outcomes impossible (16.7-100%).

For some of the assessments, it is necessary that the patients follow instructions. Therefore, not following instructions seemed to be a major barrier (62.5-100%) in nine of the 12 patients (75%) at T0; in five of the eight patients (62.5%) at T1; and in one of the six patients (16.7%) at T2.

T0 showed different Red Flags for mobilization of the patients; ICP monitoring (58.3%), sedation (50%), excised bone after decompressive craniectomy (16.7%), External Ventricular Drainage (EVD) (8.3%), neurological decline (8.3%), fever (8.3%) and an unstable vertebral fracture (8.3%). Some outcomes (Brunnstrom stages, MAS, (m)NSA, MRC) could be tested on the hospital bed. Bed rest was not a barrier for the assessment of these outcomes. In contrast, outcomes measuring physical activity outside the bed were often restricted by prescribed bed rest. This was a barrier for nine of the 12 patients (75%) at T0; in 37.5-60% a barrier in three of the eight patients (37.5%) at T1; and in 50-100% a barrier in three of the six patients (50%) at T2.

Particularly, reduced physical capacity was a barrier in the assessment of functional outcomes at the ICF level of activities, including muscle strength, transferring, standing and walking. As time passed, reduced physical capacity was perceived as a barrier in a smaller amount after two weeks (25-33.3%) compared to T0 (66.7-70%) or one week after trauma (50-60%).
When patients were not able to walk (FAC <3), functional outcomes assessing walking ability and walking capacity could not be measured in 100% of the cases.

In a few cases, there were other reasons why functional outcomes were not assessable. Pain was in 10% of the patients a barrier to assess TIC and BBS at T0. Assessment of the FAC was hampered by pain (10%) and the presence of an unstable vertebral fracture (10%) at T0. Pain (16.7%) and the presence of an

unstable vertebral fracture (8.3%) were also barriers for measuring TUG, 10MWT and 6MWD at T0.

Discussion

The purpose of this study was to test whether and when it is feasible to measure functional outcomes in the clinical phase in patients with MTBI and STBI. Our results showed that the Brunnstrom stages and the MAS were measurable in 50% of all eligible patients at T0 and in 75% of all eligible patients at T1 and T2. According to our feasibility criteria, these outcomes were feasible at T0, T1 and T2. Because it was not necessary that patients needed to follow instructions, these functional outcomes were most feasible.

Within 72 hours after TBI, a physical therapist is limited to measure functional outcomes as a result of barriers like sedation, not able to follow instructions, bed rest, no physical capacity or not able to walk. As hospitalization progresses, assessment of functional outcomes became more feasible probably due to the effect of recovery after TBI or physical therapy.[9] The most striking finding was that the MRC and (m)NSA was measured better at T2 (33.3%) compare with T1 (37.5%). We expected that the feasibility of these functional outcomes would increased over time. However, these results could be explained by the fact that patients with good recovery had transferred to a local hospital.

However, none of the remaining six patients were able to walk two weeks after TBI. This might be caused by selection of the severely affected patients who still needed specialized care in a university hospital instead of transferring to a general hospital or even discharged home. Only one of the six patients was able to walk with the support of one person (FAC score = 2), at T2.

Another explanation for the absence of recovery of walking ability could be the Red Flags for mobilization such as ICP monitoring in combination with sedation (33.3%), excised bone after decompressive craniectomy (33.3%) and External Ventricular Drainage (EVD) (33.3%), in three patients, two weeks after trauma.

This is the first study that describes the assessment of functional outcomes in the clinical phase after MTBI and STBI. Katz et al.[10] and Black et al.[13] also described measurement of functional outcomes in patients with MTBI and STBI, only during the rehabilitation phase. In contrast to our study, they were not faced with the barriers

related to the early phase after TBI. Presence of hampering barriers would be an explanation why functional outcomes have never been studied in the clinical phase after TBI. This study confirms that there are many barriers hampering the application of outcomes but adds that the Brunnstrom and the MAS, can be measured early.

Also different from our study, Katz et al.[10] and Black et al.[13] studied functional outcomes with the aim to predict recovery of independent walking ability, however, they did not described feasibility of these outcomes.

Kalmar et al. (ref 45) examined the feasibility of a brief neuropsychologic test battery during acute inpatient rehabilitation after MTBI and STBI. Approximately two thirds of screened patients were able to complete a brief neuropsychologic test battery at two to six weeks post injury, regardless of PTA status.[38] In contrast to our study, patients with minimally conscious were excluded. Tests were performed at admission to inpatient rehabilitation within 72 hours of discharge from acute care. Therefore they were not hampered by barriers like sedation or patients who were not able to follow instructions. Although we started measuring early during the clinical phase, none of the patients hemodynamic instability was hampering the assessment. Kalmars study[38] investigated the feasibility of neuropsychological tests, so bed rest, conditional capacity or walking ability were no hampering barriers, compared to our study.

Limitations

This was a pilot study including its limitations. First, the single-center study in an one university hospital makes generalizability of the findings difficult.

Second, the sample size (n=12) was probably caused by a short inclusion period, and consisted mainly of patients with STBI with a heterogeneity type of brain injury that also reduced the generalizability. Probably caused by the fact that this pilot study was performed at a level one trauma center, where generally the severely affected patients are admitted. In addition a large number of patients were lost to follow two weeks after trauma (50%), due to transferring to a general hospital. If we would be able to include a larger number of patients with MTBI, performing an multi-center study, it would be more feasible to assess functional outcomes, given the better cognitive and motor function of this population compared to patients with STBI.[3]

Early mobilization of ICU patients is usual care at the RUNMC, even in patients with TBI.[39] Therefore, it might be easier and more quickly feasible to assess functional outcomes in this setting. This could introduce some treatment and policy bias.
Finally, the feasibility criteria can be discussed. They were based on clinical experiences of the physical therapist and might have been too ambitious.

Recommendations for future research

For the implementation of a larger trial, we recommend to use more observational functional outcomes to assess the functional recovery of patients with MTBI and STBI, including observations of the presence of spontaneous motor activity of extremities. Including the Brunnstrom stages and the MAS.
However, to predict recovery of walking ability it would be necessary to measure functional outcomes at the ICF level of activities including walking tests at baseline. Therefore, measurements of functional outcomes should be started two or three weeks after MTBI and STBI including a longer follow-up. Probably the test battery could be minimized, so patients would be able to perform the measurements, despite of reduced physical capacity.
Furthermore, we want to perform a multi-center study, so it might be possible to continue the assessment when the patient is transferred to a local hospital. In addition, the possibility rises to include more patients because of the heterogeneity in patients with TBI.

Conclusion

The measurements Brunnstrom stages and MAS were feasible to measure in the clinical phase in patients with MTBI and STBI. Other functional outcomes at the ICF level of function and capacity were not feasible to measure within two weeks after TBI.
Considering the results of present study, it is questionable whether it is even possible to assess functional outcomes during the first weeks after TBI, to predict recovery of independent walking ability six months after onset of TBI. We might need to search for other predictors for recovery of walking ability as pre-existing outcomes including age or pre-existent functioning.

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Tables and figures

Figure 1: Flow chart participants

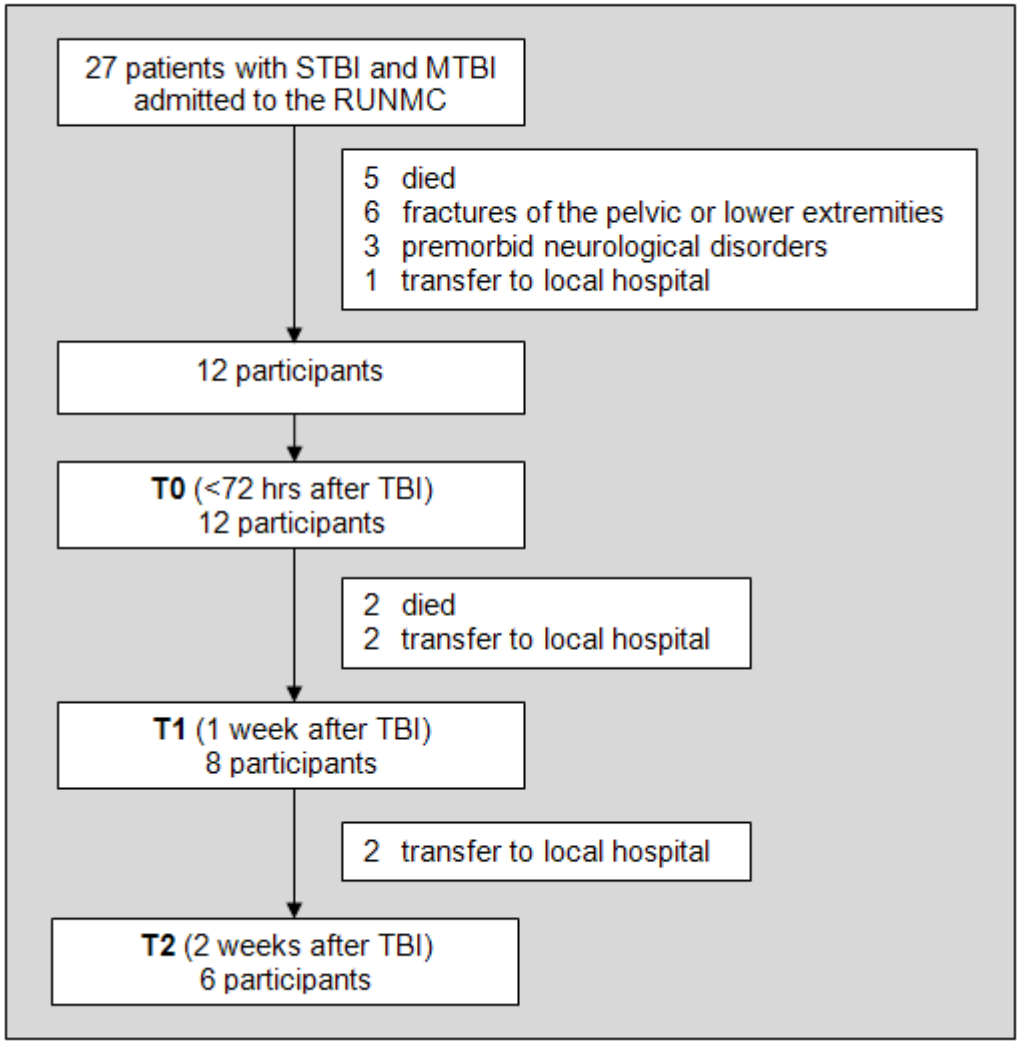

Table 2: Medical and demographical data of the participants

			TBI patients (n=12)
Mean age in years (range)			52,7 (22-73)
Gender (male/female)			7/5
BMI (kg/m²) mean (range)			25.2 (21.5-29.5)
Kind of accident	traffic accident	motor	1
		bicycle/scooter	6
	sport accident		1
	fall from a height		4
Severity of trauma	STBI		11
	MTBI		1
Type of trauma*	contusion		4
	SDH		8
	EDH		1
	SAH		4
	DAI		2
Localization of trauma	left hemisphere		3
	right hemisphere		7
	both sides		2

*Data are means (range) or numbers. TBI, Traumatic Brain Injury; BMI, Body Mass Index; kg, kilogram; m, meter; STBI, Severe Traumatic Brain Injury; MTBI, Moderate Traumatic Brain Injury; SDH, Subdural Hematoma; EDH, Epidural Hematoma; SAH, Subarachnoid Hemorrhage; DAI, Diffuse Axonal Injury. * Combination of type of trauma possible*

Table 3: Feasibility scores for the functional outcomes.

	Feasibility score		
Functional outcomes	**T0 (n=12)**	**T1 (n=8)**	**T2 (n=6)**
ICF level of function			
Brunnstrom stages	50	87.5	83.3
MAS	50	75	83.3
(m)NSA	33.3	37.5	33.3
MRC	25	37.5	33.3
ICF level of activity			
TCT	16.7	37.5	50
TIC	16.7	37.5	50
BBS	16.7	37.5	50
RMI	16.7	37.5	50
FAC	16.7	37.5	50
TUG	0	0	0
10MWT	0	0	0
6MWD	0	0	0

Data are percentages (%). T0 = <72 hrs after TBI; T1 = 1 week after TBI; T2 = 2 weeks after TBI. (m)NSA, (modified)Nottingham Sensory Assessment; MRC, Medical Research Council scale; MAS, Modified Ashworth Scale; TCT, Trunk Control Test; TIC, Transfer Intensive Care scale; BBS, Berg Balance Scale; RMI, Rivermead Mobility Index; FAC, Functional Ambulation Scale; 10MWT, Ten Meter Walking Test; TUG, Timed Up and Go test; 6MWD, Six Minutes Walking Distance.

Table 4a: Overview of barriers hampering the assessment of functional outcomes at T0 (n=12).

Functional outcomes / Barriers	Brunnstrom stages (n=6)	MAS (n=6)	(m)NSA (n=8)	MRC (n=9)	TCT (n=10)	TIC (n=10)	BBS (n=10)	RMI (n=10)	FAC (n=10)	TUG (n=12)	10MWT (n=12)	6MWD (n=12)
Sedation	6 (100%)	6 (100%)	6 (75%)	6 (66.7%)	6 (60%)	6 (60%)	6 (60%)	6 (60%)	6 (60%)	6 (50%)	6 (50%)	6 (50%)
Not able to follow instructions	n.a.	n.a.	8 (100%)	9 (100%)	9 (90%)	9 (90%)	9 (90%)	9 (90%)	n.a.	9 (75%)	9 (75%)	9 (75%)
Bed rest	n.a.	n.a.	n.a.	n.a.	9 (90%)	9 (90%)	9 (90%)	9 (90%)	9 (90%)	9 (75%)	9 (75%)	9 (75%)
No physical capacity	n.a.	n.a.	6 (75%)	6 (66.7%)	7 (70%)	7 (70%)	7 (70%)	7 (70%)	7 (70%)	8 (66.7%)	8 (66.7%)	8 (66.7%)
Not able to walk	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	12 (100%)	12 (100%)	12 (100%)

Table 4b: Overview of barriers hampering the assessment of functional outcomes at T1 (n=8).

Functional outcomes / Barriers	Brunnstrom stages (n=1)	MAS (n=2)	(m)NSA (n=5)	MRC (n=5)	TCT (n=5)	TIC (n=5)	BBS (n=5)	RMI (n=5)	FAC (n=5)	TUG (n=8)	10MWT (n=8)	6MWD (n=8)
Sedation	1 (100%)	1 (50%)	1 (20%)	1 (20%)	1 (20%)	1 (20%)	1 (20%)	1 (20%)	1 (20%)	1 (12.5%)	1 (12.5%)	1 (12.5%)
Not able to follow instructions	n.a.	n.a.	5 (100%)	5 (100%)	5 (100%)	5 (100%)	5 (100%)	5 (100%)	n.a.	5 (62.5%)	5 (62.5%)	5 (62.5%)
Bed rest	n.a.	n.a.	n.a.	n.a.	3 (60%)	3 (60%)	3 (60%)	3 (60%)	3 (60%)	3 (37.5%)	3 (37.5%)	3 (37.5%)
No physical capacity	n.a.	n.a.	3 (60%)	3 (60%)	3 (60%)	3 (60%)	3 (60%)	3 (60%)	3 (60%)	4 (50%)	4 (50%)	4 (50%)
Not able to walk	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	7 (87.5)	7 (87.5)	7 (87.5)

Table 4c: Overview of barriers hampering the assessment of functional outcomes at T2 (n=6).

Functional outcomes / Barriers	Brunnstrom stages (n=1)	MAS (n=1)	(m)NSA (n=4)	MRC (n=4)	TCT (n=3)	TIC (n=3)	BBS (n=3)	RMI (n=3)	FAC (n=3)	TUG (n=6)	10MWT (n=6)	6MWD (n=6)
Sedation	1 (100%)	1 (100%)	1 (25%)	1 (25%)	1 (33.3%)	1 (33.3%)	1 (33.3%)	1 (33.3%)	1 (33.3%)	1 (16.7%)	1 (16.7%)	1 (16.7%)
Not able to follow instructions	n.a.	n.a.	4 (100%)	4 (100%)	3 (100%)	3 (100%)	3 (100%)	3 (100%)	n.a.	4 (66.7%)	4 (66.7%)	4 (66.7%)
Bed rest	n.a.	n.a.	n.a.	n.a.	3 (100%)	3 (100%)	3 (100%)	3 (100%)	3 (100%)	3 (50%)	3 (50%)	3 (50%)
No physical capacity	n.a.	n.a.	1 (25%)	1 (25%)	1 (33.3%)	1 (33.3%)	1 (33.3%)	1 (33.3%)	1 (33.3%)	2 (33.3%)	2 (33.3%)	2 (33.3%)
Not able to walk	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	6 (100%)	6 (100%)	6 (100%)

T0 = <72 hrs after TBI; T1 = 1 week after TBI; T2 = 2 weeks after TBI; n.a., not applicable; (m)NSA, (modified)Nottingham Sensory Assessment; MRC, Medical Research Council scale; MAS, Modified Ashworth Scale; TCT, Trunk Control Test; TIC, Transfer Intensive Care scale; BBS, Berg Balance Scale; RMI, Rivermead Mobility Index; FAC, Functional Ambulation Scale; 10MWT, Ten Meter Walking Test; TUG, Timed Up and Go test; 6MWD, Six Minutes Walking Distance.