



Predicting Functional Impairment in patients with chronic subdural hematoma treated with burr hole Trepanation—The FIT-score

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ABSTRACT

Objective: It remains difficult to estimate prolonged functional impairment in patients with chronic subdural hematoma (cSDH) treated with burr hole trepanation. We aim to establish a score that reliably predicts post-operative functional impairment.

Patients and methods: Retrospectively analysis of a prospective institutional database. cSDH patients operated in 2013–2016 were identified. Clinical outcome was dichotomized into presence (modified-Rankin-Scale (mRS) ≥ 2) or absence of functional impairment (mRS 0–1) at discharge and last follow-up. A score was developed, based on the effect sizes of a set of outcome predictors. Its accuracy was tested using Area Under the Receiver-Operating Characteristic (AUROC) curve analysis. The 2017 cohort served for internal validation.

Results: A cohort of 253 patients (mean age 75 years, 75% male) was analyzed, of which 77 patients (30%) remained functionally impaired. In multivariate analysis, severe motor deficits at admission (OR 5.84, 95% CI 2.71–12.59, $p < 0.001$), age (≥ 85 years: 5.53, 2.14–14.32, $p < 0.0001$) and disorientation at admission (2.65, 1.139–5.05, $p = 0.003$) were associated with persistent functional impairment. Based on those variables, we created the “Functional Impairment after burr hole Trepanation” (FIT-score), which showed an AUROC of 0.77 (95% CI 0.70–0.83) for impairment at discharge and 0.76 (0.70–0.82) for impairment at follow-up. Internal validation confirmed the model with an AUROC of 0.79 (0.68–0.91) at discharge and 0.77 (0.64–0.91) at follow-up.

Conclusions: The FIT-score is likely to assist the physician when counseling patients and relatives pertaining to the need for postoperative rehabilitation and mid- to long-term supportive home care.

1. Introduction

Burr hole trepanation for chronic subdural hematoma (cSDH) is one of today's most frequently performed neurosurgical procedures. Given the trend towards aging Western societies, an increase in the cSDH prevalence will presumably lead to even higher need for surgical treatment in the future [1,2]. There are ongoing discussions in the neurosurgical community how to best evacuate cSDHs [3–6], while there remains a paucity of research focusing on prediction of (prolonged) disability after cSDH evacuation. This is a relevant matter, though, since cSDH predominantly present in elderly patients, who

often show multiple comorbidities [7,8]. In this vulnerable population, even minor events – such as burr hole trepanation – may delicately interfere with the marginally compensated previous independence in activities of daily living (ADLs). While motor deficits usually improve quickly after surgery, in clinical routine we regularly observe a persistent and profound impact of the cSDH on a patient's cognitive and functional status, even in the aftermath of successful evacuations [9]. This might be due to the residual affection of the brain by the hematoma, but possibly also the need for hospitalization and surgical therapy factors into this, surely representing a distinct event in the (elderly) patient's life [2,10].

Abbreviations: AUC, Area Under the Curve; ADL, activities of daily living; AUROC, Area Under the Receiver-Operating Characteristic; cSDH, chronic subdural hematoma; CI, confidence interval; CT, computed tomography; IQR, interquartile range; FIT-score, Functional Impairment after burr hole Trepanation score; FU, follow-up; GCS, Glasgow Coma Score; LOH, length of hospitalization; mRS, modified Rankin scale; ROC, Receiver-Operating Characteristics; SD, standard deviation

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Being able to return home and continue the premorbid life is among the leading concerns of patients and their relatives when facing the diagnosis. Having the possibility to achieve this goal is a major driver for the decision to operate. However, not all patients will recover well enough to again care for themselves and live independently [9,11–13]. Predicting the inability to perform all previous ADLs with high accuracy would therefore help counsel patients and relatives in therapeutic decision-making, but also support the early selection of patients who might need further (geriatric) rehabilitation or home care after discharge.

In this research, we aimed to design a simple score that would accurately predict functional impairment after burr hole trepanation for cSDH, based on a set of readily available baseline variables.

2. Patients and methods

This was a retrospective analysis of a prospective, institutional database containing longitudinal patient data, including treatment, complications and validated scores representing a patient's physical condition/outcome [14].

2.1. Study design and patient identification

Records of all patients undergoing surgical treatment for a cSDH between 01/2013 to 12/2017 were retrieved in a query of our database. For this study we selected patients with complete relevant data, undergoing first-time burr hole trepanation for uni- or bilateral cSDH. Given their different characteristics and prognosis, patients undergoing re-do surgery or requiring (mini-) craniotomy were not considered [15].

2.2. Surgical technique and patient management

Patient management and the surgical technique of burr hole trepanations in cSDH in our department follow a standardized protocol described previously [15,16]. All symptomatic patients, particularly those with large hematomas (maximal axial diameter > 15 mm or relevant midline shift) were commonly operated within 24 h, except in the case of a major contraindication. Coagulation parameters were checked before surgery. In patients under antiaggregation or anticoagulation, the operation was delayed whenever possible until hemostasis and thrombus function were restored. Our departmental protocol aims at maintaining platelets at $> 100 \times 10^9/\text{dl}$ and an international normalized ratio of ≤ 1.2 . Coagulation abnormalities were actively reversed preoperatively with prothrombin complex concentrate or fresh frozen plasma, if urgent surgery was required. Antiplatelet medication was stopped 5–7 days prior to surgery; if urgent surgery was required, one unit of platelet concentrate was administered immediately preoperative [15]. Routinely, double burr hole trepanation under general anesthesia with the placement of a subperiosteal drain was performed. Reported recurrence rates in cSDH are as high as 33% but generally around 8–15%. While it remains debated, whether placing the drain in the superiosteal or subdural space is superior, our department favors subperiosteal drain placement for the better safety profile [4,17,18]. Postoperatively, patients were kept immobilized for 48 h in a flat supine position until the subperiosteal drain was removed. In absence of residual deficits, patients were discharged from day three on. No routine postoperative cranial computed tomography (CT) was performed during hospital stay if patients showed an improvement in symptoms after surgery. We routinely performed follow-up in our outpatient clinic with cranial CT scans and physical examination at 6 (and 12) weeks postoperatively. Follow-up was continued on an individual basis afterwards in patients with residual hematoma.

2.3. Variables and patient outcome grouping

All data were extracted from the database and disease-specific data

were added by reviewing electronic patient records, as described previously [15]. Patient's baseline and clinical characteristic variables included age, sex, preoperative GCS, preoperative orientation (oriented/disoriented), preoperative motor deficits (none/mild deficits/severe deficits) and anticoagulation or antiplatelet therapy (yes/no). In addition, length of hospitalization (LOH, in days), length of follow-up (LFU, in days) and location after discharge were analyzed. Disease-specific radiographic data included existence of bilateral cSDH (yes/no), hematoma thickness in mm and midline-shift in mm, following the protocol of a recent prospective multi-center audit for cSDH [19]. In case of a bilateral cSDH the larger hematoma was used to define hematoma thickness.

Patients were dichotomized into two cohorts, those with any relevant functional impairment at discharge and last recorded follow-up (modified Rankin Scale (mRS) ≥ 2), and those with complete recovery (mRS = 0–1).

2.4. Statistical considerations

The 2013–2016 dataset was used for score development, and the 2017 dataset for internal validation. In the development dataset, differences in patient baseline characteristics and disease-specific factors between cohorts were analyzed using Pearson's chi-square tests for categorical variables, student's t-tests for variables on an interval, or Mann-Whitney *U* test for variables on an ordinal scale. Data were presented as count (percent), mean (standard deviation (SD)), or median (interquartile range (IQR)), as appropriate. The effect size of the relationship between the outcome (persistent functional impairment at last follow-up) and several clinical variables was determined using multivariate logistic regression. Those variables were patient age (≥ 85 , 70–84 or < 70 years), preoperative orientation (oriented vs. disoriented) and motor function (severe motor deficits, mild motor deficits or none). Mild motor deficits were defined as combined NIHSS arm and leg motor deficit score = 1–2, meaning either "limited effort against gravity in one limb" or "both arm and leg drifts down during examination". Severe motor deficits were defined as NIHSS combined arm and leg motor deficit score ≥ 3 meaning either "no effort against gravity in one limb" or "limited effort against gravity in both limbs". The Glasgow Coma Score (GCS) at admission, an independent predictor of functional impairment in the univariate analysis, was not included in the multivariate model for its collinearity with the included variable "orientation". From here, a scoring system, the "Functional Impairment after burr hole Trepanation" (= FIT-score), was designed assigning a score to each predictor. Individual total scores were calculated based on the sum of all ratings. Finally, Area Under the Receiver-Operating Characteristic (AUROC) curve analysis was used to determine model discrimination. An Area Under the Curve (AUC) of 0.5 indicates no discrimination, whereas an AUC of 1 indicates perfect discrimination. The Kruskal-Wallis Test was used to compare mean length of hospitalization with different FIT-scores. Pearson's chi-square tests were used to compare surgical revision rates and the relative number of patient's being able to be discharged home with different FIT-score values.

Statistical analysis was performed using SPSS software 23.0.0.0 (IBM Corp., Armonk, NY, USA) and receiver operating curve analysis was carried out using R software (<https://www.r-project.org/>) with "pROC" package. *p* values < 0.05 were considered statistically significant.

2.5. Ethical considerations

The local ethics committee (Kantonale Ethikkommission KEK-ZH 2012–0244) approved prospective data collection in the patient registry and waived patient consent due to the observational nature of the study. The study is registered at <http://clinicaltrials.gov> (NCT01628406) and follows the STROBE recommendation for observational studies. The authors report no relevant conflicts of interest.

Table 1

Patient characteristics and preoperative disease specific characteristics for the two cohorts at last follow-up. Data is presented as count (percent) for categorical variables, mean (standard deviation (SD)) for variables on an interval scale, and median (interquartile range (IQR)) for variables on an ordinal scale. *mRS*, modified Rankin Scale.

Variable	No functional impairment at last follow-up (mRS = 0–1) (n = 176)	Functional impairment at last follow-up (mRS = 2–6) (n = 77)	p-value
Sex, n (%)			0.051
Female	50 (28%)	13 (17%)	
Male	126 (72%)	64 (83%)	
Age in years, mean (SD)	74 (12)	79 (10)	0.025
GCS at admission, median (IQR)	15 (0)	15 (1)	< 0.001
Follow-up time in days, mean (SD)	89 ± 92	82 ± 93	0.412
Preoperative orientation, n (%)			< 0.001
Disoriented	33 (19%)	33 (43%)	
Oriented	143 (81%)	44 (57%)	
Preoperative motor deficit, n (%)			< 0.001
Severe	25 (14%)	32 (41%)	
Mild	59 (34%)	26 (34%)	
None	92 (52%)	1 (25%)	
Anticoagulation therapy, n (%)			0.236
No	144 (82%)	58 (75%)	
Yes	32 (18%)	19 (25%)	
Antiplatelet therapy, n (%)			0.454
No	140 (80%)	58 (75%)	
Yes	36 (20%)	19 (25%)	
Bilateral cSDH, n (%)			0.081
No	131 (74%)	49 (64%)	
Yes	45 (26%)	28 (36%)	
Hematoma thickness in mm, mean (SD)	24.2 (7.0)	25.4 (7.2)	0.255
Midline-shift in mm, mean (SD)	7.0 (5.1)	6.6 (4.9)	0.751

3. Results

3.1. Patient population and univariate analysis

A total of n = 294 procedures for the evacuation of cSDH were identified. Of those 41 were omitted (n = 27, undergoing re-do surgery; n = 13, undergoing craniotomy; n = 1, missing relevant data). Thus, a total of 253 patients (mean age, 75 years, 75% male) undergoing burr hole trepanation for cSDH were evaluated, of those 176 patients (70%) with complete recovery and 77 patients (30%) with persistent functional impairment at last follow-up. Mean follow-up time in all patients was 87 days (SD, ± 92 days) with no difference between the two groups (p = 0.412). Sex, preoperative anticoagulation or antiplatelet therapy were balanced between the groups. Concerning the radiographic data no significant difference were found between patient without and with functional impairment at follow-up including rate of bilateral cSDH (26% vs 36%, p = 0.081), hematoma thickness in mm (24.2 vs 25.4, p = 0.255) and midline shift in mm (7.0 vs 6.6, p = 0.751, Table 1). In the cohort with functional impairment at last follow-up, GCS at admission (p < 0.001), age (p = 0.025), impaired orientation (p < 0.001) and presence of severe and mild motor deficits at admission (p < 0.001) differed from the group without functional impairment at last follow-up (Table 1). The rate for cSDH recurrence needing revision surgery within 90 days from the index procedure was 40/253 (15.8%) with a mean time to revision of 21 days (± SD 21 days). Patients requiring revision surgery were more likely to present with functional impairment at last follow up (21/40; 53%) than patients not requiring revision surgery (56/213; 26%; p = 0.001).

3.2. Multivariate analysis

In multivariate analysis preoperative severe motor deficit had the strongest association with functional impairment (Severe deficit: OR 5.84, 95% CI 2.71–12.59, p < 0.001) followed by higher age (Age ≥ 85 years: OR 5.53, 95% CI 2.14–14.32, p < 0.001) and preoperative disorientation (OR 2.65, 95% CI 1.39–5.05, p = 0.003; Table 2).

Table 2

The effect size of the relationship between a baseline predictor and persistent functional impairment at last follow-up is estimated using multivariate logistic regression analysis. *OR*, Odds ratio; *CI* Confidence Interval.

	OR	95% CI	p-value
Age, years			
Age < 70 (reference)			
Age 70–84	2.18	0.94–5.07	0.071
Age ≥ 85	5.53	2.14–14.32	< 0.001
Motor deficit			
None (reference)			
Mild	2.00	0.97–4.13	0.061
Severe	5.84	2.71–12.59	< 0.001
Orientation			
Normal (reference)			
Disoriented	2.65	1.39–5.05	0.003

Table 3

The FIT-score. Minimum score 0 (least likely to experience functional impairment); maximum score 5 (most likely to experience functional impairment).

Characteristics	Point(s)
Age, years	
< 70	0
70–84	1
≥ 85	2
Motor deficit	
None	0
Mild	1
Severe	2
Orientation	
Normal	0
Disoriented	1

3.3. AUROC analysis of functional impairment

In order to develop a prediction scale for persistent functional

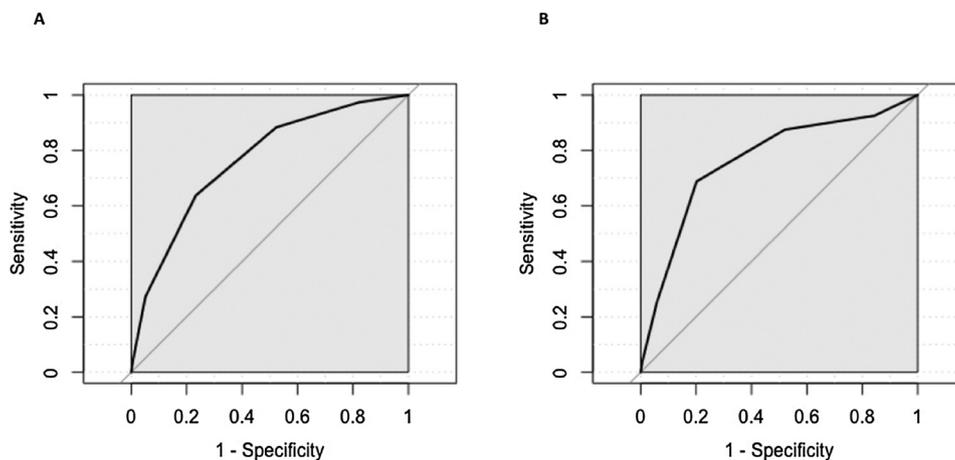


Fig. 1. Receiver-Operating Characteristics (ROC) curves for the FIT-score are shown at (A) last follow-up and (B) discharge. The model showed good discrimination (area under the curve (AUC) at discharge AUC = 0.77, 95% confidence interval (CI) = 0.70–0.83 and at last follow up AUC = 0.76, 95% CI = 0.70–0.82).

Table 4

Coordinates of the FIT-score Area Under the Receiver-Operating Characteristic (AUROC) curve at discharge and last follow-up. The bold values represent the FIT-score threshold discriminating between patients with or without functional impairment with optimal sensitivity and specificity.

Test result positive if \geq	Discharge		Last Follow-up	
	Sensitivity	Specificity	Sensitivity	Specificity
0	1	1	1	1
1	0.93	0.16	0.97	0.18
2	0.88	0.48	0.88	0.48
3	0.69	0.80	0.64	0.77
4	0.25	0.94	0.27	0.95
5	0.04	0.99	0.04	0.99

impairment the FIT-score was designed using the three identified variables (Table 3). A minimum score of 0 indicates best prognosis while the maximum score of 5 indicates worst prognosis (therefore highest likelihood of persistent functional impairment). The model’s discrimination capability for persistent functional impairment was determined by AUROC analysis, which showed an AUC of 0.77 (95% CI = 0.70–0.83) at discharge and AUC of 0.76 (95% CI = 0.70–0.82) at last follow-up (Fig. 1). Based on the AUROC analysis we determined a FIT-score of ≥ 3 as the best threshold to discriminate between complete recovery and persistent functional impairment with a sensitivity of 0.69/0.64 and a specificity of 0.8/0.77 (Table 4).

3.4. Analysis of secondary clinical outcome variables

Higher FIT-scores showed a trend towards longer LOH, as depicted in Fig. 2 ($p = 0.31$). Moreover, there was a gradual decrease in the relative number of patients able to be discharged home with higher FIT-scores (Fig. 3; $p < 0.001$). The FIT-score was unsuitable to predict the need for revision surgery (AUC = 0.51, 95% CI 0.41–0.60).

3.5. Internal validation and comparison with other scoring systems

The 2017 cohort from our database comprised 65 patients (mean age 75 years, 48 male (74%)), with a mean follow-up time of 75 days (SD 55 days; see Supplementary Table 1 for more detailed information on this cohort). Of those, 22/65 (34%) patients showed a persistent functional impairment at discharge and 15/65 (23%) at last follow-up. Internal validation confirmed the predictive capabilities of the FIT-score with an AUROC of 0.79 (95% CI = 0.68–0.91) at discharge and AUROC of 0.77 (95% CI = 0.64–0.91) at last follow-up.

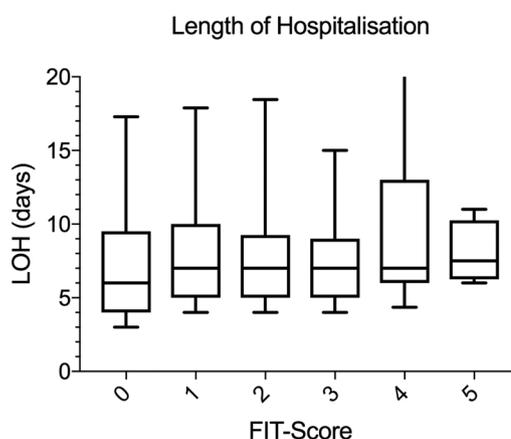


Fig. 2. Box plots depict the tendency of an increase in median length of hospitalization (LOH) with higher FIT-scores ($p = 0.31$). Box plots represent the median (horizontal line), the interquartile range (box) as well as the 5th and the 95th percentile (whiskers).

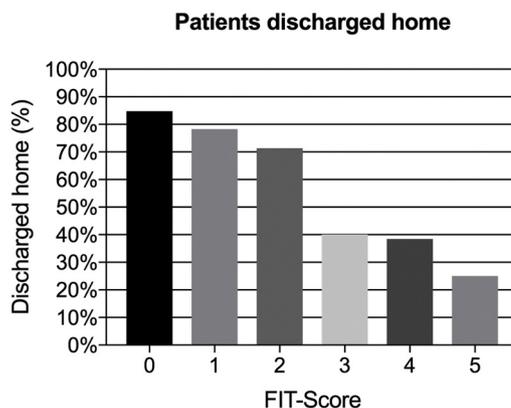


Fig. 3. The bar chart indicates the decreasing proportion of patients able to be discharged home (in %) with higher FIT-scores (Pearson’s chi-square, $p < 0.001$).

Additionally we validated the recently proposed scoring system by Kwon et al., applying the grading system to our data of 180 patients with unilateral cSDH [20]. While the score by Kwon et al. yielded an AUC of 0.79 (95% CI 0.71–0.86), the FIT-score achieved a comparable AUC of 0.80 (95% CI 0.73–0.87) in this subgroup,

4. Discussion

This study set out to predict persistent functional impairment after burr hole trepanation in patients with cSDH. From a set of readily available parameters, three key variables with highest predictive capacities were selected for the FIT-score: patient age, preoperative motor deficits and disorientation. The FIT-score now represents a practical and easy-to-use grading system with a good accuracy to predict functional impairment at time of hospital discharge (AUC 0.77) and at follow-up (AUC 0.76).

The credibility of our results is supported by the prospective data collection and the internal consistency of the proposed FIT-score with the primary and secondary outcome measures. A higher FIT-score was not only associated with an increased risk of persistent functional impairment at discharge and last follow-up but also led to a non-significant increase in median LOH and a significantly decreasing of proportion of patients able to be discharged home. In addition, we could validate our model by applying it to a separate patient cohort, which substantiated the predictive capabilities of the grading system. Previous studies demonstrated correlations between a reduced neurological admission status and unfavorable outcome for a variety of neurological diseases, including cSDH [2,12]. In addition, higher age was positively associated with poor prognosis and death in published cohorts of patients operated for a cSDH [9,12,20–22]. Our current results are in line with the previous findings, as the preoperative variables with highest predictive capacity for postoperative functional disability were preoperative motor deficits (severe deficits: OR 5.84, mild deficits: OR 2.0) followed by age (age \geq 85 years: OR 5.53, age 70–84 years: OR 2.18) and disorientation (OR 2.65). In fact, by probing the admission GCS in our cohort as a single predictor of functional impairment at follow up the AUROC analysis yielded a mere AUC of 0.64 (95% CI 0.56–0.71) underlining the additional value of the composed FIT-Score.

In general, previous studies on prognostic modeling in cSDH have concentrated on the risk of hematoma recurrence, rather than clinical outcome [23–26]. Apart from the patient's baseline variables, several imaging characteristics like hematoma size, density, midline-shift, or the presence of membranes have all been found to be associated with a higher chance for hematoma recurrence [23,24,27–29]. Interestingly in the present dataset, we could not find a significant association between clinical patient outcome (functional impairment) and any radiologic factors.

Recently, Kwon et al. described a scoring system predicting unfavorable outcome (mRS 2–6) in patients undergoing surgery for an unilateral cSDH on a scale from 3 (best prognosis) to 13 (worst prognosis) [20]. Their scoring system was based on six variables, including two imaging characteristics (hematoma thickness & midline-shift), which was reported to achieve an excellent discrimination (AUC of 0.95) in the developing cohort of 154 patients [20]. Applying the score by Kwon et al. to our subgroup of 180 patients with unilateral cSDH resulted in a considerably lower predictive accuracy (AUC of 0.79, 95% CI 0.71–0.86) than the one previously reported by the authors. Despite its simplicity, the FIT-score showed a comparable discrimination (AUC of 0.80, 95% CI 0.73–0.87). Its simple structure, allowing for accurate prediction of a well-defined and relevant outcome (functional impairment at discharge and follow-up) based on weighted effect sizes of three readily available baseline key variables, is the particular value of the FIT-score.

With improved quality of today's patient care, neurosurgeons also face growing expectations on the patients' and relatives' side [30]. In Western countries, we observe a trend towards lower acceptance for sub-optimal outcomes, possibly due to a lack of patient-care in the modern family structures. This is especially true for a relatively "benign" and in principle "curable disease" like cSDH. The overall good prognosis of cSDH is expressed by a 70% rate of patients that will recover (nearly) complete, without any relevant functional impairment at last follow up. The results obtained in our cohort are comparable to the

published literature [9]. However, not all patients will recover well enough to again attain an independent status. In this sense, an honest and transparent discussion about the risk for prolonged functional impairment can further strengthen the doctor-patient relationship and positively influence the postoperative patient management. We deliberately focused on the prediction of even slight postoperative disabilities (mRS \geq 2) in order to support the early selection of patients who might require further (geriatric) rehabilitation or home care after discharge. A patient graded "mRS 2" is no longer able to perform ADLs that were possible before the operation, e.g. cooking, taking care of the housework, reading or working, with possible impact on patient's quality of life [31]. In contrast, a patient grade "mRS 0 or 1" will be able to resume of previous activities after discharge, obviating the need for assistance by relatives or a supportive home care agency. Being able to predict the risk of functional disabilities after surgery might therefore facilitate counseling of patients and relatives about a realistic estimation of outcome and to help them adjust to this change in their lives. Based on the present results, in patients with FIT-score of \geq 3 a thorough discussion about his/her social situation and future prospects would be advisable, possibly initiating the hospital social services at an early time point.

4.1. Strengths and limitations

The most relevant limitation of our study is the arguably short follow up time with an average of three months. This is due to the fact that no further controls were performed, given that the clinical and radiological treatment result at the first follow-up was favorable. While the time frame is in line with previous published studies, questions about long-term disability remain currently unanswered. For the scope of this work, however, the follow-up time is adequate as focus is laid on the accurate prediction of functional impairment after discharge in order to counsel patients and coordinate immediate post-treatment care. Since our focus was to develop a prediction score that could be applied at the hospital admission the FIT-score does not include other factors (e.g. recurrence rate) that will unquestionably have an effect on patient's outcome along the clinical course. While this study was analyzed in a retrospective fashion, strengths of the work are the prospective data collection, the relatively large and unselected cohort, as well as internal validation of the model. Nevertheless, external validation of the FIT-score, preferably by multicenter datasets, is required to prove that our findings also apply to different settings and populations.

5. Conclusion

We have developed a practical and easy-to-use scoring system that predicts functional impairment after burr hole trepanation in cSDH patients with good accuracy based on readily available parameters. The FIT-score is likely to assist the physician when counseling patients and their relatives pertaining to the need for postoperative (geriatric) rehabilitation and mid- to long-term supportive home care.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:<https://doi.org/10.1016/j.clineuro.2019.05.012>.

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