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ORIGINAL ARTICLE

Rehabilitation pathways and functional independence one year after severe traumatic brain injury

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ABSTRACT

BACKGROUND: After severe traumatic brain injury (TBI) it is recommended that patients in need of rehabilitation be transferred directly from acute care to specialized rehabilitation. However, recent European cohort studies found a variety of care pathways and delays in admission to rehabilitation after severe TBI.
AIM: To study the pathways within rehabilitation services in a Norwegian national cohort with severe TBI and the association to functional independence 12 months post-injury.
DESIGN: Observational prospective multicenter study.
SETTING: Regional trauma centers.
POPULATION: A total of 163 adults, age 16-85 years, with severe TBI.
METHODS: The main variables were transfer between acute care and rehabilitation, type of rehabilitation services and functional independence. Results: 75% of the patients had specialized TBI rehabilitation, 11% non-specialized and 14% no in-patient rehabilitation. In total, 48% were transferred directly to specialized rehabilitation from acute units in regional trauma centers. There were no differences in injury severity between patients transferred directly and non-directly, but the direct-transfer patients were younger. At 12 months post-injury, 71% were functionally independent and 90% lived in their home. Younger age, fewer days of ventilation and shorter post-traumatic amnesia were associated with independence. Among patients treated with specialized rehabilitation, direct transfer to rehabilitation was associated with functional independence (OR=4.3, P<0.01).
CONCLUSIONS: A direct clinical pathway including specialized rehabilitation in dedicated units was associated with functional independence.
CLINICAL REHABILITATION IMPACT: Direct pathways from acute care to sub-acute specialized rehabilitation might prove beneficial to functional status.

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Key words: Critical pathway - Multicenter study - Rehabilitation - Treatment outcome - Brain injuries.

Traumatic brain injury (TBI) is a major public health issue and a health care challenge.[1] Recent European cohort studies of patients with severe TBI have found a variety of care pathways and delays in admission to rehabilitation that were negatively associated with outcome.[2-5] Early rehabilitation with a direct discharge from acute care to a rehabilitation unit seems to be beneficial.[2, 6] A multidisciplinary plan of services as well as a well-organized clinical pathway have been observed to improve functional outcome.[7] However, these studies lack detailed descriptions of care pathways in a representative broad cohort of patients with severe TBI.

Some studies conclude that patients with severe TBI should receive specialized rehabilitation after acute care.[3, 8] In 2005, the Norwegian Health Authorities recommended that patients with severe TBI in need of rehabilitation should be transferred directly from the regional acute department to a specialized rehabilitation department. These recommendations were in line with clinical TBI management procedures in other Scandinavian countries, which are based on a highly centralized continuum of care extending from the acute through the post-acute phases.[9] In previous European studies 45-50% of patients with severe TBI were referred directly from regional acute care to brain injury rehabilitation centers, 2-19% of the patients received non-specialized rehabilitation and 6-36% of the patients received no in-patient rehabilitation.[3, 5, 10] There was concern that patients were discharged without adequate assessment and management of rehabilitation needs,[3] as well as being referred directly to nursing homes.[10] Thus, there is a need to study the extent to which continuous rehabilitative care is delivered to individuals who require in-patient rehabilitation after sever TBI.

In cohort studies, older age,[3, 11] pupillary dilation, GCS score, signs of raised intracranial pressure in the CT scan, and the duration of post-traumatic amnesia [12] have been determinants of functional outcomes at one year. Additionally, less days in intensive care,[3, 5] less delays in rehabilitation admission and less post-acute complications were associated with a better functional outcome.[5] The impacts of acute injury severity indicators together with direct transfer from acute care to rehabilitation are less clear in severe TBI patients.[3-5]

Accordingly, the aims of this study were:

— to describe treatment pathways within rehabilitation services for patients with severe TBI in a Norwegian national cohort;

— to evaluate functional independence at 12 months post-injury in relation to continuous or broken pathways from a regional acute neurosurgical department to specialized TBI rehabilitation.

Materials and methods

The study was conducted in conformity with the Declaration of Helsinki, and approved by the Regional Committee for Medical Research Ethics, South-East Norway (No. SO8378a).

This project was a multicenter prospective cohort study in Norway that included adults with severe TBI who were admitted to regional trauma centers with a neurosurgical department.[13] The four participating regional trauma referral centers were the University Hospital of North Norway for the northern region, St. Olav's Hospital Trondheim University Hospital for the central region, the Oslo University Hospital for the southeast region and the Haukeland University Hospital in the western region. Only one center, the Stavanger University Hospital in the western region was not able to participate. The Norwegian hospital structure includes local hospitals that serve small areas and regional trauma centers located in university hospitals that serve the local hospitals in the region.

Participants

The inclusion period lasted from January 2009 to January 2011. The inclusion criteria were as follows: Norwegian resident; aged ≥ 16 years; admission within 72 hours to a regional trauma referral center; severe TBI defined by an unsedated Glasgow Coma Scale (GCS) score of 3-8 in the first 24 hours after injury and by ICD 10 diagnosis (S06.1-S06.9). Patients were excluded if they had pre-injury progressive or other neurological diseases or injuries (N.=19); suffered from premorbid severe psychiatric illnesses (N.=11); severe substance abuse (N.=16); or were homeless (N.=2). Patients injured abroad (N.=5) were not included, nor were patients who did not consent themselves or where a close relative declined participation on their behalf (N.=10).

A total of 278 patients were eligible for inclusion and 163 patients completed the 12-month follow-ups. Out of the original eligible group of 278 patients 100 died in the first 12 months. The majority of those, *i.e.* 80 patients, died after hospital admission.[13] Most patients died within the first 48 hours, or within 3-7 days after admission. The highest fatal outcomes were in the older patients, and in those injured by falls.[13] The total eligible sample at 12 months was 178 and the 163 participants represented 92% of the survivors included in

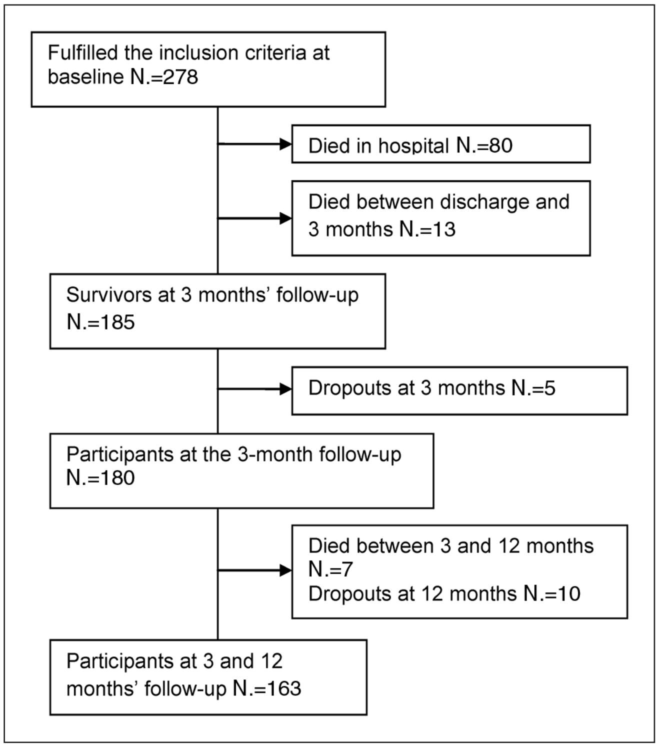

Figure 1.—Flow chart for the study.

the study [4] (Figure 1). There were no statistically significant differences in the age or gender of the 15 patients who dropped out compared with the patients who participated.

Data collection

Information was obtained from hospital records and data from the trauma registries. Additional information was collected from the patients or their relatives using a standard telephone interview at three months. At 12 months post-injury, data were primarily collected during a hospital visit using interviews and clinical evaluations (95%) or when a visit was not possible, through telephone interviews (5%).

Demographic variables were age, gender, and marital status. The level of education was dichotomized as low (12 years or less) or high (13 years or more, *i.e.*, university college / university education). The employment status was categorized as working/studying, unemployed, retired or on sick leave/receiving a pension.

Acute injury-related variables

The lowest GCS score within the first 24 hours was registered.[14] The Abbreviated Injury Severity Score (AIS) [15] and the Injury Severity Scale (ISS) were used to indicate the severity of the brain injury and total body injury.[16] The ICD-10 diagnosis of medical complications was collected from medical records. The duration of post-traumatic amnesia (PTA) was categorized as <7 days, 7-13 days, 14-20 days, 21-27 days and >27 days.[17] PTA was evaluated based on the daily nurse reports or the Galveston Orientation and Amnesia Test [18] for patients staying in rehabilitation centers. The duration of PTA was dichotomized into less than or more than 27 days for the analysis.

Elements in the treatment pathways

The length of stay (LOS) and the type of acute hospital department was recorded. The discharge place from the regional acute department (ICU or neurosurgical department) was classified as the patient's home, a nursing home (skilled nursing facility), an acute hospital department or a rehabilitation unit (specialized or non-specialized).

Figure 2 illustrates alternative continuous treatment chains from injury to the first in-hospital rehabilitation stay to a specialized TBI rehabilitation unit.[19] This study recorded instances of direct transfer from acute care in the regional ICU/neurosurgical department to a specialized TBI rehabilitation department or a non-specialized rehabilitation facility and the number of patients who had a broken chain and a delayed transfer to rehabilitation.

Description of the rehabilitation services and units

The specialized TBI rehabilitation units differed from rehabilitation in other settings in specific ways. All were physical medicine and rehabilitation departments with a defined responsibility for patients with severe TBI from early stages after trauma, *i.e.* when the patients were medically stable. These units were (generally) integrated in hospital departments or a specialized rehabilitation hospital (Guidelines for the Management of Severe Traumatic Brain Injury, 3rd edition).[20] All of the specialized TBI rehabilitation units employed multidisciplinary teams consisting of a

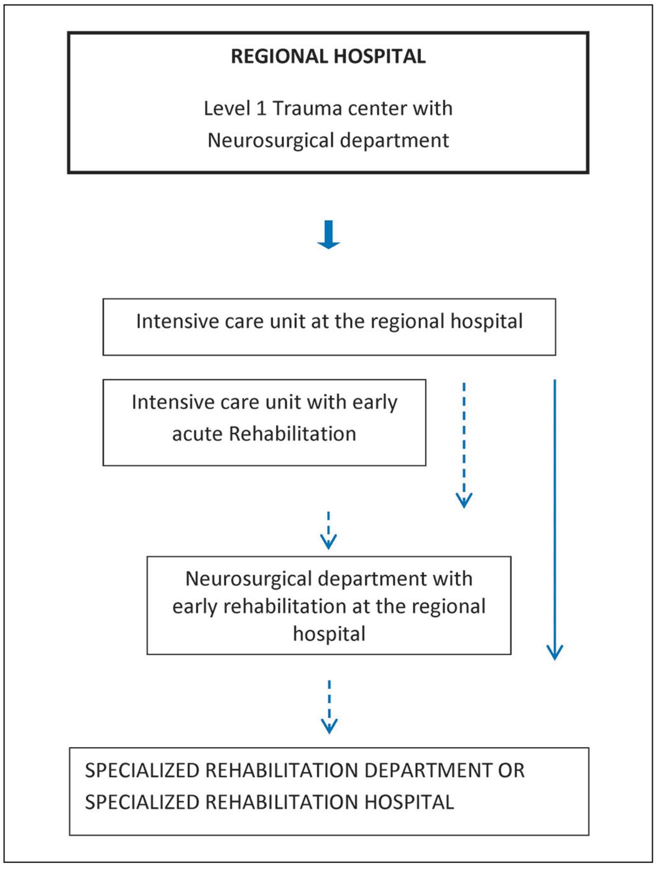

Figure 2.—The first inpatient rehabilitation stay: alternative continuous treatment chains from acute care to specialized rehabilitation care at the regional hospital department.

nurse, an occupational therapist, a physical therapist, a psychologist/neuropsychologist, a speech therapist, a medical doctor specializing in physical medicine and rehabilitation or neurology, and a social worker. Some units included additional professionals. The staffs were trained for care and rehabilitation with patients with severe TBI. All of the teams applied a rehabilitation plan that set goals for the rehabilitation process. All of the patients underwent systematic assessments, and received daily therapy on weekdays with higher intensity than in general rehabilitation units. For the patients with specific needs, therapy was also provided at night and on weekends. This therapy consisted of *e.g.* lung-therapy, mobilization and basic ADLs, provided by therapists or nurses.

The non-specialized TBI rehabilitation units were geriatric units or rehabilitation units in local hospitals. The staff had limited specific training in rehabilitation after severe TBI in the sub- acute stage. The (total) number of patients who received rehabilitation and the rehabilitation LOS and time from injury to the first and second rehabilitation stays were recorded.

Rehabilitation phases are commonly divided into acute rehabilitation, sub-acute rehabilitation and post-acute rehabilitation. These terms are used in this study, defined as follows: Acute rehabilitation occurs during coma and arousal states with the primary aims of preventing complications, regulating sensory input and increasing mobility. Sub-acute (generally in-patient) rehabilitation is designed to facilitate functioning, and its major goals are optimal physical and cognitive functioning, independence in basic and instrumental ADL and coping with the new life situation. The post-acute rehabilitation phase includes outpatient therapy to promote social participation and re-entry into the community.[21]

Rehabilitation services were recorded during the acute and sub-acute in-patient stays and comprised physiotherapy, occupational therapy, and/or rehabilitation by a multidisciplinary team. Rehabilitation services offered in the community during the post-acute phase (*e.g.*, home nursing, physiotherapy, occupational therapy, psychologist visits, and work with teachers) were also recorded. The patient's residence at the 12-month follow-up was registered as the patient's home, sheltered housing or an institution.

Ambulatory rehabilitation teams

Ambulatory rehabilitation teams are interdisciplinary teams in a hospital that provide individualized follow-up services in the community after discharge from rehabilitation. Their services often involve providing information to and guiding community-based staff and communicating with the patient and family members. In the south-east region of Norway, the ambulatory rehabilitation team visits local hospitals when patients are not transferred directly from the regional acute department to rehabilitation.

Measurements at 12 months post-injury

Functional independence was defined as the actual use of formal personal assistance at 12 months post-injury, after discharge from hospital. The concept ‘functional independence’ was broadly defined comprising self-care, and areas requiring more seldom formal assistance (housekeeping, leisure). The actual use of personal assistance was classified in the following 5 categories: several times a day, once a day, once every 7 days, once every 14 days, never. Functional independence was in the analysis dichotomized into no use of personal assistance (independent) *vs*. use of personal assistance (dependent). To evaluate the functional independence variable with respect to the proportion of functional dependent/independent individuals, we used the Glasgow Outcome Scale Extended (GOSE) [22] scores as a comparison.

Statistical analysis

The descriptive data are presented as means, standard deviations (SD) and ranges, as medians and interquartile ranges [IQRs] or as proportions of subjects within predefined categories. Cross-tabulations with χ^2 tests were performed for nominal data; the non-parametric Fisher’s exact test or Spearman’s test was performed when indicated. Independent sample t-tests or ANOVA with LSD post-hoc analysis were used to compare the means between two groups. Non-parametric statistical analyses were applied when the data were not normally distributed.

A multivariate binary logistic regression analysis was conducted with functional independence from personal assistance (dichotomized into “independent” [*i.e*., never requiring assistance] *vs*. “dependent” [*i.e*., requiring personal assistance several times a day, once a day, every week, or every two weeks]) as the dependent variable. The independent variables in model 1 (with the total population group) were demographic factors (age and gender), injury severity (lowest GCS score), artificial ventilation (days), Rotterdam CT score, AIS head score, number of complications, PTA (dichotomized as less than (=1) and more than 27 days (=2). Model 2 (with the specialized rehabilitation group) also included the LOS in rehabilitation and whether discharge from the regional acute department followed a continuous chain directly to specialized rehabilitation (=1) or a broken chain (=2). We used a manual backward procedure with removal of non-significant variables. Nagelkerke R-squares was provided. The level of significance was set at $P<0.05$. The model fit was investigated using the Hosmer and Lemeshow test. The statistical analyses were performed using SPSS for Windows version 20 (SPSS Inc., Chicago, IL, USA).

Results

Demographic details and injury-related variables for the 163 participants are presented in Table I. The proportion of male participants was 78%, and the mean age was 40 years (range 16-85, median 36). The main injury mechanisms were transportation and fall accidents. The majority of the participants (83%) had AIS head scores of 4-5. The mean lowest GCS score was 5.7±1.9.

TABLE I.—*Demographic characteristics and acute injury-related variables for 163 patients with severe traumatic brain injury.*

Variable	Value
Age (years), mean (SD)	40.1 (18.6)
Age 16-39 years	89 (55%)
Age 40-64 years	56 (34%)
Age ≥65 years	18 (11%)
Gender	
Male	127 (78%)
Female	36 (22%)
Living status	
Married/cohabiting (% married)	68 (41%)
Level of education (N.=157)	
High (>12 years), college or university	49 (31%)
Employment status (working/studying) pre-injury (N.=162)	
Working or studying	106 (66%)
Unemployed	10 (6%)
Retired	19 (12%)
On sick leave or receiving social and disability pension	27 (16%)
Cause of injury	
Transportation accident	73 (45%)
Fall accident	72 (44%)
Violence	7 (4%)
Other	11 (7%)
Injury severity	
AIS head score, mean (SD) (N.=161)	4.3 (0.9)
GCS – lowest, mean (SD)	5.7 (1.9)
ISS score, mean (SD)	28.1 (11.7)
Rotterdam CT score, median [IQR]	4 [3-4]
Length of stay in ICU (days), median [IQR]	8 [3-13]
Days with artificial ventilation, median [IQR]	5 [1-9]
Intracranial pressure elevated, recorded	44 (27%)
Craniotomy	46 (28%)
Post-traumatic amnesia (N.=160)	
<27 days	89 (54%)
>27 days	74 (46%)
Length of stay in the acute department (days), median [IQR]	13 [7-24]

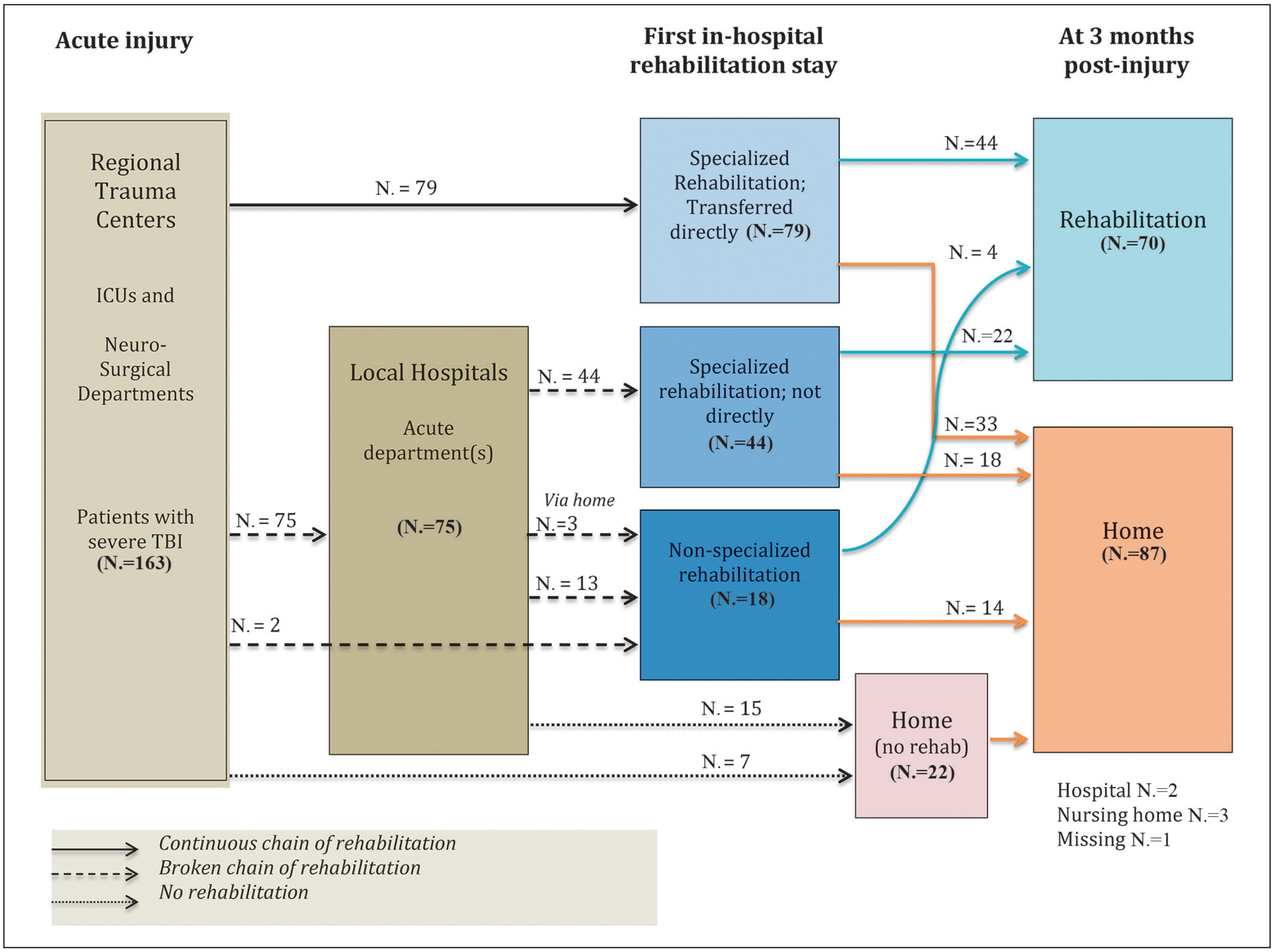

Figure 3.—Clinical pathways of care and rehabilitation in a Norwegian severe TBI cohort.

LOS and the duration of rehabilitation

The median LOS at the ICU was 13 days with IQR 7-24. The median duration of rehabilitation for the 140 patients in the sub-acute phase (first in-patient rehabilitation stay) was 36 days (IQR 10-66). The median total number of rehabilitation days during the first year post-injury, including rehabilitation during the sub-acute and post-acute phases, was 59 days (IQR 31-94.5).

Clinical pathways

As Figure 3 illustrates, 141 (87%) patients received rehabilitation. Seventy-nine (48%) patients were directly referred to specialized rehabilitation from the acute wards in the regional hospitals, whereas 62 (38%) had either a broken clinical pathway to specialized rehabilitation (N.=44, 27%) or were referred to non-specialized rehabilitation units (N.=18, 11%). Twenty-two patients (13%) were not referred to any in-patient rehabilitation during the first year post-injury. The patients with no rehabilitation were less severely injured and had significantly fewer medical complications in the acute stage than the patients who received specialized rehabilitation (Table II). The patients who were discharged directly to specialized rehabilitation were younger ($P<0.001$) and more often working/studying ($P<0.001$) than the patients who were not discharged directly to

Table II.—*Demographic and acute injury-related characteristics of 163 patients with severe traumatic brain injury according to the four different rehabilitation pathways.*

	Specialized rehabilitation		Non-specialized rehabilitation* (N.=18)	No rehabilitation (N.=22)	P value
	Transferred directly (N.=79)	Not transferred directly (N.=44)			
Demographics					
Age (years), median [IQR]	28 [20-42] [b, c, d]	47 [26-59] [a, c]	58.5 [39-71] [a, b]	4500.5 [27-64] [a]	<0.001
Gender					
Male (N.=127)	62 (78%)	36 (82%)	14 (78%)	15 (68%)	0.656
Living status					
Married/cohabiting (N.=68)	26 (33%)	22 (50%)	11 (61%)	9 (41%)	0.059
Level of education					
High (>12 years) (N.=49)	29 (37%)	10 (25%)	4 (25%)	6 (27%)	0.517
Employment status					
Working/studying (N.=107)	64 (81%)	23 (52%)	6 (33%)	14 (64%)	
Unemployed, on sick leave or receiving a pension (N.=56)	15 (19%)	21 (48%)	12 (67%)	8 (36%)	<0.001
Injury-related variables					
Cause of injury mechanism					
Transportation (N.=73)	38 (48%)	25 (58%)	7 (39%)	3 (14%)	
Fall, violence, other (N.=90)	41 (52%)	18 (42%)	11 (61%)	19 (86%)	0.006
AIS head score	5 [4-5] [d]	5 [4-5] [d]	4 [3-5]	4 [200.75-5] [a, b]	0.062
ISS	29 [21-34] [d]	29 [22-39] [d]	25 [21.5-31]	21 [13-26] [a, b]	0.003
Rotterdam CT score (worst)	4 [3-4] [d]	4 [3-4] [d]	4 [3-5]	3 [2-4] [a, b]	0.089
GCS score	6 [3-7]	6 [3-8]	7 [5.5-8]	6 [5-7]	0.431
Ventilation days (N.=159)	10 [2-19] [d]	10 [3-19] [d]	4 [1-10]	1 [1-200.5] [a, b]	<0.001
Number of complications	2 [1-2] [d]	1.5 [1-3] [d]	1.5 [1-2.25] [d]	0 [0-1] [a, b, c]	<0.001
PTA category >4 weeks (N.=75)	43 (54%)	25 (59%)	6 (33%)	1 (5%)	<0.001
LOS ICU days (N.=160)	8 [4-15] [d]	8.5 [5-13.5] [d]	7.5 [3-11]	2 [1-500.5] [a, b]	<0.001
LOS acute department regional hospital (N.=163)	17 [11-30] [b, c, d]	12 [7-21] [a, d]	11 [7-19] [a, d]	400.5 [3-7] [a, b, c]	<0.001
LOS acute departments total	18 [12-31] [b, d]	38 [22.5-55.5] [a, d]	26.5 [16-45.5] [b, d]	500.5 [4-1200.5] [a, b,c]	<0.001
LOS sub-acute first inpatient rehabilitation (N.=140)	54 [31-90] [b, c]	37 [20-62] [a]	32 [15-47] [a]	–	0.004
LOS rehabilitation total (N.=140)	74 [40-106] [b, c]	47 [23-64] [a]	35 [21-61] [a]	–	<0.001

*Non-specialized rehabilitation is defined as organized rehabilitation units in local hospitals (N.=11) or community- based rehabilitation units (N.=7). The values are numbers or the median and interquartile range [IQR].

[a] Significant difference from "Specialized rehabilitation, transferred directly"; [b] significant difference from "Specialized rehabilitation, not transferred directly"; [c] significant difference from "Non-specialized rehabilitation"; [d] significant difference from "No rehabilitation".

specialized rehabilitation, whereas they had comparable scores on all of the measures of acute injury severity (AIS head, ISS, Rotterdam CT score, GCS, and PTA) and the number of days with artificial ventilation. Further, there was no difference between the groups in number of a wide variety of recorded complications of respiratory, cardiovascular, metabolic, hormonal and infectious origin; but type of complication was not analyzed more thoroughly. The patients who were referred directly to specialized TBI rehabilitation had a shorter LOS in the acute departments (including local hospitals) and a longer LOS during rehabilitation. The patients who received non-specialized rehabilitation were older (P<0.001) than the patients who were referred to specialized rehabilitation. The duration of the ICU stay was comparable for the patient groups who received specialized rehabilitation and those who received non-specialized rehabilitation.

Rehabilitation services during the acute and post-acute phases

Fifty patients (31%) received acute comprehensive rehabilitation in an early rehabilitation section integrated in the ICU (only available at the Oslo University Hospital). In all, 139 (86%) patients received physical therapy and 56 (35%) patients received occupational therapy during the acute rehabilitative phase.

At 12 months post-injury, the following services were delivered: a home nurse for 19% of the patients, physical therapy for 37% and occupational therapy for 14%. Psychology and educational services were each provided to 7% of patients. Other services included technical aids for 30% of the participants and housing adaptations for 19%. Ambulatory rehabilitation service was provided for 15% of the participants. In all, 90% lived in their own home at 12 months.

Functional independence at 12 months post-injury

A total of 114 patients (70%) did not require any help, 11 patients (7%) required assistance once every 7 to 14 days, and 38 patients (23%) depended on daily help. Table III shows the characteristics of the 114 patients who were independent *vs*. the 49 patients who depended on weekly or daily help. Of the 49 dependent patients, 51% had GOSE 2-4 and 29% GOSE 5. As Table III

Table III.—*Dependency on personal assistance 12 months after severe traumatic brain injury in relation to demographics, acute injury severity and treatment and rehabilitation related factors.*

	Independent of personal assistance (N.=114)	Dependent on personal assistance (N.=49)	P value
Demographics			
Age (years), mean (SD)	38.4 (18.2)	44.0 (19.1)	0.076
Gender, male	90 (79%)	37 (76%)	0.628
Living status, married/ cohabiting	48 (42%)	20 (41%)	0.844
High level of education (>12 years)	31 (27%)	18 (37%)	0.132
Acute injury-related variables			
AIS head score (N.=161)	4.5 [4-5]	5 [4-5]	0.209
ISS score	26 [20-33]	29 [25-35]	0.117
GCS score	6 [4-8]	6 [3-7]	0.087
Rotterdam CT score	3 [3-4]	4 [3-4]	0.002
Ventilation days (N.=159)	5 [1-12]	16.5 [6-24]	<0.001
N. of complications	1 [0-2]	2 [1-3]	<0.001
PTA>4 weeks (N.=161)	36 (32%)	39 (80%)	<0.001
LOS ICU (N.=160)	7 [3-11.0]	10.5 [5-16]	0.002
LOS acute departments regional hospital	12 [6-18]	24 [10-35]	<0.001
LOS acute departments total	16 [10-26]	42 [30-57]	<0.001
GOSE score 12 months post-injury			0.001
GOSE score 2-4 (N.=25)	0 (0%)	25 (51%)	
GOSE score 5 (N.=30)	16 (14%)	14 (29%)	
GOSE score 6-8 (N.=108)	98 (86%)	10 (20%)	
Rehabilitation pathways			
Specialized rehabilitation, transferred directly (N.=79)	58	21	
Specialized rehabilitation, not transferred directly (N.=44)	22	22	0.009[a]
Non-specialized rehabilitation (N.=18)	15	3	
No rehabilitation (N.=22)	19	3	0.002[b]
Length of stay			
LOS first in-patient rehabilitation (N.=140)	(N.=94) 37 [23-64]	(N.=46) 61 [35-103]	0.001
LOS second in-patient rehabilitation (N.=52)	(N.=35) 18 [7-31]	(N.=17) 18 [8.5-33.5]	0.800
LOS third in-patient rehabilitation (N.=18)	(N.=10) 6 [4-11.5]	(N.=8) 16 [5-40]	0.146
LOS fourth in-patient rehab (N.=4)	(N.=3) 5 [3.5-55]	(N.=1) 10	1.000
LOS total rehab, first year post-injury (N.=140)	(N.=94) 49 [27-80]	(N.=46) 72 [49-119.5]	<0.001

Values are provided as numbers or as the median and the [IQR].
Significance tests for differences between continuous values: non-parametric Kruskal-Wallis test.
PTA: percutaneous transluminal angioplasty; IQR: interquartile range; LOS: length of stay; ICU: intensive care unit.
[a] Significant difference between patients referred directly from acute care to a rehabilitation unit and patients not referred directly to rehabilitation (Pearson's χ^2 test); [b] significant difference between the 4 different rehabilitation pathways (Pearson's χ^2 test).

shows, acute injury severity and acute and rehabilitation LOS differed between the groups. A total of 123 patients received specialized rehabilitation (with direct or non-direct transfer), and being discharged directly from regional acute care to rehabilitation was significantly related to independence 12 months post-injury ($P<0.009$, df=1, Pearson's χ^2 test).

Regression analyses of functional independence

The first model (N.=163) included the total study-population, and older age, more days of ventilation and a longer PTA duration were significant predictors of dependence in the multivariate logistic regression analysis (Nagelkerke R-squared: 0.345). The second model (N.=123) included the patients who were treated in a specialized rehabilitation ward. Older age, more days of ventilation and longer stays in rehabilitation wards were significantly related to dependence (Table IV). Discharge directly from the regional ICU/neurosurgical ward to specialized rehabilitation was a significant predictor of functional independence. This association remained significant after controlling for age, days of ventilation and length of rehabilitation (Nagelkerke R-squared: 0.425). The Hosmer and Lemeshow tests indicated a good model fit for both models.

Discussion

In this national cohort of 163 patients with severe TBI, the patients typically followed one of four clinical pathways: 1) a direct pathway to sub-acute specialized TBI rehabilitation (48%); 2) a broken pathway that included specialized TBI rehabilitation *via* a local hospital (27%); 3) in-patient service that included non-specialized rehabilitation (11%); and 4) a pathway that did not include rehabilitation (14%). One of the main findings was that the direct pathway was associated with functional independence in severe TBI patients, compared with the broken pathway to specialized rehabilitation. Patients following the direct pathway were also more satisfied with the treatment and rehabilitation.

Treatment pathways and rehabilitation services

To the best of our knowledge, this is the first study on treatment pathways with a national cohort of patients with severe TBI. The finding that nearly half of the patients (48%) followed the direct pathway to specialized TBI rehabilitation is in accordance with studies from Paris (45%) and Sweden/Iceland (46%).[3, 5] Patients who were directly discharged to specialized rehabilitation were younger and had a higher employment rate at the time of injury, which is in line with other findings.[3, 23] A study from the USA also found that younger age was the most consistent predictor of discharge to rehabilitation compared with "sub-acute care".[23] In contrast, a recent Dutch study found that age was not an important factor in the decision for discharge options.[10] A mean age of approximately 40 years old and a predominance of male patients (78%) in the present study are in accordance with other studies.[3, 5, 24, 25] An age difference of 20 years between patients with direct transfer and those with non-direct transfer, without significant differences between younger and older participants on acute injury severity measures, indicate that age was considered

Table IV.—*Multivariate binary logistic regression analyses of the effect of demographic and injury related variables on dependency of personal assistance at 12 months post-injury.*

Independent variables	OR	95% CI	P value	Nagelkerke R^2
Model 1. Total population (N.=163)				
Age, years	1.03	1.00-1.05	0.027	0.345
Ventilation days	1.05	1.01-1.10	0.014	
PTA>4 weeks	5.25	2.07-13.29	<0.001	
Model 2. Specialized rehabilitation group (N.=123)				
Age, years	1.05	1.01-1.08	0.004	0.425
Specialized rehabilitation, not discharged directly	4.22	1.49-11.93	0.007	
Ventilation days	1.07	1.02-1.11	0.003	
LOS first rehabilitation, days	1.02	1.01-1.03	0.002	

Model 1: Hosmer and Lemeshow test: χ^2, 9.47, df 8, Sig. 0.304.
Model 2: Hosmer and Lemeshow test: χ^2, 7.67, df 8, Sig. 0.466.
PTA: percutaneous transluminal angioplasty; LOS: length of stay.

when transferring patients to specialized rehabilitation in the present study.

In the present study, the median LOS in the regional ICU was 8 (range 3-13) days and the patients who were discharged directly to specialized rehabilitation had the same length of ICU stay as patients who were discharged non-directly. The length of ICU stay is in accordance with a similar study of severe TBI from Australia/New Zealand,[24] but the LOS in the ICU was shorter than in studies from Sweden/Iceland [5] and France.[3] In Norway there is a limited capacity of regional ICUs, and therefore, transfers to ICUs in local hospitals is often necessary. In addition, LOS differences among countries may be caused by differences in health care financing and insurance, the organization of acute and rehabilitative care after TBI and resource allocation.[23, 26]

The proportion of participants admitted to non-specialized rehabilitation in the present study (11%) is in accordance with a French study,[3] but higher than the 7% reported in the Swedish/ Icelandic study.[5] The apparent difference between Norway and Sweden/Iceland could be due to age-limited inclusion criteria in the latter study with an upper age limit of 65 years while in Norway 11% of the patients were 65 years or older. Acute injury severity was not significantly different for participants receiving specialized rehabilitation compared to those in the non-specialized pathway. A possible type II failure may have led to coverage of less severe traumas in patients with a non-specialized pathway. In Norway, nursing homes are no longer used routinely in the pathways of care in TBI. In contrast, a recently published Dutch study reported that 16% of patients with severe TBI (mean age 40 years) were referred directly from the trauma center to nursing homes.[10] In many countries there seems to be a need for defined pathways of care for transferral from the trauma center to rehabilitation.

The proportion of patients with severe TBI who were transferred home without rehabilitation in the current study (13%) was higher than in Sweden (6%), and lower than in France (36%) and the Netherlands (22%).[3, 5, 10] As expected these patients had clearly less severe acute injuries and 86% of the injuries were caused by falls, violence and other injuries. However, the design of the study does not allow for conclusions with regard to unmet rehabilitative needs among these patients.

Level of functional independence at 12 months

A total of 70% of the population was independent, i.e., did not require formal care, at 12 months. This is in line with Corrigan *et al*. who reported that after inpatient rehabilitation, 78% of the patients were living independently at 12 months post-injury.[27] Other studies also found that between 61 to 74% of a population of severe TBI survivors had a favorable outcome (GOSE 5-8) at 12 months post-injury.[5, 24] Functional outcomes in this study seem fairly representative of survivors one year after severe TBI. An important point is, however, that the need for help is also present among nearly half of the individuals with GOSE 5 (lower moderate disability).[22] When these individuals are included within the proportion of individuals with a favorable outcome, one may underestimate the need for services after TBI.

Associations between functional outcome and rehabilitation pathways

The present study adds to the growing literature demonstrating positive associations between functional outcome and a continuous treatment chain between acute care and rehabilitation. Scandinavian studies on severe TBI have shown a better functional outcome for patients who received an early and continuous rehabilitation,[2] an effective combination of medical and rehabilitation efforts,[6] and centralized (*vs*. decentralized) rehabilitation.[9] Moreover, a Swedish/Icelandic study showed a more favorable outcome at one year for patients who had shorter times between intensive care discharge and rehabilitation admission.[5] A continuous rehabilitation trajectory has also been associated with reduced costs and improved outcomes after severe TBI.[28] In fact, a previous study that used the same cohort as the current study found that direct discharge to specialized rehabilitation increased functional improvement from 3 to12 months post-injury.[4]

Studies have found that younger age is related to a better outcome after rehabilitation discharge.[1] In the present study, when the significant influence of age was controlled for in the multivariate analysis, a direct discharge to rehabilitation was still significantly associated with the dependence outcome. In addition, days of artificial ventilation were significantly associations with dependency as expected. Godbolt et al. found a poorer outcome in patients with complications,[5, 29] as found in the present bivariate analyses. Longer LOS in rehabilitation is often associated with a poorer outcome because of the selection of patients with more severe disabilities and slower recovery.[5]

Strengths and limitations of the study

There may be confounding factors that biased the present results. For example, the prioritization of patients for direct, early transfer to specialized rehabilitation may also depend on factors that were not measured, and particularly subtle early signs of neurological recovery, which may occur despite a seemingly comparable severe initial injury. Although patients with direct and non-direct transfer to specialized rehabilitation had comparable numbers of complications, types of complications were not analyzed more thoroughly. Reports of a patient's premorbid fitness and the availability of family resources may also influence clinical decision-making and the outcome.[30] All of these limitations concern the design of this type of observational study, in which selection bias can be present and conclusions about causal relationships are not possible. Despite these considerations, and the lack of randomized controlled studies, we argue that continuous treatment chains from acute care to specialized TBI rehabilitation likely contribute to enhanced recovery and reduced hospital costs. This argument is in line with a newly published study on the cost-effectiveness of a continuous chain of rehabilitation after severe TBI.[28]

The dependency measure could seem coarse but was evaluated against the GOSE to secure validity. The strength of this study is based on its national cohort, as few national studies have continuously followed up patients with severe TBI for one year, starting with the acute phase. Relatively few patients were lost to follow-up. Additionally, the recruitment was prospective, the patient population was homogeneous regarding injury severity, and there was limited recruitment bias because of the rigorous inclusion and exclusion criteria. Patients in this cohort were representative of surviving adults who have sustained severe TBI and who did not have severe pre-injury conditions.

Conclusions

Findings indicate that a clinical pathway in which specialized rehabilitation is delivered without delay in dedicated units may contribute to enhance independence in severe TBI patients. Elderly subjects were less likely to experience this pathway compared with younger subjects. The need for specialized rehabilitation after severe TBI is not surprising given the medical complexity and severity of this condition. These findings support the importance of direct pathways from acute care to sub-acute specialized rehabilitation.

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