**NHFD 2019 annual report: methods used for statistical analysis**

## Introduction

The analyses used for the NHFD 2019 annual report were carried out by the Nuffield Department of Orthopaedics, Rheumatology and Musculoskeletal Sciences (University of Oxford). These analyses were largely identical to those used in the preparation of reports for previous years, which have been previously described in detail[1]. This document outlines where previous methods have been adapted or new approaches introduced.

## Data quality screening

NHFD data for patients admitted within the period 1st January 2018 to 31st December 2018 were screened for completeness and the following exclusion criteria were applied:

- Missing data on gender
- Age <60 or >115
- Duplicate records (based on flag created by Crown Informatics)
- Missing data on admission date
- Missing data on vital status at 30-days
- Records with admission date after surgery date

## Funnel plot methodology

Crude and adjusted 30-day mortality rates within each of the hospitals (n=175) was estimated and presented using funnel plot methodology as previously described[1] and as outlined by Spiegelhalter (2005) [2]

The 95% and 99.8% control limits around the target performance (national average) were created using 1.96 and 3.09 standard deviation limits, expressing the uncertainty arising from sampling variability for the range of hospital sample sizes encountered. Adjusted estimates were derived using a logistic regression model[2], with adjustment made for covariates as described by Carmen *et al* [3]. Differences between the model used here and that of Carmen *et al*. include the use of three rather than two categories for pre-operative mobility, and the inclusion of a continuous variable for age rather than 10-year categories. The linearity of association between age and mortality was inspected and considered the best approach as compared to the use of a fractional polynomial model. Multiple imputation using chained equations[4] was used to deal with missingness in ASA grade, admission source, pre-fracture mobility and fracture type, although only a single imputed dataset was analysed.

## Run charts

For hospital-specific mortality run charts, the 30-day mortality rate for the UK (across all hospitals) at each quarter – with a 1-year 'lookback' (i.e. annualised) – between 1st January 2017 to 31st December 2018 was used as the target performance, using data dating back to

1st January 2016. The 95% and 99.8% control limits were created using 1.96 and 3.09 standard deviations, taking into account the number of annualised hip fracture admissions per quarter within each hospital. Annualised crude and adjusted 30-day mortality rates per quarter were plotted over these control lines for each hospital. The adjusted annualised 30-day mortality rates were derived at each quarter using the same indirect standardization approach as carried out for the risk-adjustment for the mortality funnel plot.[2] A logistic regression model was used for 2016-2018 data, with covariates being the same as for the mortality funnel plot except that age was entered in 5-year categories rather than on a continuous scale. The coefficients from this model are included in the appendix section (below).

## References


1. Tsang C CD. Statistical methods developed for the National Hip Fracture Database annual report, 2014: a technical report. London: The Royal College of Surgeons of England, 2014.
2. Spiegelhalter DJ. Funnel plots for comparing institutional performance. *Statistics in medicine* 2005; **24**(8): 1185-202.
3. Tsang C, Boulton C, Burgon V, Johansen A, Wakeman R, Cromwell DA. Predicting 30-day mortality after hip fracture surgery: Evaluation of the National Hip Fracture Database case-mix adjustment model. *Bone Joint Res* 2017; **6**(9): 550-6.
4. Pedersen AB, Mikkelsen EM, Cronin-Fenton D, et al. Missing data and multiple imputation in clinical epidemiological research. *Clin Epidemiol* 2017; **9**: 157-66.


## Appendix

| Case-mix adjustment model (2016-2018) | | |
|---|---|---|
| | coefficient | OR |
| **intercept** | -5.1137 | |
| **age*** | | |
| 70-79 | 0.2724 | 1.3131 |
| 80-89 | 0.6328 | 1.8830 |
| 90+ | 1.0604 | 2.8874 |
| **gender** | | |
| male | 0.6019 | 1.8255 |
| **Admission source** | | |
| Not from own home | 0.2054 | 1.2280 |
| **ASA grade** | | |
| 3 | 1.0190 | 2.7704 |
| 4 or 5 | 2.0791 | 7.9973 |
| **mobility** | | |
| Mobile outdoors with 1 or 2 aids or frame | 0.2759 | 1.3177 |
| Some indoor or no functional mobility | 0.6057 | 1.8326 |
| **fracture type** | | |
| Extracapsular, including other | 0.0667 | 1.0690 |

* actual model for funnel plot treats age as continuous. Model for runcharts uses 5-year age bands