ORTHOPAEDIC SURGERY

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Evaluating risk factors following surgery for periprosthetic fractures around hip and knee arthroplasties

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Abstract

Background The increasing demand for arthroplasty has resulted in an inevitable rise in the number of periprosthetic fractures around implants. Survival factors looking into patient's comorbidities and how they influence outcome are rare. This study aims to identify correlations between survival post-injury and pre-existing comorbidities.

Methods A total of 144 patients underwent operative treatment for either a hip or a knee periprosthetic fracture from January 2008 to August 2017 at our Major Trauma Hospital. The mean age at injury was 80.9 years old (SD 9.9). Each patient had a case-based analysis to ascertain injury characteristics, operative parameters and comorbidities.

Results The mean survival was 12.7 months (95% CI 8.4–17.1). Survival analysis showed a correlation between age more than 75 years old ($p = 0.001$), ASA grade of 3 or higher ($p = 0.009$ Breslow's test), history of CVA or TIA ($p = 0.038$ Breslow's test), dementia ($p = 0.002$ log rank test), depression ($p = 0.013$ log rank test) and gender ($p = 0.041$, Breslow's test) and survival post-periprosthetic fracture. Survival within the first year following injury was found to be affected by the presence of osteoporosis ($p = 0.020$) and dementia ($p = 0.002$).

Conclusion Periprosthetic fractures are associated with a high mortality risk (34.7%). Operative risks can be minimised with careful optimisation and surgical planning. ASA, age and comorbidities (dementia, CVA or TIA, osteoporosis) have a significant correlation with survival post-injury. Hence, careful patient selection for operative treatment is advised.

Keywords Periprosthetic fracture · Mortality · Comorbidities

Introduction

Periprosthetic fractures (PPF) are a potentially devastating complication following total hip arthroplasty (THA) and total knee arthroplasty (TKA). It is the third-most common reason for hip or knee revision surgery [1–3]. A variety of classifications exist to try and assist with the diagnosis and management of these fractures, which have shown a good overall treatment outcome [4–6]. Examples of those

classification systems include Vancouver [7], Su [8], Felix and Associates' Classification [9], and the Unified Classification system [10], which allow for a logical treatment choice.

A successful outcome in PPF surgery is largely governed by the patient's pre-morbid condition, soft tissue envelope, complexity of the surgery and ability to rehabilitate. Furthermore, the biomechanics of how an implant works are better understood and the design keeps evolving [1, 5, 11–14]. This patient population is not dissimilar to the fracture neck of femur; however, the surgery is often much more complex and demanding, associating the PPF treatment with high morbidity and mortality [1, 2, 4, 5, 11–13, 15]. There is little reported evidence regarding patient survivorship following PPF treatment and mortality following fixation is poorly understood [1].

In this retrospective study, we are examining the survival of periprosthetic fractures of THA, hemiarthroplasty and TKA in our major trauma centre. We look into factors that

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can influence survival, including injury characteristics, surgical factors and comorbidities.

Patients and methods

The prospectively kept database at the Royal Stoke University Hospital (RSUH) was examined from January 2008 to August 2017. All patients who had sustained a PPF, affecting a hip or a knee prosthesis, were included. Each patient identified had a case note analysis to ascertain age, gender, American Society of Anaesthesiologist (ASA) grade and comorbidities [16]. The following comorbidities were included: ischaemic heart disease, cardiac arrhythmias, heart failure, hypertension, chronic obstructive pulmonary disease, diabetes mellitus, osteoporosis, hypothyroidism, rheumatoid arthritis, renal failure, history of stroke or transient ischaemic attack, dementia, depression, epilepsy, Parkinson's disease, excess alcohol and history or presence of cancer. The type of implant was recorded, whether it was a THA, or a TKA, or a hemiarthroplasty. The Vancouver classification system was used for fractures around hemiarthroplasty and THA [7]. The Su classification system was used for the femoral component in TKA [8]. The Felix and Associates' classification system was used for the tibial component of TKA [9]. All falls from standing height were considered low-energy causes of injury, whereas anything more severe such as road traffic injuries and falls from higher height were considered as high energy. No intraoperative periprosthetic fractures were noted. The post-operative weight-bearing status was evaluated and determined the patient's functional status. The surgical treatment was divided into osteosynthesis, revision arthroplasty and a combination of the two. Conservative management was also noted and included in our analysis. Mortality was documented and correlated with specific comorbidities.

A total of 144 patients (145 fractures) were identified with a mean age of 80.9 years old [standard deviation (SD) 9.9]. There were 55 male and 89 female patients. Statistical analysis was done using the SPSS version 23.0 programme.

Statistical analysis

For categorical risk factors, the chi-square test was used to identify any potential correlation (i.e. comorbidities), whereas for constant variables or multilevel group variables, a univariate analysis of variance was done (i.e. fracture pattern). Pearson's correlation coefficient is used to show significance of each factor in relation to mortality. Furthermore, Fisher's exact test was used to analyse the first-year post-injury, due to the low number of patients. The Kaplan–Meier technique was used to predict survival with 95% confidence intervals. The log rank test was used to assess significant

differences between different factors in the long term, and Breslow's (generalised Wilcoxon) test for non-proportional event rates. Out of the two tests, the one with the highest significance was reported. Cox regression analysis was used for risk analyses and identification of hazard ratios. Binomial distribution was used for simple sample analyses. Bonferroni's correction was used in the case of multiple comparisons, to avoid alpha error. A p value < 0.05 was considered significant. Results for significant factors are demonstrated as hazard ratios (HR) with corresponding confidence intervals (CI).

Results

Out of 144 patients, 117 (81.3%) had a fracture around a hip prosthesis and 27 (18.8%) had a fracture around a knee prosthesis ($p < 0.001$, binominal test). More specifically, 94 (65.3%) had fractures around a THA, 27 (18.8%) had a fracture around a TKA, 20 (13.9%) had a fracture around a hemiarthroplasty and 3 (2.1%) had a fracture around a revision THA. There were 70 (48.6%) fractures involving the right side and 72 (50.0%) involving the left side. There was 1 patient (0.7%) that had a bilateral injury. This patient had bilateral THA, and the right side was treated conservatively and the left was operated. The patient was included in the operative group as he had undergone surgery. There was one patient (0.7%) that had an acetabular fracture of a THA and was treated conservatively, and hence placed in the non-operative group. In total, 44 patients (30.5%) were treated conservatively and 100 patients (69.5%) were operated. At the time of our analysis which was a year after the last patient was included, 50 patients (34.7%) had died. More specifically, the deaths were 16 patients (11.1%) from the conservative group and 34 patients (23.6%) from the operated group. The injury classification and surgical characteristics are summarised in Table 1. Only the ASA grade was found to be significant in our correlation analysis with a p value = 0.011 (95% CI).

Survival analysis

The mean survival was 12.7 months (95% CI 8.4–17.1). The type of initial implant did not have any bearing on the mean survival (THA 10.1 months, 95% CI 5.7–14.5 vs TKA 18.7 months, 95% CI 9.2–28.1 vs hemiarthroplasty 13.8 months, 95% CI 0–30; $p = 0.358$, log rank test). In the group that had a PPF around a revision implant, all the patients were still alive at the time of data collection. Figure 1 outlines the survival of each type of initial prosthesis. It was also noted that the patients with a PPF around a hemiarthroplasty had a worse outcome on the initial few months

Table 1 Injury and surgical characteristics

	Mortality				
	Dead		Alive		p value (chi square)
	N	Percentage	N	Percentage	
Classification					
A	7	14	13	13.8	0.591
B1	7	14	22	23.4	
B2	13	26	26	27.7	
B3	6	12	8	8.5	
C	5	10	9	9.6	
Distal femoral 1	1	2	4	4.3	
Distal femoral 2	4	8	5	5.3	
Distal femoral 3	7	14	4	4.3	
Acetabular	0	0	1	1.1	
Tibia 1	0	0	1	1.1	
Tibia 2	0	0	0	0	
Tibia 3	0	0	1	1.1	
Cemented vs uncemented					
Cemented	25	50	43	45.7	0.626
Uncemented	25	50	51	54.3	
Initial prosthesis					
THA	30	60	64	68.1	0.348
TKA	12	24	15	16	
Hemiarthroplasty	8	16	12	12.8	
Revision	0	0	3	3.2	
Surgical fixation					
Osteosynthesis	15	45.5	32	48.5	0.943
Revision	3	9.1	5	7.6	
Combined	15	45.5	29	43.9	
Cause of fracture					
Low	48	96	93	98.9	0.240
High	2	4	1	1.1	
ASA					
<3	16	32	51	54.3	**0.011**
≥3	64	68	43	45.7	
Weight-bearing status					
FWB	30	60	62	66	0.052
PWB	8	16	23	24.5	
NWB	12	24	9	9.6	

Significant value of $p < 0.05$ is in bold

after operation. In total, 50 (34.7%) patients died from our cohort study and 35 (24.3%) died within the first 12 months.

First-year survival

The mean survival for 12 months post-injury was 5.3 months (95% CI 4.1–6.5, $p < 0.001$). Figure 2 demonstrates this observed early mortality in our group of patients. A chi-square test was performed to analyse the first-year mortality

following a periprosthetic injury. Significant factors affecting survival were osteoporosis and dementia with a two-sided Fisher's exact test value of 0.02 and 0.002, respectively.

Patient characteristics and mortality

In Table 2, significant comorbidities and correlation analysis are demonstrated (p value, chi square, 95% CI). Medical comorbidities that have a significant effect on mortality included chronic obstructive pulmonary disease ($p = 0.012$) and renal failure ($p = 0.006$). Patients were also divided in two groups, one group aged 75 years or less and one more than 75 years old. There was a significant correlation for the group aged more than 75 years old and mortality ($p = 0.001$). The following factors did not have a significant effect on mortality; gender ($p = 0.296$); type of fracture ($p = 0.591$); cement use ($p = 0.626$); prosthesis ($p = 0.348$); surgical fixation ($p = 0.943$); cause of fracture ($p = 0.240$); weight-bearing status ($p = 0.052$).

Survival analysis using Kaplan–Meier testing showed significantly lower survival in patients with an ASA grade of 3 or higher (Fig. 3a, $p = 0.009$ Breslow's test), history of CVA or TIA (Fig. 3b, $p = 0.038$ Breslow's test), depression (Fig. 3d, $p = 0.013$ log rank test) and gender (male) (Fig. 3d, $p = 0.041$, Breslow's test), whereas, it showed an increased survival in patients with dementia (Fig. 3c, $p = 0.002$ log rank test).

Risk analysis (Cox regression)

The Cox regression analysis was used to identify significant increased risk of early death. Although a history of CVA or TIA and gender (male) showed an increasing risk in initial analysis with Kaplan–Meier testing, they were not significant when analysed using Cox regression analysis ($p = 0.067$, $p = 0.106$, respectively). Table 3 summarises the significant risk factors' mean survival and hazard ratios. Furthermore, a multivariate analysis was performed using the risk factors that demonstrated a significant risk of death in the pre-analysis. A history of CVA or TIA and dementia were the only two risk factors to be significant, with $p = 0.006$ [HR 0.2 (95% CI 0.1–0.7)] and $p = 0.005$ [HR 3.6 (95% CI 1.5–8.8)], respectively.

Discussion

The majority of the literature related to PPF treatment focuses on functional outcomes and post-operative complications [1, 4, 11–13]. Some studies have reported on survival following PPFs; however, a detailed analysis is uncommon and it is usually a secondary outcome [1].

Fig. 1 Kaplan–Meier curve of survival after periprosthetic fractures
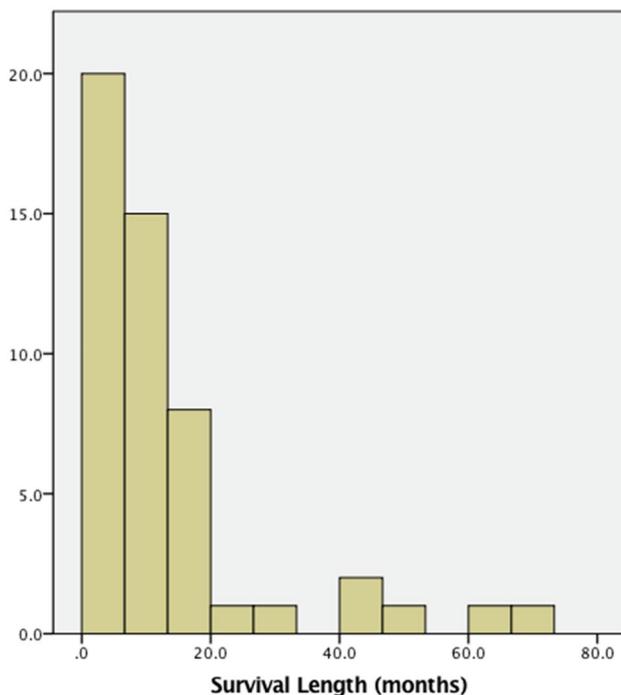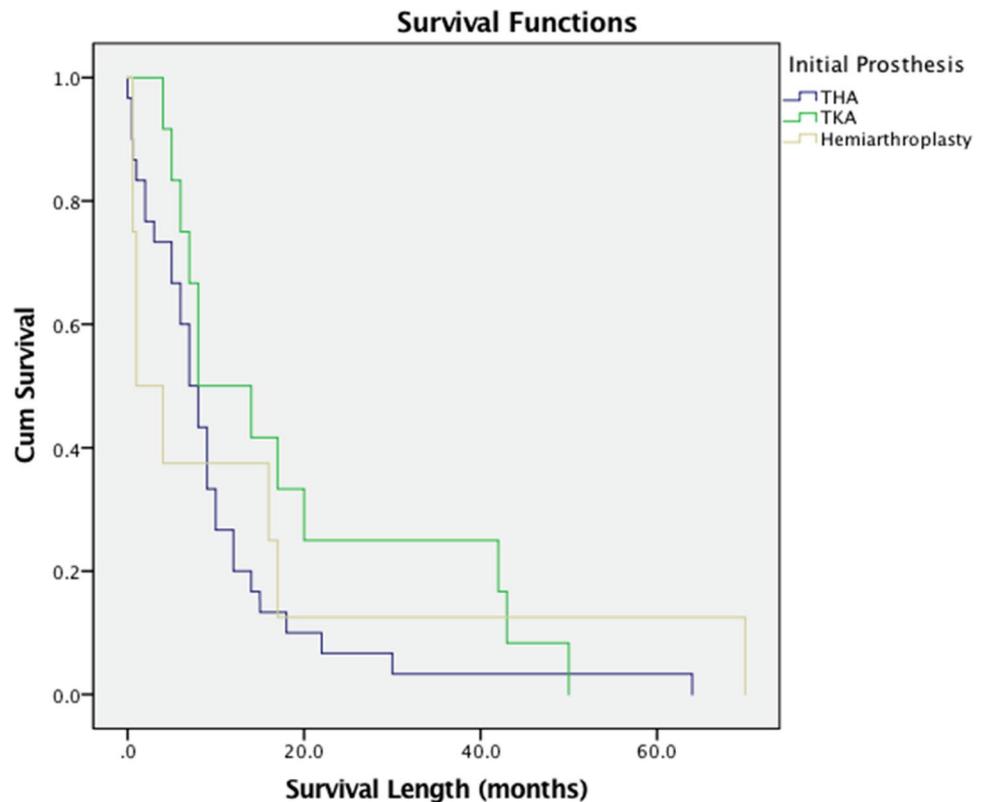

Fig. 2 Mortality following periprosthetic fracture

PPFs are quite severe injuries and require a plethora of resources to manage. A large number of studies are hard to find and the low number of patients can impair analysis [1, 3]. A multi-centre analysis may yield more numbers of patients and a more detailed statistical analysis.

Our study population is quite elderly with 114 patients (79.2%) being over 75 years old. The cognitive function, as well as the functional outcomes in this group of individuals, is quite challenging to elicit [1, 2].

Griffiths et al. found a decrease in survival in individuals that had an operative fixation 72 h post-injury [17]. Our study evaluated operative treatment and timing to surgery, without any correlation. Furthermore, we divided the timing into groups of operating within 5 days, 5–10 days and more than 10 days, in hope of showing some significance, but there was no correlation with mortality ($p = 0.379$ chi-square test). Other studies have not found a correlation between time to surgery and mortality [2].

The ASA scoring system is already validated in stratifying risk in other injuries [2, 18, 19]. In our study, ASA score correlation with mortality is shown to be significant in predicting survival. A COX regression analysis shows a HR of 2 (95% CI, $p = 0.027$). This strengthens and validates the use of ASA scoring prior to surgery. The type of anaesthesia has not been evaluated, as practice varies. The ASA is a validated tool, with a standardised grading system, making it easier to re-produce. Furthermore, current research exists

Table 2 Mortality correlated with comorbidities

	Mortality				
	Dead		Alive		p value (chi square)
	N	Percentage	N	Percentage	
Ischaemic heart disease					
Yes	13	26	18	19.1	0.341
No	37	74	76	80.9	
Cardiac arrhythmias					
Yes	6	12	11	11.7	0.958
No	44	88	83	88.3	
Heart failure					
Yes	5	10	5	5.3	0.293
No	45	90	89	94.7	
Hypertension					
Yes	30	60	54	57.4	0.088
No	20	40	40	42.6	
Chronic obstructive pulmonary disease					
Yes	11	22	7	7.4	**0.012**
No	39	78	87	92.6	
Diabetes mellitus					
Yes	8	16	12	12.8	0.593
No	42	84	82	87.2	
Osteoporosis					
Yes	7	14	12	12.8	0.835
No	43	86	82	87.2	
Hypothyroidism					
Yes	2	4	13	13.8	0.066
No	48	96	81	86.2	
Rheumatoid arthritis					
Yes	3	6	4	4.3	0.643
No	47	94	90	95.7	
Renal failure					
Yes	8	16	3	3.2	**0.006**
No	42	84	91	96.8	
CVA or TIA					
Yes	6	12	11	11.7	0.958
No	44	88	83	88.3	
Dementia					
Yes	9	18	10	10.6	0.214
No	41	82	84	89.4	
Depression					
Yes	3	6	8	8.5	0.589
No	47	94	86	91.5	
Parkinson's disease					
Yes	2	4	4	4.3	0.942
No	48	96	90	95.7	
Epilepsy					
Yes	1	2	4	4.3	0.482
No	49	98	90	95.7	
Alcohol excess					
Yes	0	0	3	3.2	0.202

Table 2 (continued)

	Mortality				
	Dead		Alive		p value (chi square)
	N	Percentage	N	Percentage	
No	50	100	91	96.8	
History of cancer					
Yes	9	18	11	11.7	0.298
No	41	82	83	88.3	

Significant values of $p < 0.05$ are in bold

to show no correlation between different types of anaesthesia and mortality, but supports correlation between ASA and mortality [1]. It has been hypothesised that survival has been depending on surgical factors, rather than pre-operative comorbidities [17, 20]. Our study did not show a correlation between surgical factors and survival as shown in Table 1. There was no significant correlation between the fracture classification, the use of cement, the type of initial prosthesis, the type of surgical fixation and mortality. This further strengthens our argument that the pre-morbid status of the patient is a significant factor for survival in PPF patients.

Initial analysis showed a correlation between renal failure and COPD as comorbidities increasing the risk of mortality, but survival analysis using Kaplan–Meier and Cox regression analysis testing did not show a further correlation. Our patient population has multiple comorbidities and certain comorbidities have a bigger impact on mortality than others. They may also suffer from a recent acute deterioration of their functional status, complicating their management and worsening some of the comorbidities tested (i.e. acute kidney injury, infection). Each patient has a multidisciplinary approach to their management plan. Patients with stable prostheses are treated conservatively and allowed to mobilise as able. Patients that would benefit with an operation are optimised and discussed with our anaesthetic colleagues. Patient optimisation with medical input from an elderly care physician and surgical planning prior to surgery is justifiable, as to reduce perioperative complications and mortality.

Mardian et al. demonstrated a positive correlation between mortality and age over 75 years old, and cardiovascular comorbidities [1]. Our study has demonstrated a similar effect, as increasing age (75 years old or more group) is a significant risk factor for mortality ($p = 0.001$, chi-square test). Cardiovascular comorbidities did not show a positive correlation with mortality as summarised in Table 2.

Park et al. suggests a sixfold increase in perioperative periprosthetic fractures in patients suffering from hemiparesis or hemiplegia [21]. In our study group, there were no perioperative PPF, but neurological conditions such as dementia and a history of CVA or TIA were identified
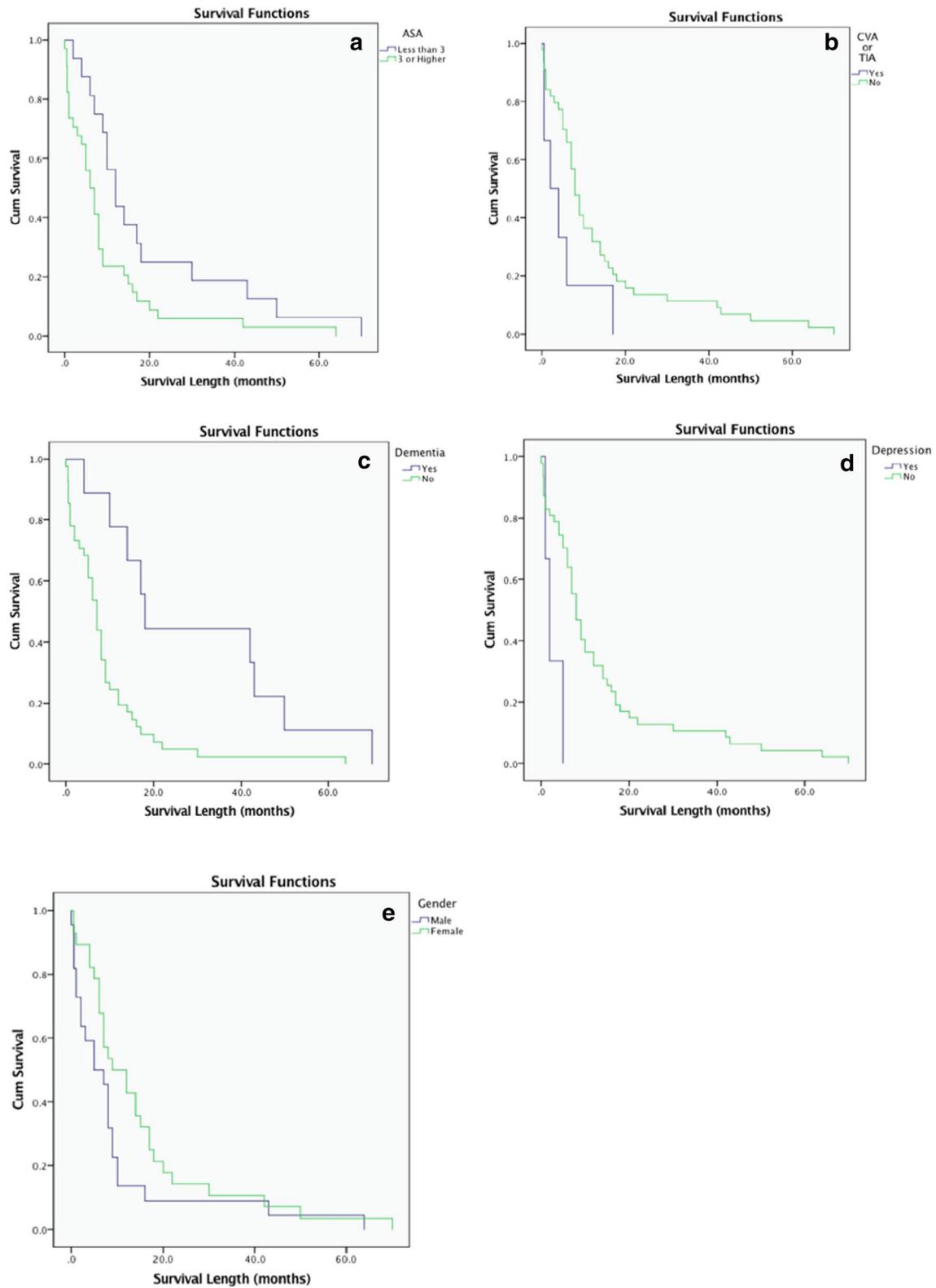
Fig. 3 Kaplan–Meier survival curves by **a** American Society Anaesthesiologists Score (ASA), **b** history of cerebrovascular accident or transient ischaemic attack, **c** dementia, **d** depression, **e** gender

Table 3 Survival by significant risk factors

Risk factor	Mean survival (95% CI) (months)	p value	Hazard ratio (95% CI)	p value
ASA		p = 0.009 Breslow's test	2.0 (1.1–3.7)	p = 0.027
< 3	19.6 (10.3–29.0)			
≥ 3	9.5 (5.2–13.8)			
CVA or TIA		p = 0.038 Breslow's test	0.5 (0.2–1.1)	p = 0.067
Yes	5.0 (0.1–10.0)			
No	13.8 (9.0–18.6)			
Dementia		p = 0.002 log rank test	3.2 (1.4–7.0)	p = 0.004
Yes	28.8 (15.2–44.3)			
No	8.9 (5.6–12.4)			
Depression		p = 0.013 log rank test	0.2 (0.1–0.8)	p = 0.025
Yes	2.7 (0.3–5.0)			
No	13.4 (2.3–8.8)			
Gender		p = 0.041 Breslow's test	0.6 (0.4–1.1)	p = 0.106
Male	9.7 (3.3–16.0)			
Female	15.1 (9.3–21.0)			

as significant risk factors for survival. Fuchtmeier et al. reports worse outcomes in 121 periprosthetic fractures if the patients had a higher ASA score, were older and suffered from dementia [2]. Although our study shows the same in respect of ASA and age, we identified that patients with dementia had an increased survival with a HR of 3.2 (95% CI, p = 0.004).

Singh et al. also found osteoporosis to be a significant risk factor in his study of 23 patients [18]. We have identified a correlation between dementia and mortality in PPFs, which is also seen in our first-year survival analysis. We have also identified osteoporosis to be a significant factor for survival in our first-year analysis. Taking into account that the majority of deaths were observed within the first year (24.3% of total population), this emphasises the impact of these comorbidities for patient survival.

There were 50 patients (34.7%) that died in our cohort, with 16 patients (11.1%) being from our conservative group and 34 patients (23.6%) from the operated one. There is an increase in probability of death in the operative group. In particular, we observed a 3.5 times increase compared to the non-operated group. The decision to operate was taken after a multidisciplinary discussion took place and operative treatment was thought to be of benefit. The two groups were of similar comorbidities, with the operative group being 2.3 times bigger (100 vs 44). There is obviously the possibility that patients may be too unwell for theatre post-injury and operating on them may mean imminent death. Overall, careful selection for operative treatment is advisable and a stratification tool would be of use. The risks of surgery should be explained, emphasising the increased risk of death. A further study looking into neurological factors and osteoporosis, and evaluating

outcomes in the short-term and long-term post-injury may be of value.

In terms of prevention, Lindah et al. suggests that high-risk patients for a PPF should have routine radiographic follow-up, as to identify possible loosening and intervene prior to fracture [3]. Bhattacharyya et al. reported an 11% mortality following fixation of periprosthetic fractures and advised revision arthroplasty rather than fixation in Vancouver B-types. This is advisable when both choices can be considered possible [20].

In conclusion, PPF are associated with a high mortality risk (34.7%). No operative risk factors or time to operate from injury were significant. Hence, a careful optimisation of the patient prior to operative treatment is paramount and will allow for modifiable risk factors to be optimised and hopefully improve survival. Our initial analysis showed a correlation between mortality and older age, COPD and renal failure. In particular, there is an increased risk of death in patients over the age of 75 years old. An increase in mortality in the operative group of 3.5 times more than in the conservative group was noted. This advocates a careful selection of patients to operate, as well as emphasising the increased risk of death. By doing a survival analysis, the ASA grade was also found to be significant, further validating the tool. Furthermore, a history of CVA or TIA, dementia, depression and gender (male) were significant comorbidities. In the multivariate analysis, CVA or TIA history and dementia were shown to be the only two comorbidities to be significant. More specifically, it showed that dementia was not associated with an increased risk of death. Finally, in the first-year post-injury, the two comorbidities to be significant for survival were dementia and/or osteoporosis. The major determinant on a patient's outcomes post-periprosthetic

injury can be evaluated by their ASA, their age and their comorbidities.

Compliance with ethical standards

Conflict of interest The authors certify that they have no affiliations with or involvement in any organisation or entity with financial interest or non-financial interest in the subject matter discussed in this manuscript.

Ethical approval and consent No animals or human subjects were used for this project. This was a retrospective study evaluating comorbidities and their outcomes post-periprosthetic fractures around hip and knee arthroplasties. Hence, IRB approval was not sought or required. No consent was sought or required.

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