British Journal of Anaesthesia **109** (4): 546–50 (2012)
Advance Access publication 22 June 2012 · doi:10.1093/bja/aes187

BJA

CLINICAL PRACTICE

Nottingham Hip Fracture Score: longitudinal and multi-centre assessment

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Editor's key points

- The Nottingham Hip Fracture Score (NHFS) has been developed to predict outcome after hip fracture surgery.
- The performance of the NHFS was studied in three large UK hip fracture units including 7290 patients.
- Recalibration of the original equation resulted in a robust tool for predicting 30 day mortality after hip fracture applicable to multiple UK centres.

Background. The Nottingham Hip Fracture Score (NHFS) was developed and validated in a single centre in 2007 as a predictor of 30 day mortality. It has subsequently been shown to predict longer term and functional outcomes. We wished to assess the ability of NHFS to predict outcomes in other centres and to investigate the change in outcome after hip fracture over time.

Methods. The NHFS was calculated for all patients with data from three UK hip fracture units: Peterborough (1992–2009), Brighton (2008–9), and Nottingham (2000–9) including 4804, 585, and 1901 patients, respectively. The logistic regression was used to recalibrate the NHFS to 30 day mortality across the three units using a random selection of 50% of the data set. Calibration was assessed using the Hosmer–Lemeshow goodness of fit.

Results. The median (inter-quartile range) NHFS values were Peterborough [4.0 (1–6)], Brighton [5.0 (3–7)], and Nottingham [5.0 (3–7)]. There was no correlation between 30 day mortality and time (R^2=0.05, P=0.115). The proportion of patients with NHFS≥4 showed a weak correlation with time (R^2=0.2, P=0.003). The original NHFS equation overestimates mortality in the higher-risk groups. A modified equation shows good calibration for all three centres {30 day mortality (%)=$100/1+e^{[(5.012\times(\text{NHFS}\times 0.481)]}$}. The hospital was not a predictor of 30 day mortality.

Conclusions. The NHFS, with an updated equation, is a robust predictor of 30 day mortality after hip fracture repair in geographically distinct UK centres.

Keywords: elderly; hip fracture; mortality; orthopaedic; outcome; scoring

Accepted for publication: 12 April 2012

Hip fracture in the elderly is associated with a high postoperative mortality, poor functional outcome, and significant financial and social costs.[1 2] The accurate prediction of risk is important for informed decision-making, communication with patients and relatives, planning of care, and internal or external audit of outcomes. The Nottingham Hip Fracture Score (NHFS) was originally developed and validated for a single-centre data set from 2000 to 2007.[3] It has been shown to be reliable in predicting 30 day mortality,[3] 1 yr mortality,[4] and functional outcome,[5] and has been used for stratification in a clinical trial.[6] Although it has been promoted as a tool for use in other units,[7] to date there have been no published data on its performance elsewhere. There has been a downward trend both in the prevalence of hip fracture[1] and in postoperative mortality in the UK in recent years,[8] and the original predicted mortality might no longer be valid due to improvements in multi-disciplinary care. We therefore wished to investigate the performance of the NHFS across separate large hip fracture units.

Methods

Databases

The Nottingham hip fracture database has been described previously.[3] It contains preoperative social, functional, medical, and physiological data; surgical, anaesthetic, and orthogeriatric interventions; and outcome data including length of stay, complications, discharge destination, and mobility at discharge. These data are collected prospectively by dedicated audit officers; internal audit has demonstrated high levels of accuracy. The Peterborough (1992–2012) and Brighton[9] (2005–2012) databases are similar, although with slightly different data captured. All three data sets allow for the calculation of the NHFS and determination of 30 day postoperative mortality. Data used in the original

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Table 1 Nottingham Hip Fracture Score. MMTS, mini-mental test score. Original predicted 30 day mortality is calculated by substituting the total NHFS into the equation: 30 day mortality (%)=$100/1+e^{[4.7182-(NHFS/2)]}$. New predicted 30 day mortality is calculated by substituting the total NHFS into the equation: 30 day mortality (%)=$100/1+e^{[5.012-(NHFS\times0.481)]}$

Variable	Value	Score	Proportion in complete data set (%; *n* = 11 670)
Age	<66	0	3.8
	66–85 yr	3	58.3
	≥86 yr	4	36.9
Sex	Male	1	21
Admission Hb	≤10 g dl^{-1}	1	10
MMTS	≤6 out of 10	1	33
Living in an institution	Yes	1	27
Number of co-morbidities	≥2	1	25
Malignancy	Yes	1	8

Table 2 Predicted values for 30 day mortality by the NHFS

Total NHFS	Predicted 30 day mortality (%)	
	Original NHFS	New NHFS
0	0.9	0.7
1	1.5	1.1
2	2.4	1.7
3	3.8	2.7
4	6.2	4.4
5	9.8	6.9
6	15	11
7	23	16
8	33	24
9	47	34
10	57	45

derivation of NHFS from Nottingham were not included in the calculation of scores.

Nottingham Hip Fracture Score

The NHFS is a summative score of seven preoperative variables which give an estimated risk of 30 day post-operative mortality using a standard logistic regression (Tables 1 and 2).

The NHFS was calculated for all patients aged more than 60 with complete data for each of the units and predicted and observed 30 day mortality calculated (Table 3).

A revised equation for converting the NHFS to the predicted mortality was derived using the complete combined data for 1992–2009 and standard logistic regression with NHFS and hospital as the two predictors (backward stepwise logistic regression, using 0.05 for entry and 0.1 for removal). A training set of 50% of subjects, chosen at random, was used to generate the equation with the remaining 50% used for validation. The goodness-of-fit was assessed for training and validation sets with the Hosmer–Lemeshow tests. We specified that adequate goodness-of-fit would be achieved if $P>0.05$.

Results

A total of 7290 patients were available for analysis of 30 day mortality and the NHFS (Table 2). The overall 30 day mortality for the complete cohort was 6.6%. The mortality was related to the NHFS in the overall cohort and for each centre individually (Tables 3 and 4).

There was a statistically significant difference between the NHFS for the three sites (Kruskal–Wallis, $P<0.001$). The median (inter-quartile range) was: Peterborough [4.0 (1–6)], Brighton [5.0 (3–7)], and Nottingham [5.0 (3–7)].

There was no correlation between 30 day mortality and time ($R^2=0.05$, $P=0.115$) (Fig. 1). The proportion of patients with the NHFS≥4 showed a weak correlation with time ($R^2=0.2$, $P=0.003$).

Table 3 Numbers of patients according to site and NHFS in the development sets

NHFS	Peterborough			Brighton			Nottingham			Overall		
	Number	(% of unit total)	30 day mortality	Number	(% of unit total)	30 day mortality	Number	(% of unit total)	30 day mortality	Number	(% of total)	30 day mortality
0	42	2	0.0	4	1	0	13	1	0.0	59	2	0.0
1	31	1	3.2	2	1	0	14	2	0.0	47	1	2.3
2	21	1	0.0	3	1	0	8	1	0	32	1	0
3	529	22	1.7	41	14	0	173	19	1.7	743	21	1.6
4	652	27	5.1	77	26	1.3	261	28	3.1	990	27	4.3
5	575	24	8.9	89	30	9.0	224	24	7.1	888	25	8.5
6	375	16	12.0	42	14	9.5	175	19	9.7	592	16	11.2
7	145	6	15.2	24	8	25	50	5	14	219	6	16.0
8	20	1	35.0	12	4	16.7	14	2	0	46	1	19.6
9	2	0.08	50.0	2	0.7	0.0	2	0.2	0.0	6	0.03	16.7
Total	2393			296			934			3623		

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Table 4 Numbers of patients according to site and NHFS in the validation sets

NHFS	Peterborough			Brighton			Nottingham			Overall		
	Number	(% of unit total)	30 day mortality	Number	(% of unit total)	30 day mortality	Number	(% of unit total)	30 day mortality	Number	(% of total)	30 day mortality
0	40	2	0.0	1	0.4	0	18	2	0.0	59	1	0.0
1	38	2	0.0	2	1	0	10	1	0	50	1	1.3
2	7	0.3	0.0	0	0.0	0	7	1	0.0	14	1	0.0
3	549	23	2.2	29	10	3.4	138	14	2.2	716	20	2.1
4	643	27	3.7	84	29	3.6	307	32	3.6	1034	28	3.8
5	591	25	8.0	85	29	2.1	254	27	8.7	930	25	8.6
6	389	16	12.3	45	16	8.9	162	17	8.0	596	16	11.3
7	134	6	13.4	32	11	15.6	62	6	11.3	228	6	12.3
8	19	1	26.3	10	3	20.0	8	1	12.5	37	1	28.1
9	1	0.04	0.0	1	0.4	100	1	0.10	0	3	0.08	0.0
Total	2411			289			967			3667	0.08	0.0

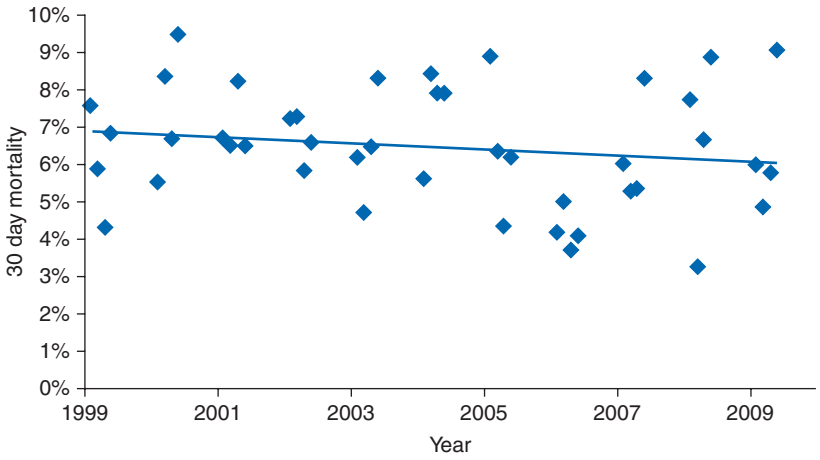

Fig 1 The longitudinal change in 30 day mortality after hip fracture repair in all three units studied. Thirty day mortality is shown for each quarter. There is no significant correlation between time and 30 day mortality (R^2=0.027).

Overall, the original NHFS equation overestimates mortality in the higher-risk groups (Tables 2–4).

The hospital was not a significant factor in logistic regression using both the NHFS and site as predictors. The logistic regression using the NHFS as the sole predictor gives good calibration for all the development sets (by site and overall) and on the validation sets (all $P>0.1$).

The proportions of patients (from the complete data set, including the original cohort) with the individual score items are given in Table 1 (11 670 patients in total).

Discussion

These data suggest that the NHFS, a scoring system for assessing the risk of 30 day mortality after hip fracture repair, is applicable outside its original derivation cohort. The original equation overestimated risk at lower and higher scores. A revised equation, using the same relative attribution of risk factors, has good calibration across all three units in both development and validation sets. In particular, the score is accurate for the most prevalent group with NHFS 4–6.

The risk status of those with hip fracture, as measured by the NHFS, increased over time, suggesting that the population is becoming more frail. These data are intentionally from before the introduction of Best Practice Tariff.[10] Nationally, there has been a downward trend in mortality over the last 2 yr that might not have been seen in these data.

We chose to recalculate the relationship between 30 day mortality and the original NHFS rather than create a new scoring system based on complete re-analysis of the data. We chose to do this for theoretical and practical reasons. First, the ordinal relationship between the NHFS and 30 day mortality is apparent in the data for the individual units and the combined data set supporting the premise that the NHFS is a predictor of outcome. Secondly, the individual

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components of NHFS are well-recognized independent predictors of outcome after hip fracture, so re-analysis was unlikely to produce major differences in predictor variables. Thirdly, the NHFS is already used in its current form, so changing the variables is, on a practical level, not helpful. The association between NHFS and 1 yr mortality and functional outcome remains valid as these studies stratified patients based on their absolute NHFS rather than on the predicted 30 day mortality. In line with previous studies, most notably POSSUM/P-POSSUM,[11] we chose to treat the NHFS as a single predictor variable.

To have clinical credibility, any scoring system should ideally be demonstrated to be robust in more than its original derivation cohort. The original work demonstrated validity in a validation data set, but this was limited to Nottingham data. These new data demonstrate that the NHFS is a robust tool in clinically, demographically, and geographically distinct units within the UK. This would suggest that further multi-centre validation across the UK would be appropriate. Given the differences that exist in models of care and populations between the UK and other countries, we do not know whether the NHFS has validity in other countries. There is no perfect scoring system that combines the ease of use and relevant clinical validity. The NHFS is a compromise between simplicity (such as the ASA classification) and complexity. The calculated coefficients from the original derivation of the NHFS are not integer values and were deliberately rounded to create an accessible score at the expense of some accuracy.

Although calibration of NHFS with 30 day mortality in the complete set and for individual units is acceptable, the proportion of patients with a high (>4) NHFS appears to be increasing slightly with time. This would suggest that outcomes for these patients are improving, despite an increase in frailty. However, it does mean that in the future, the NHFS is likely to require recalibration to these improved outcomes.

These data, which represent a sample size equivalent to 17% of the annual number of hip fractures in England,[1] also provide useful information regarding individual factors relevant to those caring for people with hip fracture. Marked cognitive dysfunction (AMTS$\geq$6) on admission is common, occurring in around one-third of people. This frequency supports the new UK NICE hip fracture quality standard for hip fracture that all patients should be assessed for confusion on admission.[12] It also has implications for research studies. We would argue that studies in hip fracture should have to provide strong justification of why confused patients should not be included. Severe anaemia (Hb$<$10 g dl^{-1}), a known risk factor for poor outcome,[13 14] is common affecting 10% of patients, and coupled with the blood loss in the perioperative period should be a strong driver towards research aimed at managing this effectively. Other workers have also demonstrated the association between perioperative anaemia and poor outcome in the elderly.[15] The recent FOCUS study[16] suggested no benefit of a liberal postoperative transfusion threshold in relation to mobility or mortality, although cardiac complications were higher in the restrictive group. Other workers have suggested that haematopoietic agents (i.v. iron, erythropoietin) confer benefit without the risks (and costs) of transfusion.[17] Frailty is recognized as a marker of poor outcome in hospital and community settings. To an extent, the NHFS is a summary measure of various surrogates of frailty in the elderly. Future work might examine the clinical utility of extending the application of the NHFS to non-hip fracture areas albeit with the modification of outcome such as mortality after medical admission, laparotomy, or pubic ramus fracture.

Although randomized controlled trials are viewed as the gold standard for identifying effective treatment, high-quality databases allow for the observational description of 'all' patients undergoing a specific procedure and analysis of pragmatic interventions such as the type of anaesthesia[18] in comparison with very much smaller randomized controlled trials of subgroups of the hip fracture population, extrapolated to the hip fracture population as a whole.[19] National data collection would assist in this process: the National Hip Fracture Database collects most of the NHFS fields already. Prospective collection of the three data fields not currently collected by NHFD (Hb, Cancer, two or more co-morbidities) would confirm (or refute) the accuracy of the NHFS, and provide baseline score for future comparison, both between and within units and longitudinally over time.

On the basis of the data presented here, we believe that the NHFS is a robust tool that can be used by clinicians at the individual patient level to communicate risk with patients and carers, to help plan care, and at the unit level to assist with the audit of data.

Declaration of interest

I.K.M. has received honoraria from Schering-Plough in the past 5 yr. He is a member of the Editorial Board of the *British Journal of Anaesthesia*. He is a member of the NICE Quality Standards Topic Expert Group on Hip Fracture. M.P. has received expenses and honoraria from a number of commercial companies and organizations for giving lectures on different aspects of hip fracture treatment. In addition, he has received royalties from B. Brawn Ltd related to the design and development of an implant used for the internal fixation of intracapsular hip fractures. R.G. is Honorary Secretary Elect of the Association of Anaesthetists of Great Britain & Ireland (AAGBI). He is a member of the Editorial Board of *Anaesthesia*. He was the chair of the AAGBI Hip Fracture Guideline Group and founded the Hip Fracture Perioperative Network. S.M.W. is a Council member of the Age Anaesthesia Association, research co-ordinator for the NHS Hip Fracture Anaesthesia Network, represents the Hip Fracture Perioperative Network to the National Hip Fracture Database, sits on the AAGBI Hip Fracture Anaesthesia working party, and provided expert advice to NICE concerning 'The management of hip fracture in adults' (CG124). He is an editor of *Anaesthesia*. C.G.M. is the chair of the British Orthopaedic Association Trauma Group and a member of the Department of Health Fragility Fracture Board. He has received honoraria from

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Smith and Nephew in the past 2 yr. He is on the International Editorial Board of *Injury*.

Funding

No external funding was used for this study.

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