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Higher 30-day Mortality Associated with the use of Intramedullary Nails Compared to Sliding Hip Screws for the Treatment of Trochanteric Hip Fractures: a Prospective National Registry Study

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ABSTRACT

Aims

To investigate the association between the type of surgical intervention used to treat trochanteric hip fractures and 30-day mortality.

Patients and Methods

Analysis of data from the National Hip Fracture Database collected 1/1/2011-31/12/2014, using generalised linear models with incremental case-mix adjustment (patient, non-surgical and surgical characteristics and socioeconomic indicators). 82,990 patients with trochanteric hip fractures were included.

Results

Short and long intramedullary nails were associated with an increase in 30-day mortality (adjusted OR 1.125 [95% CI: 1.040, 1.218]; p=0.004) compared to sliding hip screws (12.5% increase). If this were causative, it would represent 98 excess deaths over the 4 year study period and one excess death would be caused by treating 112 patients with an intramedullary nail rather than a sliding hip screw.

Conclusions

There is a 12.5% increase in the odds of 30-day mortality associated with the use of intramedullary nails to treat trochanteric hip fractures compared to sliding hip screws.

Clinical Relevance:

- Due to the association with lower mortality, sliding hip screws should be used in preference to intramedullary devices to treat trochanteric hip fractures, other than for particular fracture subtypes (e.g. pathological and atypical fractures).
- Further randomised controlled trials comparing intramedullary and extramedullary devices should not be performed unless they are adequately powered to detect a difference in mortality between the treatment groups.

INTRODUCTION

Approximately 65,000 hip fractures occur annually in the NHS[1] with a total cost of £2 to 3 billion.[2] 1.6 million hip fractures occur worldwide annually which could rise to 6 million by 2050.[3] Hip fracture treatment aims to efficiently restore function and relieve pain with the lowest possible risk of morbidity and mortality.

Trochanteric fractures represent between one third and one half of hip fractures.[1,4,5] There is controversy regarding treatment. Some authorities recommend an extramedullary device (e.g. sliding hip screw; SHS),[6] others recommend that either a SHS or intramedullary nail (IMN) can be used[7] and some recommend the use of IMN (e.g. cephalomedullary nails) in all but the most simple and stable of fractures.[8] IMN can be short or long. Long IMN are preferentially selected for the treatment of certain fracture subtypes (e.g. pathological and atypical) to provide fixation along the whole bone. A recent Cochrane review suggests a lower complication rate for SHS compared to IMN with equivalent functional outcomes and no difference in mortality.[9] Despite this, the use of the more expensive IMNs[6] has increased.[10]

Publications concerning hip fractures have tended to disregard published clinical trial evidence.[11] Studies to date have been underpowered to establish a difference in mortality. We hypothesised that there may be an association between the use of extramedullary (SHS) versus intramedullary devices (IMN) for the treatment of trochanteric hip fractures and 30-day mortality due to the instrumentation of the femoral intramedullary canal. To obtain a large enough sample size to determine if this was the case, the National Hip Fracture Database (NHFD), a large and comprehensive national database of patients with a hip fracture and case ascertainment rates of over 95%, was studied.

PATIENTS AND METHODS

Using data from the NHFD, we investigated the 30-day mortality rates associated with trochanteric fracture treatment with either an SHS, long IMN or short IMN. Patients admitted to a hospital in England and Wales during 2011 to 2014 were included.

Data Source and Population

The NHFD began data collection in 2007 and since January 2011, data capture is estimated to have been over 95%.[12] Patients' details with traceable National Health Service (NHS) numbers were passed by Crown Informatics (NHFD data processor) to the NHS Personal Demographics Service, who provided the date of death from the Office for National Statistics (ONS). Anonymised data were then passed to the research team.

All individuals admitted with a trochanteric hip fracture between the 1st January 2011 and the 31st December 2014 that underwent surgery within 30-days of admission (or date of fracture if already an inpatient) and mortality status at 30-days were included. Exclusions were: Intracapsular and subtrochanteric fractures; surgical interventions other than SHS or IMN; unknown time to surgery; length of stay; time to surgery <0 hours or >30-days; length of stay <0 hours; unknown discharge destination; age <60 and >120 years; unknown age, gender and residence prior to admission (figure 1).

The primary outcome is death at 30-days following trochanteric hip fracture. Deaths occurring prior to 30-days were determined using a combination of Office for National Statistics death records, and/or time of discharge/discharge destination, which also indicates when a patient has died. Contralateral hip fractures in the same patient were considered independent events.

The primary exposure was the type of surgical intervention received: Sliding hip screw (SHS), short intramedullary nail (IMN) or long IMN.

All analyses were adjusted for the month and year of admission[4,13] using month and year indicator variables respectively, due to the strong association between mortality and season.[4] Models also included patient-level (Sunday surgery, time to surgery, out of hours surgery, age, sex, pre-admission residence, American Society of Anesthesiologists (ASA) grade, pre-operative abbreviated mental test score (AMTS), pathological fracture, pre-operative mobility), non-surgical treatment (falls assessment, multi-disciplinary team (MDT) assessment), perioperative (anaesthetic type) and socioeconomic confounding factors (Supplementary Material Table 1).

Statistical Analysis

Means, standard deviations, and interquartile points were used to describe continuous variables. Frequencies and percentages were used to describe categorical variables. The associations between 30-day mortality and surgical intervention were modelled using logistic regression. Confounder adjustment was conducted incrementally (Table 1). Model 0 was unadjusted. Model 1 adjusted for patient-level confounding factors. Model 2 further adjusted for non-surgical treatment factors, model 3 further adjusted for perioperative factors and model 4 further adjusted for socioeconomic position. Given the strength of the seasonal association with mortality, we used a wide variety of seasonal model specifications to investigate the primary effect's sensitivity to these assumptions using two alternative seasonal specifications, an elapsed month parameterisation and a trigonometric regression (Fourier series).[14,15] Data were examined for interactions between the primary exposure and

ASA grade and gender. All analyses were conducted in Stata 14.0 (StataCorp LP, College Station, TX).

Missing data

There were 52,481 complete cases available. Assuming the data were missing at random, we imputed missing values using multiple imputation with chained equations (MICE; Supplementary Material Table 2). Sex-specific imputation models were used for each variable that contained missing data, and combined prior to analysis. One hundred sex-specific imputed data sets were generated with a burn-in of 30 repetitions. This allowed analysis of 82,990 cases in the models specified above. Complete case and multiple imputation case data are presented for clarity.

RESULTS

Between 1st January 2011 and 31st December 2014, there were 258,891 treatment episodes for hip fracture. Following application of inclusion/exclusion criteria, 82,990 cases were available for analysis (figure 1).

26% of trochanteric fractures occurred in males, in whom the crude 30-day mortality rate was higher than females (10.6% vs. 6.7%). 86.7% of trochanteric fractures were treated with an SHS, 7.9% with a long IMN and 5.5% with a short IMN. For the NHFD, there has been a trend towards decreased use of SHS in trochanteric fractures (84% in 2011; 80% in 2016). The NHFD records substantial variation with 4% of patients receiving a SHS in some hospitals compared to 100% in others.[16] Patient age, pre-operative AMTS and length of time to surgery were similar between the groups (Table 2), as were the type of residence patients were admitted from, overall condition (ASA grade), pre-operative mobility, whether MDT and falls assessment were conducted and type of anaesthesia (Table 3). As expected, a higher proportion of patients had a pathological fracture in the long IMN group (4.1%; n=187) compared to the SHS (0.6%; n=255) and short IMN groups (1.0%; n=29). When the crude length of stay was considered, in those alive at 30 days it was longest for long IMNs (median 18.2 days (interquartile range (IQR) 11.4,32.1)), than short IMNs (median 16.8 days (IQR 10.7,28.3)) and SHSs (median 16.5 days (IQR 10.1,29.1)) although these differences were small with wide variance.

In the unadjusted analysis, the 30-day mortality was lowest for SHSs (7.6%), then short IMNs (8.2%) then long IMNs (8.3%). These differences persisted in logistic regression models, despite adjustment for patient, non-surgical treatment, perioperative and socioeconomic confounding factors (Table 4). The short and long IMN groups were combined for further analysis. In crude analysis of complete case data, the use of IMN was associated with higher odds of death at 30-days (odds ratio (OR) 1.148 [95% CI: 1.046, 1.261]; p=0.004) compared with the use of SHS, this, albeit weaker association persisted after multiple imputation (OR 1.092 [95% CI: 1.015, 1.175]; p=0.018) (Table 5). Following multiple imputation and adjustment for patient, non-surgical treatment, perioperative and socioeconomic confounding factors, again an association between IMN use and higher 30-day mortality was seen (OR 1.125 [95% CI: 1.040, 1.218]; p=0.004) compared with the use of SHS. The crude mortality of those treated with SHS is 7.63%, and assuming the OR increase in mortality due to the use of IM nails is 1.125 and the choice of intervention is causative, this would correspond to an excess of 98 deaths over the four years studied. Alternatively, the number of patients treated with IMN rather than SHS to cause one excess death would be 112 if the choice of intervention is causative.

The sensitivity analyses using elapsed month parameterisation and trigonometric regression did not alter the interpretation of any of the results (Supplementary Material Tables 3 and 4). There was no interaction between the type of surgical intervention and ASA grade (Supplementary Material Table 5) or gender ($p>0.05$).

DISCUSSION

We have analysed 30-day mortality in patients who sustained a trochanteric hip fracture, treated with either a sliding hip screw or an intramedullary nail. In 82,990 hip fracture episodes between 1st January 2011 and the 31st December 2014, we have shown an association between the type of surgical intervention performed and the risk of 30-day mortality in both crude and adjusted analyses that, if the choice of intervention was causative, would equate to 25 excess deaths each year studied, despite the relatively low usage of IMN compared to other countries such as the USA. This difference, if there is causation, would equate to one excess death for every 112 patients treated with an IMN rather than a SHS; over the period studied 2,766 IMNs were used on average each year to treat trochanteric hip fractures in England and Wales. The differences observed were consistent across ASA grade and gender. This study is of a substantially larger population than has been included in 30 previous randomised controlled trials, which were not adequately powered to detect a difference in mortality outcomes.

Given our findings, it is reassuring to note that 87% of trochanteric hip fractures in this cohort were treated with a SHS; however, from 2011 to 2016 there has been a decrease to 75% nationally. There is significant unexplained national and global variation in practice.[1,17] Guidelines from the American Association of Orthopaedic Surgeons support the use of an IMN over a SHS to treat unstable trochanteric fractures (Arbeitsgemeinschaft für Osteosynthesefragen (AO) classification 31A2 and 31A3), and give equal recommendation to both treatments for stable trochanteric fractures (31A1). A survey of 3,784 orthopaedic surgeons in the USA revealed that only 19% primarily use a SHS for the treatment of trochanteric hip fractures,[17] despite the proven cost effectiveness of the SHS.[18] The decline in use of the SHS has been well documented.[19-21] Justification usually points towards theoretical biomechanical advantages associated with IM nailing, despite the lack of robust evidence to support this.[9] It is difficult to determine the influence of industry and reimbursement practices[19] on such a precipitous change in practice.

Current guidance from the National Institute for Health and Care Excellence (NICE) in the UK states that a SHS should be used in preference to an IMN for trochanteric (AO classification 31A1 and 31A2) fractures.[22] A 2017 meta-analysis compared mortality between IMNs and SHSs to specifically treat more unstable 31A2 fractures (where any theoretical benefit of improved stability should be most marked between the interventions);[23] four randomised controlled trials included reported one year mortality with pooled crude rates of 13% following 297 SHSs and 17% following 303 IM nails (relative risk 1.33 [95% CI: 0.92, 1.93] p=0.13).[24-27] One-year mortality may not however represent a sensitive measure of the effect of the intervention in the frail, older population that sustain a hip fracture. A study of the patient case notes of those who had died within one year estimated that 33% of deaths were unrelated to the hip fracture, with only 25% being directly related.[28] Mortality rates are seen to fall dramatically following an initial spike following hip fracture surgery.[29] Thirty-day mortality has been shown to provide a more discriminatory measure of surgical interventions in other studies of orthopaedic surgery in older people.[30,31] Only one trial included within the 2017 meta-analysis reported mortality measured at 30-days. In this trial 21% of 100 patients undergoing IMN had died at 30-days compared with 10% following 110 SHS procedures (hazard ratio 1.69 [95% CI 0.91, 3.45], p=0.13).[27] The data available in this study do not allow us to determine the cause of a difference in 30-day mortality rates between patients with trochanteric fractures treated with an IMN compared to a SHS. The most obvious difference between the interventions is the instrumentation of the femoral intramedullary canal. We feel that the deleterious effects associated with this are the most likely cause of the observed difference in mortality. Intramedullary nailing is known to be associated with increased intramedullary pressure, embolic showers and fat intravasation,[32] features that the populations studied do not cope well with due to their poor physiological reserve. As increased pressures are observed, even with simple manoeuvres such as inserting guide wires,[33] it is understandable that the effects may be common to short and long IMN, as we have observed here. The insertion of an IMN in these older individuals may represent a “second hit” during a vulnerable period physiologically.[34]

The NHFD is a disease-specific national prospective audit with data capture rates over 95% in the period of study.[12] These case ascertainment rates have continued to improve with the 2017 NHFD annual report indicating that all eligible 177 hospitals contributed data, and in comparison to the Hospital Episodes Statistics database, which is generally considered the gold standard for case ascertainment in the NHS, ascertainment rates were 104% indicating under-reporting in HES. The dataset contains detailed information on patient, non-surgical treatment, perioperative and socioeconomic confounding factors that allow for relevant risk adjustment when outcomes such as 30-day mortality are considered. The number of mandatory fields for data collection, together with a Best Practice Tariff[35] that encourages data capture ensures high rates of data capture. Despite the magnitude of the population studied, inferring causal effects from prospective observational data remains problematic and in this analysis, we are only able to determine an association, not causation.

Although it is reassuring that the results of our adjusted analyses, with multiple imputation for missing variables, were consistent with the crude analysis and incremental adjustments, we must remain cognisant of the limitations associated with the interpretation of cohort data. The NHFD does not capture data on the reasons motivating selection of surgical intervention; whether IMN are selected for individuals at higher overall risk of death is unknown (i.e. unknown confounding by indication); however, the variation in the pattern of usage across hospitals suggests hospital-level rather than patient-level characteristics may play a greater role. We did not have data on comorbidities to assess whether this assumption was correct. It is possible that adjustment for comorbidities, not available in the NHFD dataset beyond that provided by ASA grade, may have changed our results; however, this is unlikely given that scores used to predict mortality in hip fracture populations do not show greater discrimination when comorbidities are included rather than ASA.[36] We observed a higher proportion of patients with pathological fractures treated with a long IM nail; this was expected and our model accounted for this variation. Classification of hip fractures in the NHFD is carried out by the treating surgical team and it is possible some fractures were misclassified. Another limitation is the dataset grouped all patterns of trochanteric fractures (AO/Orthopaedic Trauma Association (OTA) A1, A2 and A3 fractures) together, the current evidence regarding the treatment of A3 fractures, which represent a small subset (8% of trochanteric fractures), is inconclusive, and NICE recommends that either a SHS or IMN can be used. Currently there is no conclusive evidence to show that fracture patterns, that may be considered more severe, independently predict mortality in hip fracture populations. Accordingly, hip fracture mortality risk prediction scores do not include fracture type beyond the broad categorisation we have used.[36,37] Our analysis studied 30-day mortality. We did not have data on cause of death which meant that we could not attempt to determine which deaths may have been associated with, or attributable to, the choice of surgical intervention. Other outcomes, such as length of stay, rates of post-operative mobilization, peri-operative complications will be clinically relevant to healthcare providers and patients, but were beyond the scope of this analysis. Implant costs alone are 3 times higher for short IMN than SHS and over 4.5 times higher for long IMN than SHS.[6] We do not have sufficient data to provide robust health economic estimates of differences between treatments.

We have analysed data from a large and generalisable national cohort and have demonstrated a significantly elevated association with risk of death at 30-days in patients treated with both short and long intramedullary nails, compared to sliding hip screws for the treatment of trochanteric hip fractures. Therefore, the growing global trend towards increased use of intramedullary nails for the treatment of this common fracture type is not currently justified. We believe that a randomised controlled trial adequately powered for mortality would be difficult to deliver. To be adequately powered, with an alpha value of 0.05, a power of 0.8 and an effect size of 0.1 on 30-day mortality are assumed, a simple design randomised controlled trial with a 1:1 allocation ratio would require a sample size of 23,645 patients per group. Alternative study designs, such as cluster randomised trials, may be appropriate for the study of these interventions in the hip fracture population with efficient data collection through routinely collected data sources such as the NHFD. Cluster designs would however have the effect of increasing the sample size when they account for variation between centres (or clusters). Patients, surgeons and other stakeholders need to be aware of the observed increased risk associated with intramedullary nails when selecting and commissioning operative interventions. Given the current lack of robust evidence to support the use of IMNs over SHSs for the treatment of trochanteric fractures and the higher cost of IMNs, we recommend that the SHS should be the preferred intervention for this population.

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Table 1: Model specification detailing exposure and confounding variables used within the analysis

Model	Exposures	Confounding variables
0	a) 3 implant groups (SHS, short IM nail, long IM nail) b) 2 implant groups (SHS, IM nail)	None
1	Model 0: a) 3 implant groups (SHS, short IM nail, long IM nail) b) 2 implant groups (SHS, IM nail)	Patient Level confounding factors
2	Model 1: a) 3 implant groups (SHS, short IM nail, long IM nail) b) 2 implant groups (SHS, IM nail)	Patient Level confounding factors Non-surgical treatment factors
3	Model 2: a) 3 implant groups (SHS, short IM nail, long IM nail) b) 2 implant groups (SHS, IM nail)	Patient Level confounding factors Non-surgical treatment factors Surgical treatment factors
4	Model 3: a) 3 implant groups (SHS, short IM nail, long IM nail) b) 2 implant groups (SHS, IM nail)	Patient Level confounding factors Non-surgical treatment factors Surgical treatment factors Socioeconomic position
5	Sensitivity analysis; model 4: a) 3 implant groups (SHS, short IM nail, long IM nail) b) 2 implant groups (SHS, IM nail)	Patient Level confounding factors Non-surgical treatment factors Surgical treatment factors Elapsed month seasonal specification
6	Sensitivity analysis; model 5: a) 3 implant groups (SHS, short IM nail, long IM nail) b) 2 implant groups (SHS, IM nail)	Patient Level confounding factors Non-surgical treatment factors Surgical treatment factors Fourier series seasonal specification

Definitions: Patient level confounding factors (Month of admission, Year of admission, Sunday Surgery, TTS - time to surgery[≤24 |>24] , Out of hours-<08:00 & >17:00, (Age [60 to 120], sex[male or female], pre-admission residence [own home, hospital, Nursing/rehabilitation/residential home], ASA grade[I+II, III, IV+V], Pre-operative AMTS score, Pathology[None, Malignancy, atypical], Pre-operative mobility [walks without aid, walks with aid, no functional mobility]). ***Non-surgical treatment factors*** *(Falls assessment [yes/no], Multi-Disciplinary Team Assessment [yes/no]).* ***Surgical treatment factors*** *(Anaesthetics [Spinal, Spinal and epidural or nerve block, general anaesthetic, general anaesthetic + epidural or nerve block].* ***Socioeconomic position*** *(Deciles of Income Deprivation Affecting Older People Index, Welsh Index Multiple Deprivation).*

Table 2: Descriptive statistics of continuous variables

	Fixation	Alive @ 30days n	Mean	(SD)	[range]	Dead @ 30days n	Mean	(SD)	[range]
Age at fracture (years)	SHS	66,440	83.7	(8.3)	[60, 111]	5,486	87.1	(7.5)	[88, 107]
	Long IMN	5,973	82.4	(8.7)	[60, 104]	544	85.3	(8.1)	[87, 103]
	Short IMN	4,176	83.1	(8.3)	[60, 108]	371	86.8	(7.6)	[88, 104]
	All	76,589	83.5	(8.3)	[60, 111]	6,401	86.9	(7.5)	[87, 107]
AMTS pre-operatively	SHS	55,914	6.87	(3.6)	[0, 10]	4,483	5.31	(3.9)	[6, 10]
	Long IMN	5,002	7.29	(3.4)	[0, 10]	449	6.06	(3.9)	[8, 10]
	Short IMN	3,457	7.08	(3.5)	[0, 10]	307	5.18	(3.9)	[6, 10]
	All	64,373	6.92	(3.6)	[0, 10]	5,239	5.37	(3.9)	[6, 10]
Time to surgery (hours)	SHS	66,440	30.3	(28.0)	[0.02, 691.9]	5,486	33.2	(30.6)	[24.5, 473.7]
	Long IMN	5,973	33.4	(29.8)	[0.42, 478.7]	544	37.9	(37.0)	[26.2, 384.8]
	Short IMN	4,176	30.2	(25.5)	[0.30, 363.3]	371	34.4	(31.3)	[25.0, 209.3]
	All	76,589	30.5	(28.0)	[0.02, 691.9]	6,401	33.7	(31.2)	[24.7, 473.7]
Length of stay in hospital (days)*	SHS	66,440	24.4	(181.7)	[0.1, 595.9]	5,486	12.3	(8.0)	[10.8, 30.0]
	Long IMN	5,973	26.3	(29.1)	[0.1, 1216.5]	544	12.9	(7.7)	[11.6, 30.0]
	Short IMN	4,176	23.1	(20.0)	[1.0, 183.6]	371	13.0	(10.7)	[11.2, 30.0]
	All	76,589	24.5	(169.5)	[0.1, 1216.5]	6,401	12.4	(8.1)	[10.8, 30.0]

* Note – death in hospital triggers a discharge event and therefore those that die in hospital before 30 days may artefactually appear to have a shorter length of stay

Table 3: Descriptive statistics of categorical variables

		Alive at 30 Days								Dead at 30 days							
		SHS		Long IMN		Short IMN		All		SHS		Long IMN		Short IMN		All	
		n	(%)	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)	n	(%)
	Alive/Assumed Alive	66,440	(100.0)	5,973	(100.0)	4,176	(100.0)	76,589	(100.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
	Dead	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	5,486	(100.0)	544	(100.0)	371	(100.0)	6,401	(100.0)
	Missing	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
Admitted from	Hospital	2,557	(3.8)	194	(3.2)	152	(3.6)	2,903	(3.8)	400	(7.3)	35	(6.4)	26	(7.0)	461	(7.2)
	Nursing/ Residential Home / Rehabilitation Facility	14,329	(21.6)	1,044	(17.5)	795	(19.0)	16,168	(21.1)	1,729	(31.5)	147	(27.0)	118	(31.8)	1,994	(31.2)
	Own home*	49,554	(74.6)	4,735	(79.3)	3,229	(77.3)	57,518	(75.1)	3,357	(61.2)	362	(66.5)	227	(61.2)	3,946	(61.6)
	Missing	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)	0	(0.0)
ASA Grade	1	1,197	(1.8)	78	(1.3)	96	(2.3)	1,371	(1.8)	19	(0.3)	2	(0.4)	1	(0.3)	22	(0.3)
	2	18,240	(27.5)	1,603	(26.8)	1,148	(27.5)	20,991	(27.4)	563	(10.3)	49	(9.0)	42	(11.3)	654	(10.2)
	3	36,686	(55.2)	3,324	(55.7)	2,256	(54.0)	42,266	(55.2)	2,990	(54.5)	285	(52.4)	201	(54.2)	3,476	(54.3)
	4	6,929	(10.4)	691	(11.6)	473	(11.3)	8,093	(10.6)	1,581	(28.8)	177	(32.5)	109	(29.4)	1,867	(29.2)
	5	132	(0.2)	10	(0.2)	8	(0.2)	150	(0.2)	52	(0.9)	5	(0.9)	4	(1.1)	61	(1.0)
	Missing	3,256	(4.9)	267	(4.5)	195	(4.7)	3,718	(4.9)	281	(5.1)	26	(4.8)	14	(3.8)	321	(5.0)
Pathological fracture	None	63,024	(94.9)	5,396	(90.3)	3,667	(87.8)	72,087	(94.1)	5,082	(92.6)	462	(84.9)	320	(86.3)	5,864	(91.6)
	Malignancy | Yes	385	(0.6)	246	(4.1)	42	(1.0)	673	(0.9)	65	(1.2)	41	(7.5)	9	(2.4)	115	(1.8)
	Atypical	267	(0.4)	37	(0.6)	29	(0.7)	333	(0.4)	22	(0.4)	6	(1.1)	2	(0.5)	30	(0.5)
	Missing	2,764	(4.2)	294	(4.9)	438	(10.5)	3,496	(4.6)	317	(5.8)	35	(6.4)	40	(10.8)	392	(6.1)
Pre-operative Mobility	Walks without aids	27,679	(41.7)	2,579	(43.2)	1,838	(44.0)	32,096	(41.9)	1,445	(26.3)	184	(33.8)	118	(31.8)	1,747	(27.3)
	Walks with aids	35,934	(54.1)	3,147	(52.7)	2,187	(52.4)	41,268	(53.9)	3,580	(65.3)	323	(59.4)	225	(60.6)	4,128	(64.5)
	No Functional Mobility	1,334	(2.0)	125	(2.1)	69	(1.7)	1,528	(2.0)	203	(3.7)	22	(4.0)	14	(3.8)	239	(3.7)
	Missing	1,493	(2.2)	122	(2.0)	82	(2.0)	1,697	(2.2)	258	(4.7)	15	(2.8)	14	(3.8)	287	(4.5)
Multidisciplinary rehabilitation team assessment	No	2,014	(3.0)	246	(4.1)	154	(3.7)	2,414	(3.2)	434	(7.9)	61	(11.2)	30	(8.1)	525	(8.2)
	Yes	62,601	(94.2)	5,596	(93.7)	3,965	(94.9)	72,162	(94.2)	4,839	(88.2)	466	(85.7)	339	(91.4)	5,644	(88.2)
	Missing	1,825	(2.7)	131	(2.2)	57	(1.4)	2,013	(2.6)	213	(3.9)	17	(3.1)	2	(0.5)	232	(3.6)
Specialist fall assessment	Yes	62,043	(93.4)	5,505	(92.2)	3,963	(94.9)	71,511	(93.4)	4,851	(88.4)	469	(86.2)	342	(92.2)	5,662	(88.5)
	No Falls Assessment	3,869	(5.8)	429	(7.2)	201	(4.8)	4,499	(5.9)	578	(10.5)	73	(13.4)	28	(7.5)	679	(10.6)
	Missing	528	(0.8)	39	(0.7)	12	(0.3)	579	(0.8)	57	(1.0)	2	(0.4)	1	(0.3)	60	(0.9)

Type of Anaesthesia	Spinal	19,241	(29.0)	1,513	(25.3)	1,115	(26.7)	21,869	(28.6)	1,605	(29.3)	136	(25.0)	104	(28.0)	1,845	(28.8)
	Spinal + (Epi | NB)	6,025	(9.1)	539	(9.0)	390	(9.3)	6,954	(9.1)	517	(9.4)	47	(8.6)	27	(7.3)	591	(9.2)
	GA	14,783	(22.3)	1,363	(22.8)	862	(20.6)	17,008	(22.2)	1,207	(22.0)	145	(26.7)	80	(21.6)	1,432	(22.4)
	GA + (Epi | NB)	17,360	(26.1)	1,764	(29.5)	1,176	(28.2)	20,300	(26.5)	1,406	(25.6)	149	(27.4)	111	(29.9)	1,666	(26.0)
	Other	932	(1.4)	131	(2.2)	52	(1.2)	1,115	(1.5)	44	(0.8)	11	(2.0)	1	(0.3)	56	(0.9)
	Missing	8,099	(12.2)	663	(11.1)	581	(13.9)	9,343	(12.2)	707	(12.9)	56	(10.3)	48	(12.9)	811	(12.7)

*Includes sheltered housing.

ASA = American Society of Anesthesiologists; Epi = epidural; NB = nerve block; GA = general anaesthetic

Table 4: Multivariate adjusted models with 3 groups for the effect of surgical interventions on 30-day mortality

		Complete Case Analysis (n=52 481)			Analysis after Multiple Imputation (n=82 990)		
Model	Exposure	OR	(95% CI)	P=	OR	(95% CI)	P=
0	Sliding hip screw	1			1		
	Intramedullary short nail	1.159	(1.008, 1.333)	0.038	1.076	(0.964, 1.201)	0.190
	Intramedullary long nail	1.141	(1.014, 1.284)	0.029	1.103	(1.006, 1.209)	0.037
1	Sliding hip screw	1			1		
	Intramedullary short nail	1.202	(1.040, 1.389)	0.013	1.124	(1.004, 1.260)	0.043
	Intramedullary long nail	1.181	(1.043, 1.337)	0.009	1.133	(1.028, 1.248)	0.012
2	Sliding hip screw	1			1		
	Intramedullary short nail	1.188	(1.027, 1.375)	0.020	1.115	(0.995, 1.250)	0.061
	Intramedullary long nail	1.146	(1.011, 1.298)	0.033	1.102	(1.000, 1.214)	0.051
3	Sliding hip screw	1			1		
	Intramedullary short nail	1.188	(1.027, 1.375)	0.020	1.115	(0.995, 1.250)	0.061
	Intramedullary long nail	1.146	(1.011, 1.298)	0.033	1.110	(1.007, 1.224)	0.035
4	Sliding hip screw	1			1		
	Intramedullary short nail	1.175	(1.015, 1.360)	0.030	1.121	(0.997, 1.260)	0.056
	Intramedullary long nail	1.145	(1.010, 1.297)	0.034	1.129	(1.020, 1.249)	0.019

Table 5: Multivariate adjusted models with 2 groups for the effect of surgical interventions on 30-day mortality

Model	Exposure	Complete Cases (n=52 481)				Analysis after Multiple Imputation (n=82 990)			
		OR	(95% CI)		P=	OR	(95% CI)		P=
0	Sliding hip screw	1				1			
	Intramedullary nail	1.148	(1.046,	1.261)	0.0037	1.092	(1.015,	1.175)	0.018
1	Sliding hip screw	1				1			
	Intramedullary nail	1.190	(1.079,	1.312)	0.0005	1.129	(1.046,	1.219)	0.0018
2	Sliding hip screw	1				1			
	Intramedullary nail	1.163	(1.054,	1.283)	0.0026	1.107	(1.025,	1.196)	0.0093
3	Sliding hip screw	1				1			
	Intramedullary nail	1.163	(1.054,	1.283)	0.0026	1.112	(1.030,	1.201)	0.0066
4	Sliding hip screw	1				1			
	Intramedullary nail	1.157	(1.049,	1.277)	0.0037	1.125	(1.040,	1.218)	0.0035

Figure legends:

Figure 1: Patient inclusions/exclusions into the study.