

# **Modifiable Risk Factors for Mortality in Revision Total Hip Replacement for Periprosthetic Fracture**

## **Abstract**

### **Aims**

The study aim was to identify modifiable risk factors associated with mortality in patients requiring revision total hip replacement for periprosthetic hip fracture (PPHF).

### **Patients and Methods**

Electronic records for consecutive patients undergoing revision total hip replacement for PPHF between December 2011 and October 2018 were reviewed. Data were collected for age, sex, body mass index, American Society of Anaesthesiologists physical status classification, preoperative haemoglobin, time to surgery, duration of surgery, blood transfusion, length of hospital stay and postoperative surgical and medical complications. Univariate and multivariable logistic regression analyses were used to determine independent modifiable factors associated with mortality at 90 days and one year postoperatively.

### **Results**

203 patients were identified (53% female, mean age 78 [range: 44-100]). The median time to surgery was 3 days [IQR: 2-5]. Mortality rate at one year was 13.8% (n=28). The commonest surgical complication was dislocation (n=22, 10.8%) and medical complication within 90 days of surgery was hospital acquired pneumonia (n=25, 12%). Multivariable analysis demonstrated that mortality rate one year postoperatively was fivefold higher in patients who sustained a dislocation (OR 5.03 [95% CI: 1.60-15.83], p=0.006). The mortality rate was fourfold higher in patients who developed hospital acquired pneumonia within 90 days postoperatively (OR 4.43 [95% CI: 1.55-12.67], p=0.005). No evidence was found that time to surgery was a risk factor for death at one year.

### **Conclusion**

Dislocation and hospital acquired pneumonia following revision total hip replacement for PPHF are potentially modifiable risk factors for mortality. Our study suggests that surgeons should consider increasing constraint to reduce dislocation risk and early involvement of the multidisciplinary team to reduce the risk of hospital acquired pneumonia. In our study, there was no evidence that time to surgery affected mortality, which may allow time for medical optimisation, surgical planning, and resource allocation.

## **Introduction**

Total hip replacement surgery is a highly effective procedure for improving pain, function, and quality of life in patients with osteoarthritis. Globally, the number of procedures performed annually continues to increase. Across Organisation for Economic Cooperation and Development (OECD) countries, it is estimated that the annual volume of total hip replacement surgery is expected to rise from 1.8 million hip replacements per year in 2015 to 2.8 million per year in 2050<sup>1</sup>. The increase in the prevalence of total hip arthroplasty and an ageing population is leading to an increased number of periprosthetic hip fractures (PPHFs). In England, Wales and Northern Ireland, the number of single stage revision total hip replacements for PPHF has increased from 922 procedures in 2013 to 1240 in 2018<sup>2</sup>.

Risk factors for mortality in patients undergoing surgery for native neck of femur fractures has been well studied. Among them are age, American Society for Anesthesiologists (ASA) class, low body mass index (BMI), time to surgery and low haemoglobin.<sup>3,5</sup> However, it is not clear whether these risk factors are transferable from this population to patients undergoing surgery for PPHF.

Factors that are associated with increased mortality rates following PPHF surgery are not well understood, and revision surgery is a major procedure with increased operative time, blood loss, and physiological impact than surgery for a fractures neck of femur. The identification of potentially modifiable factors is able to guide interventions to improve patient outcomes. The aim of this study is to identify factors that are associated with mortality rates one year following revision hip surgery for periprosthetic fractures.

## **Patients and Methods**

Consecutive patients undergoing single stage revision hip surgery for periprosthetic hip fractures were identified using an electronic patient records database at a single institution between December 2011 and October 2018. Eligibility criteria included all adults aged above 18 who sustained an acute fracture (requiring emergency admission and subsequent surgery during admission) of the proximal femur where the stem needed to be revised (Vancouver B2 and B3 fractures).

Patients were identified using Office of Population Censuses and Surveys (OPCS) procedure codes (Classification of Interventions and Procedures, version 4) which indicated probable PPHF (Appendix A). We also searched electronic operative records using a “periprosthetic” free-text term to identify additional potentially eligible PPHF patients. Potential PPHF patients and their respective procedures were then checked against the study eligibility criteria in a case note review.

The case note review was used to retrieve complication data for each patient and procedure, and to supplement data obtained from the electronic patient records to minimise missing data. Patient demographics (age, sex, ASA, BMI), preoperative haemoglobin g/l (Hb), presence or absence of anaemia (defined as Hb <120g/l for women and Hb <130 g/l for men), allogeneic blood transfusion, time to surgery (days), duration of surgery (minutes), length of hospital stay (days) and readmission within one year of surgery were collected. Medical complications were recorded if they occurred within 90 days of surgery and included hospital acquired pneumonia (HAP), myocardial infarction (MI), cerebrovascular infarct (CVA) and venous thromboembolism (VTE). HAP was identified based on a clinical diagnosis supported by interpretation of chest x-rays and prescription of antibiotics. Myocardial infarction (MI) was defined as a raised troponin level or identified using documentation and implementation of the Acute Coronary Syndrome protocol. CVA and VTE (including pulmonary embolism and DVT) were both confirmed on imaging. Surgical complications were recorded if they occurred within one year of surgery and included re-operation (DAIR: Debridement, Antibiotics and Implant Retention or re-revision) and dislocation.

Mortality within 90 days and 1 year were obtained from electronic patient records and data were cross referenced with the Office for National Statistics. The primary outcome measure was mortality at one year postoperatively. The sample size was dictated by the number of cases undertaken during the specified time interval and the study period started when the institution became fully 'paperless'.

### *Statistical analysis*

Baseline characteristics were described, overall and by the one year mortality outcome. Continuous data was described using mean with standard deviation and range, and median with interquartile range. Categorical data was described using numbers with percentages. Univariate logistic regression was used to explore the relationship between age, ASA, gender, pre-operative Hb, pre-operative anaemia, time to surgery, duration of surgery and medical and orthopaedic complications with mortality at 1 year. A multivariable regression model was created using a-priori risk factors identified from previous studies (age and ASA<sup>6,7</sup>) and suspected risk factors (pre-operative Hb, duration of surgery, dislocation, HAP, time to surgery, gender, blood transfusion, reoperation for DAIR, reoperation for revision and readmission for orthopaedic and medical related complications) using backward selection. The continuous variable preoperative Hb was chosen in the multivariable model over the presence or absence of preoperative anaemia to prevent dichotomisation of the data<sup>8</sup>. Risk factors were subsequently removed to identify the best-fit model, risk factor selection was guided by calculating likelihood ratios and Akaike's Information Criteria (AIC). A significance level of p-value <0.05

was used. We checked the independence of risk factors using correlation matrices. Odds ratios (OR) are reported with 95% confidence intervals (CI). 90 day mortality was analysed descriptively. Missing data was excluded from the main analysis and presented descriptively. Statistical analysis was conducted using STATA version 15<sup>9</sup>.

## **Results**

### *Patient population*

2268 patients were identified as having procedure codes which may represent surgery for PPHF. Following case note review, of the 2268 patients, 203 patients met the inclusion criteria (Table 1).

**Table 1.** Baseline characteristics of patients requiring revision total hip replacement for periprosthetic hip fracture

<b>Characteristics</b>	<b>N= 203</b>	
	<b>Mean (SD)</b>	<b>Range</b>
Age (years)	78 (11)	[44-100]
Pre-operative Hb (g/l)	116.0 (18.1)	[75-155]
	<b>n</b>	<b>%</b>
Male	95	46.8
ASA		
1 (low)	11	5.5
2	70	34.5
3	94	46.3
4 (high)	27	13.3
Missing	1	0.5
BMI		
Underweight	5	2.5
Normal	52	25.6
Overweight	64	31.5
Obese	51	25.1
Missing (height missing)	31	15.3
Patients with pre-op anaemia*	135	66.5
Patients with post-op anaemia*	196	96.6
Received an allogeneic transfusion during admission	110	54.2
Received a transfusion pre-operatively	22	10.8
Received a transfusion intra-operatively	15	7.4

Received a transfusion post-operatively	73	36.0
Patients waiting $\geq$ 3 days from admission time to surgery	128	63.2
	<b>Median</b>	<b>IQR</b>
Time from admission to surgery (days)	3	[2-5]
Duration of surgery (mins)	192	[160 - 231]

ASA =, BMI = Hb=

\*Male Hb<130g/l, female Hb<120g/l

### Mortality at one year

The mortality rate was 13.8% (n=28) one year postoperatively. The most common surgical complication was dislocation (n=22, 10.8%) (Table 2). 2% (n=4) of patients required DAIR for a persistently oozy wound and 6% (n=13) required re-revision surgery (8 for recurrent instability and five for re-fracture following another fall). Readmission to hospital due to falling was 14.8% (n=30). Overall, readmission for any reason (surgical complications within one year post-operatively and medical complications within 90 days post-operatively) was 33% (n=67). Medical complications included: hospital acquired pneumonia (n=25), MI or CVA (n=6), VTE (n=4) and urinary retention (n=1).

**Table 2.** Characteristics of patients requiring revision total hip replacement for periprosthetic hip fracture, by mortality at 1 year

Characteristics	Dead at 1 year (n=28)		Alive at 1 year (n = 175)	
	Mean (SD)	Range	Mean (SD)	Range
Age (years)	86 (10)	[49-100]	76 (11)	[44-99]
Pre-operative Hb (g/l)	106.4 (18.6)	[73-142]	117.5 (17.6)	[68-164]
	n	%	n	%
Male	16	57.1	79	45.1
ASA				
1-2	4	14.3	77	44.0
3-4	24	85.7	97	55.4
Missing	-	-	1	0.6
Pre-operative anaemia*				
No	4	14.3	64	36.6
Yes	24	85.7	111	63.4
Blood transfusion at any time				
No	10	35.7	83	47.4
Yes	18	64.3	92	52.6
Readmission*				
No	13	46.4	123	70.3
Yes	15	53.6	52	29.7
Dislocation post-surgery				
No	21	75.0	160	91.4

Yes	7	25.0	15	8.6
HAP within 90 days				
No	18	64.3	160	91.4
Yes	10	35.7	15	8.6
	<b>Median</b>	<b>IQR</b>	<b>Median</b>	<b>IQR</b>
Time from admission to surgery (days)	3	[2-5]	3	[2-5]
Length of hospital stay (days)	21	[12.5-37]	17	[12-25]
Duration of surgery (mins)	178	[154.5-201]	198	[161-235]

ASA =, Hb=, HAP =, DAIR =

\*Male Hb<130g/l, female Hb<120g/l

\*\*readmission for DAIR; re-revision; fall within one year; MI, CVA; VTE or urinary retention within 90 days

In the multivariable analysis, the risk of death at one year following a dislocation increased fivefold (OR 5.03 [95% CI: 1.60-15.83], p=0.006) and the risk of death following development of HAP was raised four fold (OR 4.43 [95% CI: 1.55-12.67], p=0.005), as was the risk when the ASA was 3 or 4 (OR 3.98 [95% CI: 1.18-13.37], p=0.025) (Table 3).

**Table 3.** Univariate and multivariable Logistic regression analysis for mortality at 1 year. Values are odds ratios (OR), 95% confidence intervals (CI) and p-values.

Risk factors	Univariate			Multivariable		
	OR	[95% CI]	P value	OR	[95% CI]	P value
Age (years)	1.11	[1.05 to 1.16]	<0.001	1.09	[1.03-1.15]	0.003
Gender						
Female		<i>Reference</i>			<i>Reference</i>	
Male	1.62	[0.72 to 3.63]	0.240	-	-	-
ASA						
1-2		<i>Reference</i>			<i>Reference</i>	
3-4	4.76	[1.58 to 14.31]	0.005	3.98	[1.18-13.37]	0.025
Pre-operative anaemia						
No		<i>Reference</i>			<i>Reference</i>	
Yes	3.46	[1.14 to 10.41]	0.027	-	-	-
Pre-operative Hb (g/l)	0.96	[0.94 - 0.99]	0.003	-	-	-
Blood transfusion*						
No		<i>Reference</i>			<i>Reference</i>	
Yes	1.62	[0.71 to 3.72]	0.251	-	-	-
Dislocation within 1 year						
No		<i>Reference</i>			<i>Reference</i>	
Yes	3.56	[1.30- 9.72]	0.013	5.03	[1.60-15.83]	0.006
HAP within 90 days						
No		<i>Reference</i>			<i>Reference</i>	
Yes	5.93	[2.32-15.12]	<0.001	4.43	[1.55-12.67]	0.005
Reoperation for DAIR within 1 year						
No		<i>Reference</i>			<i>Reference</i>	

Yes	6.65	[0.90-49.31]	0.064	-	-	-
Reoperation for revision within 1 year						
No	<i>Reference</i>			<i>Reference</i>		
Yes	1.98	[0.51- 7.69]	0.324	-	-	-
Readmission **						
No	<i>Reference</i>			<i>Reference</i>		
Yes	2.78	[1.21 to 6.13]	0.015	-	-	-
Time from admission to surgery (days)	0.96	[0.83 to 1.22]	0.634	-	-	-
Duration of surgery (mins)	0.99	[0.98-1.00]	0.055	-	-	-

ASA =, Hb=, HAP =, DAIR =

\*at pre-, intra-, and or post-surgery

\*\*readmission for DAIR; re-revision; fall within one year; MI, CVA; VTE or urinary retention within 90 days

### *Mortality at 90 days*

At 90 days post-operatively, the mortality rate was 5.4% (n=11). 25 patients (12%) developed a HAP, of whom 7 had died by 90 days (Appendix C).

### **Discussion**

The results of this study demonstrate that postoperative HAP and dislocation are associated with one-year mortality after hip revision for periprosthetic fractures. These are potentially modifiable risk factors. Increased age and ASA grade were also associated with an increased risk of death, whereas time to surgery was not. PPHFs are increasing in incidence and frequently occur in the elderly and require complex surgery, with a significant physiological insult.

Mortality at one year was 13.8% and is similar to other published rates<sup>6</sup> and lower than the rate for fracture neck of femur cohorts at one year (approximately one third of patients at one year<sup>10</sup>). Despite comparable demographics between neck of femur fracture patients and PPHF patients, the reasons behind the difference in mortality rates remain unclear. It has been suggested that it may be as a result of higher levels of preoperative mobility and higher cognitive function among PPHF patients compared with neck of femur fracture patients<sup>11</sup>. In the multivariable analysis, we found that developing postoperative HAP was associated with an increased mortality rate by a factor of four. In a recent study identifying predictors of death in native neck of femur fractures, the development of pneumonia postoperatively was also found to be one of the strongest predictors of death.<sup>12</sup> Our cohort may be at greater risk of developing HAP due to the longer operative time, and hence development of basal atelectasis, and the increased requirement for post-operative analgesia. In addition, some patients with extensive incisions for long fractures received an epidural for up to 72 hours, resulting in difficulty in early mobilisation.

There are several well-established methods for preventing HAP in patients undergoing surgery. These include education, incentive spirometry pre and post-operatively, encouraging deep breathing and coughing, oral care twice daily, regularly getting out of bed and elevating the head of the bed<sup>13,14</sup>. The application of standardised programmes and multidisciplinary team involvement have been efficacious in reducing mortality rates for neck of femur fracture patients<sup>15</sup>. The implementation of similar programmes targeted at reducing the risk of HAP for example, may improve outcomes for PPHF patients.

The dislocation rate within one year for our cohort was 10.8%. This is consistent with that of other published data with incidences of dislocation following revision surgery reported at approximately 10%<sup>16-18</sup>. A finding was that patients with a dislocation within a year of surgery were five times more likely to have died within the first postoperative year. It is not clear why dislocation is associated with increased mortality but it may be due to a further in-patient spell, with extended immobility and the physiological insult of any further surgery<sup>19</sup>. Patients with greater co-morbidity may be more likely to dislocate due to falls, poor compliance with postoperative rehabilitation, or generalised sarcopenia, and we attempted to adjust for these factors by including age and ASA in our multivariable model.

Many studies report on risk factors for dislocation in patients who have had revision total hip replacements. There are patient-related factors (age, compliance, neuromuscular conditions),<sup>20</sup> procedure-related factors such as component positioning, soft tissue tension and surgeon experience, and implant-related factors like femoral head component size or the use of an elevated rim liner remain modifiable issues<sup>21</sup>. Given the high dislocation rate after PPHF surgery and association with increased mortality, consideration should be given to increasing the level of constraint during surgery. Furthermore, the absence of an association between time to surgery and mortality affords sufficient time to identify the current implant in most cases. Options available to the surgeon may include liner exchange to increase the head size or use of a liner with an elevated wall. Dual mobility articulation has gained increasing popularity in high risk groups and results are encouraging<sup>22</sup>. Potential drawbacks with using dual mobility include concerns around wear with additional articulation<sup>23</sup> and intra-prosthetic dislocation.<sup>24</sup> However, the high age and relatively low demand common in this patient cohort may render those concerns less important than the risk of dislocation. Fully constrained liners are a valuable option to ensure stability if the existing acetabular component has a compatible option and is appropriately orientated<sup>25</sup>. If there are concerns over stability that cannot be addressed with the above options, acetabulum component revision warrants consideration. The decision to revise the acetabular component and reduce dislocation risk needs to be offset against the risk of increased blood loss and operative time.

For neck of femur fractures, there is strong evidence that delay to surgery affects mortality<sup>26</sup>. However, for PPHFs it remains unclear whether surgical delay affects the rate of complication following surgery, with some studies reporting a significant increase in complications in patients who were delayed beyond 72 hours<sup>11</sup>. In our study, there was no evidence that time to surgery was a risk factor for mortality at one year. This finding is in keeping with a more recent published study which found that delay to surgery did not affect mortality<sup>27</sup>. This suggests that hospitals and staff may be afforded time to optimise patients, plan surgery and ensure adequate resources are in place prior to operating.

The PPHF patient population is frail with significant challenges. Therefore, it requires careful consideration of pre-operative optimisation. These benefit from a multi-disciplinary approach allowing risk stratification and selection of the appropriate surgical and anaesthetic options, such as invasive monitoring. In the very high risk patient, this may allow for multi-disciplinary discussion around appropriate levels of care and initiation of treatment of reversible factors prior to operating. These discussions also inform the consent process.

To ensure a rigorously conducted study and to increase data quality, we supplemented data obtained from electronic health records by performing a case note review for each patient and procedure, and searching for missing data. Previous studies addressing risk factors for PPHFs centre on national databases, of which coding error can result in a reduction of the quality of data<sup>28</sup>. Our study found that PPHF surgery was not consistently coded (Appendix B).

There are limitations to our study. First, our results are derived from a single institution and any readmission to other hospitals with complications may not be captured. However, the majority of patients resided within the hospital catchment area and were likely to return to our centre. Tertiary referral for PPHFs is relatively uncommon. Furthermore, our imaging systems are linked with the local hospitals, further enhancing our ability to identify post-operative complications including dislocation or further revision. Second, we did not know patients pre-operative functional state, cognitive state or the age and type of implant and therefore were unable to stratify accordingly.

In summary, postoperative dislocation and HAP are potentially modifiable factors associated with increased mortality rates and may be amenable to intervention. Furthermore, understanding factors associated with adverse outcomes provides valuable information relating to patient prognosis for patients, families, and clinicians. Our study suggests that surgeons treating PPHFs should consider increasing constraint to prevent dislocation and early multidisciplinary team involvement in an attempt to reduce hospital acquired pneumonia.

## References

1. Pabinger C, Lothaller H, Portner N, Geissler A. Projections of hip arthroplasty in OECD countries up to 2050. *HIP International*. 2018;28(5):498-506.
2. NJR Patient characteristics for revision hip replacement procedures [Available from: <https://reports.njrcentre.org.uk/hips-revision-procedures-patient-characteristics>].
3. Hu F, Jiang C, Shen J, Tang P, Wang Y. Preoperative predictors for mortality following hip fracture surgery: A systematic review and meta-analysis. *Injury*. 2012;43(6):676-85.
4. Noring-Agerskov D, Laulund AS, Lauritzen JB, Duus BR, van der Mark S, Mosfeldt M, et al. Metaanalysis of risk factors for mortality in patients with hip fracture. *Danish medical journal*. 2013;60(8):A4675.
5. Chang W, Lv H, Feng C, Yuwen P, Wei N, Chen W, et al. Preventable risk factors of mortality after hip fracture surgery: Systematic review and meta-analysis. *International Journal of Surgery*. 2018;52:320-8.
6. Drew JM, Griffin WL, Odum SM, Van Doren B, Weston BT, Stryker LS. Survivorship After Periprosthetic Femur Fracture: Factors Affecting Outcome. *The Journal of arthroplasty*. 2016;31(6):1283-8.
7. Bovonratwet P, Malpani R, Ottesen TD, Tyagi V, Ondeck NT, Rubin LE, et al. Aseptic revision total hip arthroplasty in the elderly. *The Bone & Joint Journal*. 2018;100-B(2):143-51.
8. Dawson NV, Weiss R. Dichotomizing continuous variables in statistical analysis: a practice to avoid. *Medical decision making : an international journal of the Society for Medical Decision Making*. 2012;32(2):225-6.
9. StataCorp. *Stata Statistical Software: Release 15*. College Station, TX: StataCorp LLC. 2017.
10. NICE Guidance: The management of hip fractures in adults 2011 [updated May 2017]. Available from: <http://guidance.nice.org.uk/CG124>.
11. Griffiths EJ, Cash DJW, Kalra S, Hopgood PJ. Time to surgery and 30-day morbidity and mortality of periprosthetic hip fractures. *Injury*. 2013;44(12):1949-52.
12. Sheikh HQ, Hossain FS, Aqil A, Akinbamijo B, Mushtaq V, Kapoor H. A Comprehensive Analysis of the Causes and Predictors of 30-Day Mortality Following Hip Fracture Surgery. *Clin Orthop Surg*. 2017;9(1):10-8.
13. Cassidy MR, Rosenkranz P, McCabe K, Rosen JE, McAneny D. I COUGH: Reducing Postoperative Pulmonary Complications With a Multidisciplinary Patient Care Program Reducing Postoperative Pulmonary Complications. *JAMA Surgery*. 2013;148(8):740-5.
14. J. Fox KF, C. Chamness, J. Malloy, S. Hyde. Preventing hospital-acquired pneumonia (HAP) outside of the ventilator-associated pneumonia bundle Prevention Strategist, Fall, APIC publication. 2015:45-8
15. Lau T-W, Fang C, Leung F. The effectiveness of a geriatric hip fracture clinical pathway in reducing hospital and rehabilitation length of stay and improving short-term mortality rates. *Geriatric orthopaedic surgery & rehabilitation*. 2013;4(1):3-9.
16. Wetters NG, Murray TG, Moric M, Sporer SM, Paprosky WG, Della Valle CJ. Risk factors for dislocation after revision total hip arthroplasty. *Clin Orthop Relat Res*. 2013;471(2):410-6.
17. Guo L, Yang Y, An B, Yang Y, Shi L, Han X, et al. Risk factors for dislocation after revision total hip arthroplasty: A systematic review and meta-analysis. *International journal of surgery (London, England)*. 2017;38:123-9.
18. Ibrahim MS, Twaij H, Haddad FS. Two-stage revision for the culture-negative infected total hip arthroplasty. *The Bone & Joint Journal*. 2018;100-B(1 Supple A):3-8.
19. Lamb JN, Matharu GS, Redmond A, Judge A, West RM, Pandit HG. Patient and implant survival following intraoperative periprosthetic femoral fractures during primary total hip arthroplasty. *The Bone & Joint Journal*. 2019;101-B(10):1199-208.

20. Dargel J, Oppermann J, Bruggemann GP, Eysel P. Dislocation following total hip replacement. *Deutsches Arzteblatt international*. 2014;111(51-52):884-90.
21. Faldini C, Stefanini N, Fenga D, Neonakis EM, Perna F, Mazzotti A, et al. How to prevent dislocation after revision total hip arthroplasty: a systematic review of the risk factors and a focus on treatment options. *J Orthop Traumatol*. 2018;19(1):17-.
22. Romagnoli M, Grassi A, Costa GG, Lazaro LE, Lo Presti M, Zaffagnini S. The efficacy of dual-mobility cup in preventing dislocation after total hip arthroplasty: a systematic review and meta-analysis of comparative studies. *International Orthopaedics*. 2019;43(5):1071-82.
23. Guyen O. Constrained liners, dual mobility or large diameter heads to avoid dislocation in THA. *EFORT Open Reviews*. 2016;1(5):197-204.
24. Philippot R, Boyer B, Farizon F. Intraprosthetic Dislocation: A Specific Complication of the Dual-mobility System. *Clinical Orthopaedics and Related Research®*. 2013;471(3):965-70.
25. Chalmers BP, Arsoy D, Sierra RJ, Lewallen DG, Trousdale RT. High Failure Rate of Modular Exchange With a Specific Design of a Constrained Liner in High-Risk Patients Undergoing Revision Total Hip Arthroplasty. *The Journal of arthroplasty*. 2016;31(9):1963-9.
26. Fu MC, Boddapati V, Gausden EB, Samuel AM, Russell LA, Lane JM. Surgery for a fracture of the hip within 24 hours of admission is independently associated with reduced short-term post-operative complications. *The Bone & Joint Journal*. 2017;99-B(9):1216-22.
27. Bovonratwet P, Fu MC, Adrados M, Ondeck NT, Su EP, Grauer JN. Unlike Native Hip Fractures, Delay to Periprosthetic Hip Fracture Stabilization Does Not Significantly Affect Most Short-Term Perioperative Outcomes. *The Journal of arthroplasty*. 2019;34(3):564-9.
28. Patel AA, Singh K, Nunley RM, Minhas SV. Administrative Databases in Orthopaedic Research: Pearls and Pitfalls of Big Data. *JAAOS - Journal of the American Academy of Orthopaedic Surgeons*. 2016;24(3):172-9.

### **Appendix A**

Code list used to identify potential periprosthetic hip fracture patients from electronic patient records:

<b>OPCS Code</b>	<b>OPCS code description</b>
O182	conversion to hybrid prosthetic replacement of knee joint using cement
O183	revision of hybrid prosthetic replacement of knee joint using cement
W052	implantation massive endoprosthetic replacement of bone
W053	implantation endoprosthetic replacement of bone nec
W058	other specified prosthetic replacement of bone
W191	primary open reduction of fracture of neck of femur and open fixation using pin and plate
W192	primary open reduction of fracture of long bone and fixation using rigid nail nec
W201	primary open reduction of fracture of long bone and extramedullary fixation using plate nec
W202	primary open reduction of fracture of long bone and extramedullary fixation using cerclage
W208	other specified primary open reduction of fracture of bone and extramedullary fixation
W282	adjustment to internal fixation of bone nec

W284	insertion of intramedullary fixation and cementing of bone
W302	adjustment to external fixation of bone nec
W370	conversion from previous cemented total prosthetic replacement of hip joint
W371	primary total prosthetic replacement of hip joint using cement
W372	conversion to total prosthetic replacement of hip joint using cement
W373	revision of total prosthetic replacement of hip joint using cement
W374	revision of one component of total prosthetic replacement of hip joint using cement
W380	conversion from previous uncemented total prosthetic replacement of hip joint
W381	primary total prosthetic replacement of hip joint not using cement
W382	conversion to total prosthetic replacement of hip joint not using cement
W383	revision of total prosthetic replacement of hip joint not using cement
W384	revision of one component of total prosthetic replacement of hip joint not using cement
W393	revision of total prosthetic replacement of hip joint nec
W394	attention to total prosthetic replacement of hip joint nec
W395	revision of one component of total prosthetic replacement of hip joint nec
W402	conversion to total prosthetic replacement of knee joint using cement
W403	revision of total prosthetic replacement of knee joint using cement
W404	revision of one component of total prosthetic replacement of knee joint using cement
W412	conversion to total prosthetic replacement of knee joint not using cement
W413	revision of total prosthetic replacement of knee joint not using cement
W422	conversion to total prosthetic replacement of knee joint nec
W423	revision of total prosthetic replacement of knee joint nec
W425	revision of one component of total prosthetic replacement of knee joint nec
W433	revision of total prosthetic replacement of joint using cement nec
W454	attention to total prosthetic replacement of joint nec
W461	primary prosthetic replacement of head of femur using cement
W462	conversion to prosthetic replacement of head of femur using cement
W463	revision of prosthetic replacement of head of femur using cement
W468	other specified prosthetic replacement of head of femur using cement
W471	primary prosthetic replacement of head of femur not using cement
W473	revision of prosthetic replacement of head of femur not using cement
W483	revision of prosthetic replacement of head of femur nec
W484	attention to prosthetic replacement of head of femur nec
W523	revision of prosthetic replacement of articulation of bone using cement nec
W544	attention to prosthetic replacement of articulation of bone nec
W562	primary interposition arthroplasty of joint nec
W572	primary excision arthroplasty of joint nec
W574	conversion to excision arthroplasty of joint
W582	revision of resurfacing arthroplasty of joint
W641	conversion to arthrodesis and internal fixation nec

W654	primary open reduction of fracture dislocation of joint and internal fixation nec
W801	open debridement and irrigation of joint
W802	open debridement of joint nec
W803	open irrigation of joint nec
W808	other specified debridement and irrigation of joint
W813	drainage of joint
W814	incision of joint nec
W818	other specified other open operations on joint
W930	conversion from previous hybrid prosthetic replacement of hip joint using cemented acetabular component
W932	conversion to hybrid prosthetic replacement of hip joint using cemented acetabular component
W933	revision of hybrid prosthetic replacement of hip joint using cemented acetabular component
W940	conversion from previous hybrid prosthetic replacement of hip joint using cemented femoral component
W941	primary hybrid prosthetic replacement of hip joint using cemented femoral component
W942	conversion to hybrid prosthetic replacement of hip joint using cemented femoral component
W943	revision of hybrid prosthetic replacement of hip joint using cemented femoral component
W948	other specified hybrid prosthetic replacement of hip joint using cemented femoral component
W952	conversion to hybrid prosthetic replacement of hip joint using cement nec
W953	revision of hybrid prosthetic replacement of hip joint using cement nec
W954	attention to hybrid prosthetic replacement of hip joint using cement nec

### **Appendix B**

Code list of confirmed periprosthetic hip fracture patients

<b>Primary procedure codes</b>	<b>Primary procedure description</b>	<b>n</b>
W052	Implantation massive endoprosthesis replacement of bone	3
W202	Primary open reduction of fracture of long bone and extramedullary fixation using cerclage	13
W371	Primary total prosthetic replacement of hip joint using cement	1
W373	Revision of total prosthetic replacement of hip joint using cement	6
W374	Revision of one component of total prosthetic replacement of hip joint using cement	21
W381	Primary total prosthetic replacement of hip joint not using cement	1
W382	Conversion to total prosthetic replacement of hip joint not using cement	24
W383	Revision of total prosthetic replacement of hip joint not using cement	7
W384	Revision of one component of total prosthetic replacement of hip joint not using cement	53

W394	Attention to total prosthetic replacement of hip joint NEC	2
W395	Revision of one component of total prosthetic replacement of hip joint NEC	1
W461	Primary prosthetic replacement of head of femur using cement	2
W473	Revision of prosthetic replacement of head of femur not using cement	1
W941	Primary hybrid prosthetic replacement of hip joint using cemented femoral component	1
W943	Revision of hybrid prosthetic replacement of hip joint using cemented femoral component	9
W954	Attention to hybrid prosthetic replacement of hip joint using cement NEC	1

### Appendix C

Periprosthetic hip fracture cohort characteristics, by mortality at 90 days

Characteristics	Death at 90 days (n=11)		Alive at 90 days (n = 192)	
	Mean (SD)	Range	Mean (SD)	Range
Age (years)	88 (8)	[74-100]	77 (12)	[44-99]
Pre-operative Hb (g/l)	109.7 (23.2)	[73-142]	116.4 (17.8)	[68-164]
	<b>n</b>	<b>%</b>	<b>n</b>	<b>%</b>
Female	3	27.3	106	55.2
Male	8	72.7	86	44.8
ASA				
1-2	2	18.2	79	41.2
3-4	9	81.8	112	58.3
Missing			1	0.5
Pre-operative anaemia*				
No	3	27.3	65	33.9
Yes	8	72.7	127	66.1
Blood transfusion at any time				
No	4	36.4	89	46.3
Yes	7	63.6	103	53.7
HAP within 90 days				
No	4	36.4	174	90.6
Yes	7	63.6	18	9.4
	<b>Median</b>	<b>IQR</b>	<b>Median</b>	<b>IQR</b>
Time from admission to surgery (days)	3	[2-5]	3	[2-5]
Length of hospital stay (days)	16	[10-25]	17	[12-26]
Duration of surgery (mins)	159	[117-185]	196	[162-234]

ASA =, Hb=, HAP =

\*Male Hb<130g/l, female Hb<120g/l