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Original article

Validation of the Nottingham Hip Fracture Score (NHFS) to predict 30-day mortality in patients with an intracapsular hip fracture

Louis de Jong[a,*], Taco Mal Klem[b], Tjallingius M. Kuijper[c], Gert R. Roukema[a]

[a] Surgery Department, Maasstad Hospital, 3079 DZ Rotterdam, Netherlands
[b] Surgery Department, Franciscus Hospital, 3045 PM Rotterdam, Netherlands
[c] Science Board, Maasstad Hospital, 3079 DZ Rotterdam, Netherlands

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ABSTRACT

Background: The Nottingham Hip Fracture Score (NHFS) was developed to predict 30-day mortality following a fracture of the hip. While the NHFS has been validated in three hip fracture populations within Great Britain, these studies make no distinction between the type of fracture and surgery. Literature 'however' shows an increased risk for mortality after a hemi-arthroplasty following an intra-capsular hip fracture. To verify whether the mortality after an intra-capsular hip fracture is higher compared to the predicted mortality score according to the NHFS, a validation of the NHFS in patients with a hemi-arthroplasty after an intra-capsular hip fracture was performed.

Methods: The NHFS was calculated for consecutive patients presenting with an intra-capsular fracture of the hip in two level II trauma teaching hospitals between 1 January 2011 and 1 May 2016. The observed 30-day mortality was compared with that predicted by the NHFS using several validation statistics.

Results: A total of 901 patients were included in the present study. Mean age in the patients was 83 years (SD 8) and 623 (68%) of the patients were female. Almost 60% of the patients had an ASA-score (American Society of Anaesthesiologists [ASA]) of ≥ 3 and overall 30-day mortality was 9.5% ($n = 86$). The median NHFS was 5, and there was no significant change in median NHFS over the past 5 years. The mortality rate in the studied population of hemi-arthroplasty patients was significantly higher than mortality rates predicted by the NHFS ($p = 0.022$, Pearson's Chi-squared test).

Conclusions: Findings suggest that for a patient with a hemi-arthroplasty following an intra-capsular hip fracture, there could be an underestimation for the 30-day mortality rate following the NHFS prediction model.

Level of evidence: Prognostic Level III, retrospective cohort study.

1. Introduction

Fractures of the hip cause an increase in the number of emergency admissions and are associated with high overall mortality rates [1]. After a hip fracture the aim of surgical treatment is pain relief and early mobilization of the elderly patient reducing post-operative complications. Nondisplaced femoral neck fractures are in general fixated by internal fixation and displaced fractures by hip arthroplasty (THA or HA) [2,3]. Early post-operative mortality is particularly high, with reported 30-day mortality rates of 7.5–13.3% [4–7]. The risk of mortality is influenced by age, comorbidities, peri-operative management and post-operative complications [7–11]. Accurate preoperative assessment of mortality risk following a fracture of the hip supports appropriate informed consent (patient and family), timing of surgery and enables intervention possibilities for peri-operative management. Preoperative risk factors for mortality have been identified [9,10] and various risk stratification tools assessing patients risk of morbidity and mortality, such as the POSSUM (Physiological and Operative Severity Score for the enumeration of Mortality and Morbidity), the Charlson Comorbidity index and the NHFS (Nottingham Hip Fracture Score) have been developed to predict 30 day-mortality risk after surgery [12–18]. In comparison to other models, the NHFS shows the most promising results and has reasonable discrimination [19]. Development and validation of the NHFS has only been performed in hip fracture populations within Great Britain including all types of hip fractures [6,20–23]. Some literature however shows that besides cognitive impairment, abnormal ECG, age >85 years and pre-fracture mobility an intra-capsular hip fracture is significant predictor for increased mortality for frail patients compared to per trochanteric

* Corresponding author.
E-mail address: Jongl2@maasstadziekenhuis.nl (L. de Jong).

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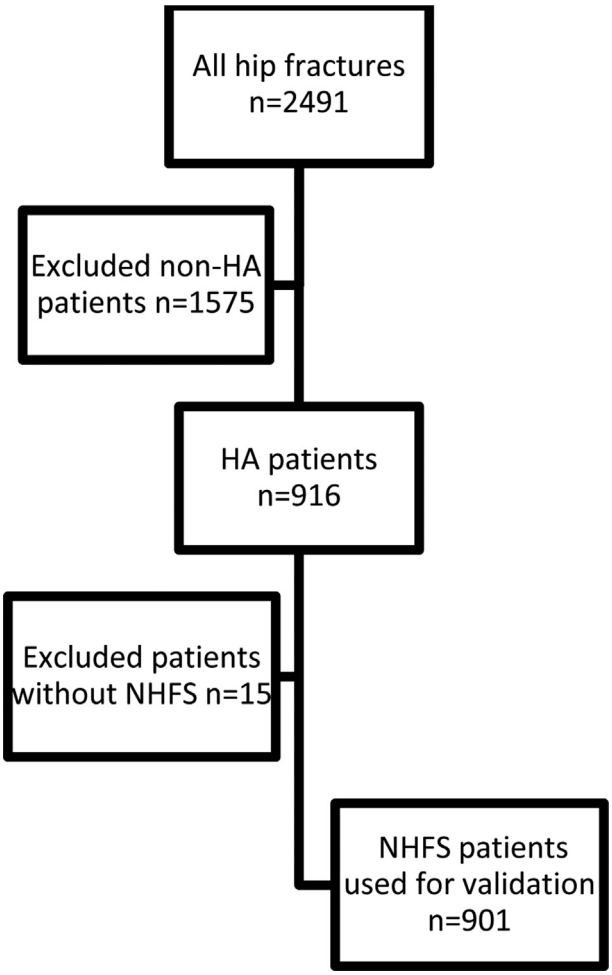

Fig. 1. Flow chart of included patients.

fractures [10,24]. Currently this type of fracture is not included as a variable in the NHFS model. If the type of fracture is important for the risk of mortality, this is a potential factor which should be used for preoperative mortality risk prediction. The aim of this study was to validate whether the NHFS model accurately predicts mortality for patients with an intra-capsular hip fracture with and following surgery using the hip hemi-arthroplasty.

2. Methods

Between 1 January 2011 and 1 May 2016, consecutive elderly patients (age > 70 years) with a fracture of the hip admitted at two level II trauma teaching hospitals located in Rotterdam, the Netherlands, were included in a hip fracture database. During this period, a total of 2491 patients were treated surgically for a fracture of the hip. Of these, 916 patients with an intracapsular fracture who were treated with a hemi-arthroplasty were included in the analysis (Fig. 1). Baseline characteristics and clinical outcomes were retrospectively obtained from the hospital records. The NHFS was calculated for each patient [13,14].

The NHFS was developed and validated as a predictor of 30-day mortality after surgery for a fracture of the hip and includes age, gender, comorbidities, an abbreviated mental test score ≤ 6 out of ten (AMTS), haemoglobin level on admission, residence and a history of malignant disease in the previous 20 years [13,14]. The NHFS is a summative score which gives an estimated risk of 30 day postoperative mortality. If the NHFS level is one, the predicted 30-day mortality rate is 0.7%, increasing up to 45% if the NHFS level is 10. In the NHFS, the AMTS is used to detect cognitive dysfunction at admission. The cut off value for cognitive impairment is ≤ 6 out of ten indicating moderate to severe impairment. If a patient scores above 6 this may be interpreted as a 'normal' cognitive function. In this study an AMTS was not available. But patients were assessed by a geriatric physician at admission, whose assessment could be obtained from the patient's charts. As the relatively high AMTS cut-off value of six in the NHFS model enables to differentiate between normal and moderate to severe grades of abnormal cognitive functioning. Hence, we used the geriatric assessment as a proxy for cognitive dysfunction by AMTS in the NHFS score. The standard hemi arthroplasty implant was a unipolar cemented (Palamed G, gentamicin impregnated cement; Heraeus, Hanau, Germany) prosthesis (Mathys CCA; Mathys Ltd. Bettlach, Bettlach, Switzerland). All patients were in follow up for at least one year after enrolment. The local ethics committee gave its approval for the study (L2017044, TWOR, Rotterdam). No external funding was used for this study and no conflict of interest has to be declared.

3. Statistical analysis

The observed 30-day mortality of the cohort was compared with that predicted by the NHFS. Overall goodness-of-fit was assessed by Pearson's Chi-squared test, using the range of possible NHFS levels as natural categories. In addition U-statistics were calculated to assess the calibration of the model [25]. Discrimination was evaluated using the concordance (c)-statistic, which is equivalent to the area under the receiver operating characteristic curve if the outcome is binary [25]. Data analysis was performed using Stata version 14.2 (StataCorp, TX, USA) and all statistical tests were two-sided with a significance level $p < 0.05$.

4. Results

The baseline characteristics of the 916 patients, are shown in Table 1. In total 15 patients (1.6%) were excluded because of missing data in the NHFS, resulting in a sample size of 901 patients (Fig. 1). The mean age was 83 years (SD 8), majority of patients were female (68%) and almost 60% had an ASA score of ≥ 3. In the 30 days following surgery, 86 of 901 cases of a hip fracture had died, giving a mortality rate of 9.5% overall in our population. The all-cause mortality, one year post-operatively, was 28% ($n = 253$) in all patients. For each level of the NHFS, observed and predicted mortality are given in Table 2. The median NHFS in our cohort was 5, with no significant change in median NHFS over the past 5 years. As expected, the observed 30-day mortality after surgery increased with a higher preoperative NHFS level. Fig. 2 shows the NHFS and the original validation cohorts by city from Moppet et al. [14].

Overall comparison of the NHFS showed significant higher mortality rates in our population of hemi-arthroplasty patients compared to the rates predicted, indicating a lack of fit. (Pearson's Chi-squared test, $X^2 = 20.83$, df = 10, $p = 0.022$) (Fig. 3). Miscalibration was also indicated by significance of the U-statistic ($p < 0.001$). Discrimination (c-statistic or area under the receiver operating curve) was 73.9% (95% CI 68.6%–79.1%). (Fig. 3).

5. Discussion

The present study aimed to validate the NHFS in a Dutch intracapsular hip fracture population. Descriptive statistics shows that the baseline characteristics are comparable to previously studied hip fracture populations with respect to age, sex, ASA classification, time to surgery, length of time in hospital stay and 30-day mortality [13,14,21,22]. Results suggests that the NHFS under predicts 30-day mortality risk after hip hemi arthroplasty for our population.

Table 1
Baseline characteristics of 916 included patients.

Variable	Overall *n*/known *n* (%)
Age (yrs), mean (SD)	83 ± 8
Female gender (%)	621/916 (68)
ASA score	
1	9/907 (1)
2	387/907 (43)
3	471/907 (52)
4	40/907 (4)
NHFS median (IQR)	5 (4 to 6)
Residential status	
Home	596/889 (67)
Semi-independent nursing home	91/889 (10)
Nursing home	202/889 (23)
Walking aids	
None	495/815 (61)
Walking-cane	22/815 (3)
Rollator	256/815 (31)
Wheelchair or mobility scooter	42/815 (5)
Comorbidities	
Dementia	230/916 (25)
Diabetes Mellitus	178/916 (19)
Obesity (BMI >30)	58/585 (10)
Underweight (BMI < 18.5)	39/585 (7)
Rheumatoid arthritis	33/916 (4)
GFR on admission	66 ± 22
Severe renal disease (GFR < 30)	54/886 (6)
Parkinson	49/916 (5)
COPD	100/916 (11)
TIA	117/913 (13)
Cerebrovascular accident	82/913 (9)
Cardiovascular disease	537/912 (59)
Myocardial infarction	92/912 (10)
Previous hip fracture surgery	106/890 (12)
Hemoglobine on admission (mmol/L)	8.0 ± 0.9
Active oncological status	63/916 (7)
Chemotherapy	6/916 (0.7)
Medication	
Polypharmacy (> 4 medications)	492/916 (54)
Inhaled steroids	65/916 (7)
Immunosuppressive therapy	57/916 (6)

ASA: American Society of Anaesthesiologists; SD: standard deviation; BMI: body mass index; NHFS: Nottingham hip fracture score; GFR: glomerular filtration rate; TIA: transient ischaemic attack; COPD: chronic obstructive pulmonary disease.

Table 2
Observed mortality for each group compared with that predicted by the NHFS.

NHFS	(*n*) mortality/total (*n*)	Cases (%)	NHFS predicted (%)
0	0/7	0	0.7
1	0/6	0	1.1
2	0/5	0	1.7
3	5/157	3.2	2.7
4	8/265	3	4.4
5	23/231	10	6.9
6	30/151	19.9	11.0
7	13/65	20	16.0
8	6/12	50	24.0
9	1/2	50	34.6

NHFS (Nottingham hip fracture score); Mortality: 30-day mortality

In theory, the higher mortality rate observed in our intra-capsular hip fracture population in the Netherlands could be attributed to unexplained geographical differences in population or healthcare, or to the selection of one specific type of hip fractures in our study [26,27]. The latter is supported by results from Smith et al. [10], who claim that the higher mortality rate after hip hemi arthroplasty could be the result of higher impact (more tissue damage and longer duration) of the operation compared to osteosynthesis of the hip [10,24]. Detailed information about the frequencies of fracture types has however not been described in earlier studies validating the NHFS [13,15,21,22].

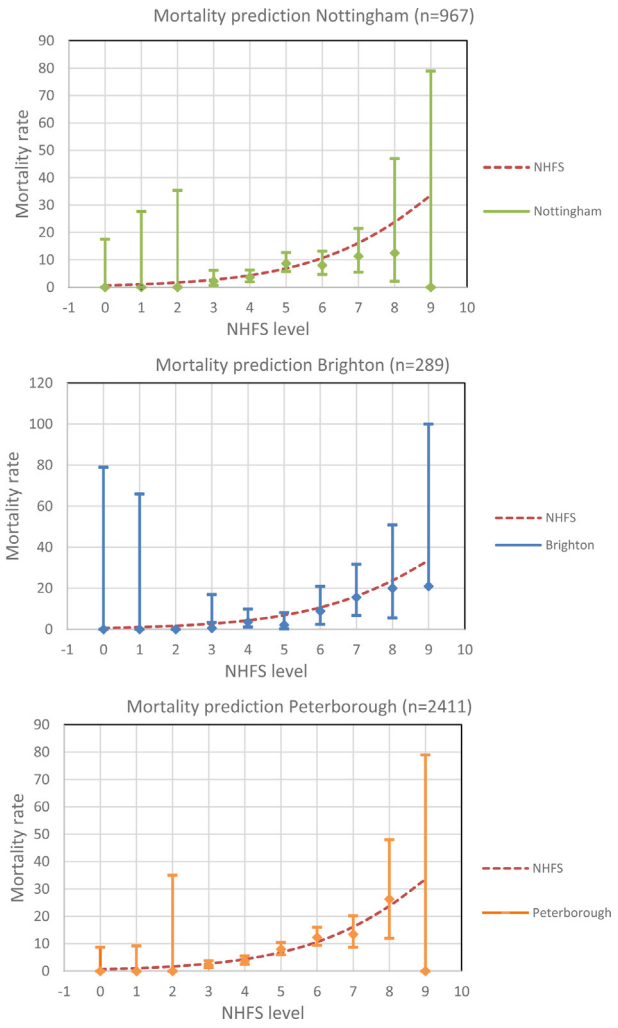

Fig. 2. Observed mortality in the original cohorts compared to the NHFS.

Table 3 describes the distribution of NHFS scores in all hip fracture cohorts. Results show higher mortality rates for patients in NHFS level 8 and 9 compared to predicted rates by the NHFS model. This is in line with the results of the study of Rushton et al. [22] who also had relatively more patients represented in these levels. In the cohorts originally used for development and validation of the NHFS, a level of 8 or 9 points was very rare, making it difficult to yield accurate predictions and to assess model performance in this range. Despite the small number of patients in these groups the NHFS still predicts mortality for these levels, potentially leading to underestimation of mortality risk. The mortality percentage found in our study and in the study of Rushton et al. could therefore potentially be more accurate for these high risk patients in the NHFS levels 8 and 9.

6. Clinical practice

The NHFS has been shown to predict the 30-day mortality adequately in elderly hip fracture patients [13,14,21,22]. As such, the NHFS is a useful tool to perform a preoperative assessment of mortality risk following a fracture of the hip, supporting clinical management on a daily base. Our study of intra-capsular hip fractures however showed significantly different mortality rates compared to the predicted rates by the NHFS model. As mentioned earlier higher mortality rates were registered before in the group with intra-capsular hip fractures suggesting the fracture and its

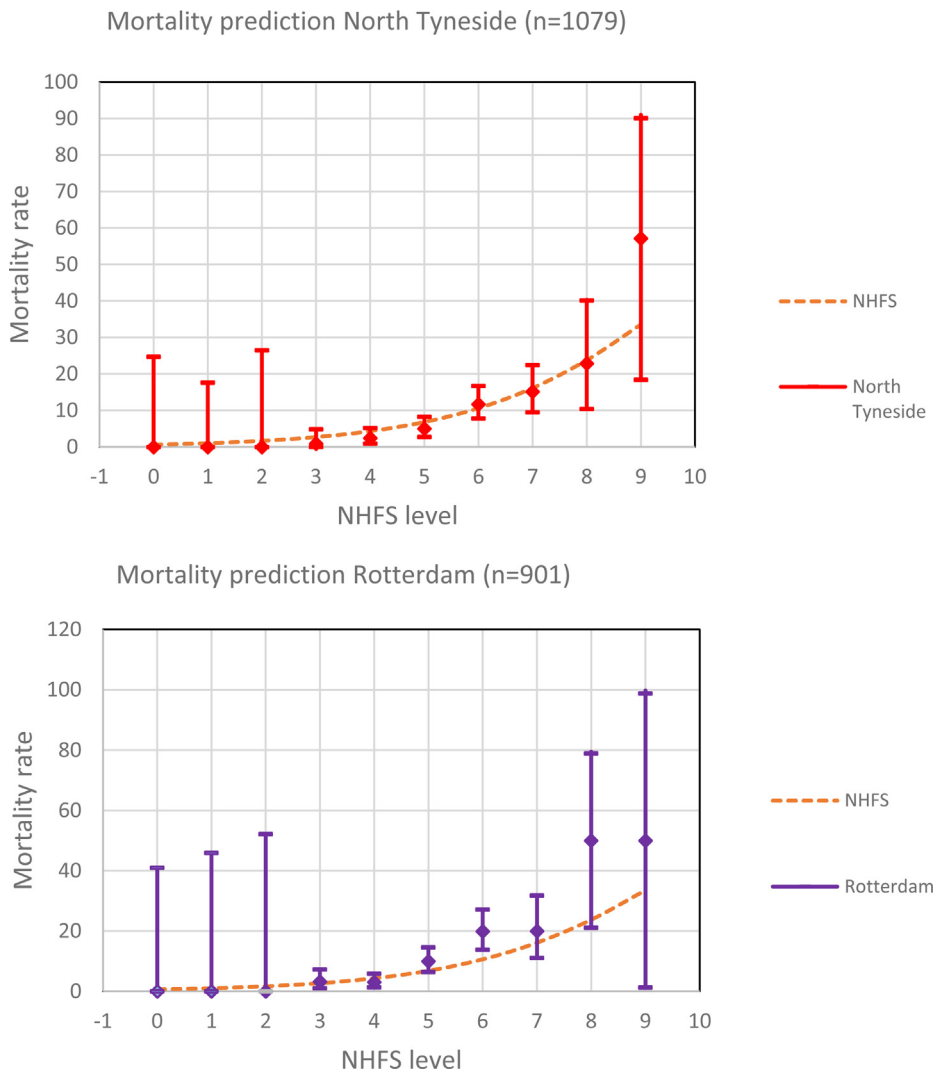

Fig. 3. Observed mortality in the validation cohorts compared to the NHFS.

Table 3
Variation in Nottingham Hip Fracture Score (NHFS) by cohort.

NHFS	Rotterdam (n = 901)	Nottingham (n = 967)	Brighton n = 289	Peterborough (n = 2411)	North Tyneside (n = 1079)
0	0	0	0	0	0
1	0	0	0	0	0
2	0	0	0	0	0
3	3.2	2.2	3.4	2.2	0.9
4	3	3.6	3.6	3.7	2.4
5	10	8.7	2.1	8.0	5
6	19.9	8.0	8.9	12.3	11.7
7	20	11.3	15.6	13.4	15.2
8	50	12.5	20	26.3	22.9
9	50	0	100	0	57.1

Nottingham, Brighton, Peterborough from Moppet et al. [11]; North Tyneside from Rushton et al. [18].

operation affects the 30-day mortality rate [10,24]. We therefore encourage future researchers to validate the NHFS in other intra-capsular fractures populations to define whether the NHFS should be recalibrated and calculated after the choice for implant.

6.1. Strengths and limitations

Existing literature describes the development and validation of the NHFS model in general hip fracture populations within Great Britain. However, there is, as far as we known, no differentiation in type of fracture and following surgery. Our study therefore aimed to validate the NHFS model in an intra-capsular hip fracture population. Due to a consecutive database in combination with electronic medical records 98% of eligible patients were included and selection bias was partly prevented. For assessment of cognition the AMTS (< 6 points) was not available, instead an existing diagnoses of dementia described in the patients charts in combination with the assessment of a geriatric physician led to one point for cognitive dysfunction, potentially leading to a small differences in classification of cognitive functioning. However, overall impact on validation

results of NHFS is expected to be small. Baseline characteristics and clinical data had to be completed in retrospect, leading to a potential absence of data on confounding factors. While in general, a sample size of at least $n = 100$ events (mortality) is recommended to have adequate power in validation studies [25], we were still able to detect differences in observed mortality rates compared to those predicted by the NHFS in our sample, suggesting lack of power was not a limitation here.

7. Conclusion

Previous findings suggest the NHFS can be used to assess a 30-day mortality prediction score in a general hip fracture population. Validation of the NHFS showed significant higher mortality rates in our population of hemi-arthroplasty patients compared to the rates predicted. Results suggest that if the NHFS is used for a patient with a hemi-arthroplasty following an intra-capsular hip fracture, this could result in an underestimation for the 30-day mortality rate. Further research is necessary to validate the NHFS in the subgroup of hip hemi arthroplasty patients and to identify whether recalibration of NHFS model for these patients would be necessary.

Disclosure of interest

The authors declare that they have no competing interest.

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Author contributions

L. de Jong: study coordinator, data analysis, writing the paper.
T.M.A.L. Klem: writing the paper.
G.R. Roukema: writing the paper.
T.M. Kuijper: data analysis, writing the paper.

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