Predictors of Mortality Following Shoulder Arthroplasty

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1. Abstract:

1.1 Introduction:

This study aims to determine 30-day, 90-day and 1 year mortality following shoulder arthroplasty and identify predictors of mortality.

1.2 Materials and Methods:

All shoulder arthroplasty cases performed at the host institution, between 2012-2018 were included. A review of patient records was completed to identify demographic data, Charlson comorbidity index, date of death and factors associated with mortality.

Mortality analysis was undertaken using 1-Kaplan Meier estimates with 95% confidence intervals. Comparative analysis was performed for mortality following shoulder arthroplasty for elective vs. trauma and for primary vs. revision surgery. A multiple regression analysis was conducted to determine which factors were associated with increased mortality risk.

1.3 Results:

640 shoulder arthroplasty cases were performed in 566 patients. There were 44 deaths, 1 occurred within 90 days and 13 within 1 year. Trauma procedures had a hazard ratio of 5.3 (95% CI 1.9 to 15.0) for mortality compared to elective procedures (5 year survival trauma 78.6% (95% CI 60.7 to 89.0); elective 91.8% (95% CI 88.1 to 94.4). 1-year mortality was predicted by presence of malignancy, liver failure, cardiac failure, peptic ulcer, trauma surgery, revision surgery, intra-operative complication, transfusion and increased length of stay.

1.4 Discussion:

30-day, 90-day and 1-year mortality following shoulder arthroplasty were 0%, 0.16% and 2%; trauma procedures had a hazard ratio of 5.3 for 1-year mortality when compared to elective surgery. Malignancy, cardiac failure, liver failure, peptic ulcer and trauma surgery are associated with an increased risk of 1-year mortality.

Keywords: Shoulder, Arthroplasty, Outcome, Mortality

2. Introduction:

Rates of primary shoulder arthroplasty in the UK have consistently risen year on year since the National Joint Registry (NJR) began reporting shoulder arthroplasty cases in 2012, 6,526 cases were performed in 2017, and this trend is mirrored worldwide.[1] Patients undergoing shoulder arthroplasty tend to be elderly, are 70% female and often suffer from substantial co-morbidities.[1,2] Given the increasing number of procedures being carried out it is important to better understand the morbidity and mortality of these procedures to the patient, and to identify any predictors of mortality which may aid in pre-operative counselling of patients, planning and optimisation.

Whilst the evidence base for mortality following shoulder arthroplasty is limited, extensive work has been done in the investigation of mortality following total hip and knee replacement (THR and TKR). Hunt et al. reported a 90-day mortality of 0.4% following 409,096 THRs and a 45-day mortality of 0.25% following 467,779 TKRs. [3] Berstock et al. reported a 30-day and 90-day mortality of 0.3% and 0.65% respectively following THR, with cardiovascular disease the leading cause of death after meta-analysis of 32 studies with over 1 million patients. [4,5] For TKR, mortality rates of 0.2% and 0.39% were found at 30 and 90 days respectively in meta-analysis of 37 studies of over 1.75 million patients, again the leading cause of death was cardiovascular disease. [6]

Mortality following shoulder arthroplasty is less well reported, and variable. Waterman et al. reported a 30-day mortality of 0.25% in 2,004 shoulder arthroplasty patients, whilst Amundsen et al. reported 0.7% in 5853 patients from the Danish Shoulder Arthroplasty Registry.[2,7] Reported figures for 90-day mortality vary from 0.39%-1.3%,[1,8,9] whilst 1 year mortality rates of 1.6%-3.8% have been reported.[1,2,10] Cardiac and abdominal disease were the leading cause of death at 30 and 90 days, with pulmonary disease and malignancy the leading cause of death at 1

year.[2] No large single centre series have been published from the UK. Data published in the NJR does not include revision procedures or have sufficient detail to examine risk factors for mortality.

The aim of this study was to quantify the 30-day, 90-day and 1 year mortality following shoulder arthroplasty and to identify any factors that were associated with an increased risk of mortality.

3. Materials and Methods:

3.1 Method

A consecutive series of shoulder arthroplasties performed at the host institution, a tertiary referral upper limb unit, between January 2012 and January 2018 was identified. Patients were included if they underwent any form of shoulder arthroplasty, including anatomic total shoulder replacement, reverse total shoulder replacement, hemiarthroplasty and revision procedures for all indications with a minimum of 1 year follow up. Patients were excluded if they did not receive a shoulder arthroplasty procedure or if there was inadequate follow up data.

A review of case notes, electronic patient record, operation note, anaesthetic chart and discharge summary was made to collect patient demographic data, co-morbidities, details of inpatient stay and date of death. A Charlson co-morbidity index was calculated for each patient.[11]

3.2 Statistical Methods

Simple descriptive statistical analysis was carried out using Microsoft Excel. Mortality analysis was carried out using 1-Kaplan Meier estimates with 95% confidence intervals (GraphPad Prism, version 8.0.1, GraphPad Software Inc.). Comparative analysis was performed for mortality following shoulder arthroplasty for elective compared to trauma indications and for primary compared to revision surgery. Comparisons were made by means of a log rank test (Mantel-Cox) to see if there was a significant difference in mortality between the groups and hazard ratios (Mantel-Haenszel) and 95% confidence intervals calculated for the comparisons.

A multiple regression analysis was conducted to determine which factors influenced the risk of mortality at defined periods following shoulder arthroplasty. *A priori* we had intended to conduct analyses for 30 days, 90 days and 1 year but no patients died within 30 days and only 1 patient died by 90 days therefore the regression was restricted to 1 year mortality (n=13 deaths) as the dependent variable of interest. Analysis of variance was used to determine if the model significantly predicted the outcome of interest. Independent variables included in the final multiple regression model were age, gender, ASA grade (1-2, 3-4), comorbidities (diabetes, liver failure, malignancy, chronic kidney disease, congestive cardiac failure, myocardial

infarction, chronic obstructive pulmonary disease, peripheral vascular disease, cerebrovascular accident, connective tissue disorder and peptic ulcer), trauma or elective surgery, primary or revision surgery, indication for primary surgery (osteoarthritis, cuff tear arthropathy, other), year of surgery to identify changes in mortality over time (2011-2014, 2015-2017), type of shoulder arthroplasty (hemiarthroplasty, anatomical total shoulder replacement, reverse geometry shoulder replacement), side, hand dominance, anaesthetic (general anaesthetic or general anaesthetic plus regional block), operating surgeon grade (Consultant or training grade), previous surgery (previous arthroscopic surgery, previous arthroplasty surgery, previous open reduction internal fixation), fixation of humeral component (cemented or uncemented), peri-operative complication, postoperative transfusion and length of stay. Comorbidities of AIDS, dementia and hemiplegia were excluded as there were no cases. Multicollinearity was assessed and addressed where it was a problem ($R^2>0.75$); it was addressed either by grouping variables (e.g. ASA grade and year of surgery) or removal of variables from the model (e.g. day of the week of surgery) until it was no longer a problem.

4. Results:

During the study period 640 shoulder arthroplasty cases were performed in 566 patients, 63 patients underwent 2nd side surgery, 11 had revision procedures in the study period. The mean age at time of surgery was 72 years (SD±10), 451 cases (70%) were performed in female patients. The most common procedure was primary reverse total shoulder replacement (287 cases; 45%) followed by primary anatomic total shoulder replacement (262 cases; 41%) and hemiarthroplasty (36 cases; 6%) of which 25 were for elective indication, 11 for trauma. Elective cases accounted for 569 (89%), with 71 (11%) due to trauma. The most common indication was osteoarthritis (289 cases, 45%), followed by rotator cuff arthropathy (160 cases; 25%). Demographic details for all patients included are provided in Table 1.

No deaths occurred within 30 days of surgery, 1 occurred within 90 days of surgery and 13 occurred within 1 year of surgery. The 30-day, 90-day and 1 year mortality was 0%, 0.16% and 2% respectively. The group who died within 1 year of surgery had a higher mean age (80 years SD±10), higher mean Charlson co-morbidity index (5.5 SD±1.9 vs. 3.3 SD±1.4) longer inpatient stay (14 days (IQR 2-23) vs. 2 days (IQR 2-4)) and had a higher proportion of trauma cases (7/13 (53%) vs. 60/596 (10%)) when compared to the group who survived the study period.

Table 1. Patient demographic data

There were 44 deaths in the follow up period, 1 of which occurred within 90 days of shoulder arthroplasty and 13 within 1 year. Fig. 1 and 2 show Kaplan-Meier survival analysis of elective vs. trauma patients, and patients undergoing primary procedures vs. revision procedures. When comparison was made between procedures performed for elective indications (n=569) and those for trauma indications (n=71), there was a significantly higher mortality in the trauma group (p=0.002). Trauma procedures had a hazard ratio of 5.3 (95% CI 1.9 to 15.0) for mortality compared to elective procedures (5 year survival trauma 78.6% (95% CI 60.7 to 89.0); elective 91.8% (95% CI 88.1 to 94.4). When primary were compared to revision procedures, there was no significant difference in mortality (p=0.181), the hazard ratio for revision procedures was 2.1 (95% CI 0.7 to 6.2) compared to primary procedures (5 year survival revision 90.9% (95% CI 79.5 to 96.1); primary 90.4% (95% CI 86.4 to 93.3).

Figure 1: Survival following shoulder arthroplasty: elective compared to trauma procedures

Figure 2: Survival following shoulder arthroplasty: primary compared to revision procedures

The multiple regression model investigating factors associated with increased 1-year mortality is shown in table 2. The analysis of variance indicated that the multiple regression model did significantly predict 1-year mortality ($p<0.0001$). 1-year mortality was predicted by the following variables in the model: liver failure ($p<0.0001$), malignancy ($p<0.0001$), congestive cardiac failure ($p=0.016$), connective tissue disorders ($p=0.032$), peptic ulcer ($p=0.001$), trauma surgery ($p=0.001$), revision surgery ($p=0.005$), peri-operative complication ($p=0.004$), postoperative transfusion ($p=0.002$) and length of stay ($p=0.019$). None of the other variables predicted 1-year mortality.

Table 2: Multiple regression model investigating factors that significantly predict mortality by 1 year following shoulder arthroplasty.

5. Discussion:

This study reports 30-day, 90-day and 1-year mortality of 0%, 0.16% and 2% following shoulder arthroplasty for all indications. Trauma patients were found to have a hazard ratio of 5.3 (95% CI 1.9-15.0) for 1-year mortality and had a significantly lower 5-year survival of 78.6% (95% CI 60.7 to 89.0) when compared to 91.8% (95% CI 88.1 to 94.4) for patients who underwent elective procedures. No significant difference was noted in 1-year mortality or 5 year survival between patients undergoing primary vs. revision procedures. Multiple regression modeling identified liver failure ($p<0.0001$), malignancy ($p<0.0001$), congestive cardiac failure ($p=0.016$), connective tissue disorders ($p=0.032$), peptic ulcer ($p=0.001$), trauma surgery ($p=0.001$), revision surgery ($p=0.005$), peri-operative complication ($p=0.004$), postoperative transfusion ($p=0.002$) and length of stay ($p=0.019$) as predictive of increased 1-year mortality.

Our figures are comparable to, if slightly below, other previously published figures. Amundsen et al. reported a 30-day, 90-day and 1-year mortality of 0.7%, 1.5% and 3.8% in a study of 5,863 primary shoulder arthroplasty procedures recorded in the Danish Shoulder Arthroplasty Registry.[2] They identified fracture patients as having a 6 times increased risk of death within 30 days of surgery when compared to a matched sample of patients from the general population,[2] which is consistent with the increased hazard ratio for 1-year mortality seen in patients undergoing shoulder arthroplasty for traumatic indication.

Farng et al. also noted increased mortality in patients undergoing primary shoulder arthroplasty for trauma reporting 2.9% 90-day mortality in trauma cases compared to 0.5% 90-day mortality in elective cases in a study of 15,288 patients.[9] Inacio et al. reported a 1-year mortality of 1.9% in 782 shoulder arthroplasty patients, but broke the group down to show that trauma patients had a 1-year mortality 5 times higher than elective patients at 5.4% vs. 1.0%.[10] They compared the quoted mortality rates to a reference group who hadn't undergone a shoulder arthroplasty procedure finding that elective patients had a lower than expected mortality rate, whilst the traumatic group did not have higher than expected mortality.[10] This lower mortality in elective

patients reflects a selection bias as patients deemed fit for elective surgery are likely to have less medical co-morbidities than the general arthritis population.[5] However in primary TKR and THR patients an excess surgical mortality has been demonstrated at 30-days and 90-days post-operation when compared to a matched group of patients awaiting the procedure.[12,13]

Two major studies have looked at predictors of mortality following shoulder arthroplasty. Singh et al. 90-day mortality and its predictors in 3,480 patients operated on at the Mayo clinic between 1976-2008.[14] They reported a 90-day mortality of 0.8% and identified higher ASA grade, higher co-morbidity scores and a diagnosis of malignancy as predictive of increasing mortality.[14] Waterman et al. reported a 30-day mortality of 0.25% in 2,004 shoulder arthroplasty patients, identifying cardiac disease and increasing age as independent predictors of mortality.[7] These studies are consistent with our findings that cardiac failure, liver failure, malignancy, peptic ulcer disease, connective tissue disease and trauma surgery were all independent predictors of 1-year mortality.

The strengths of this paper are that it is a large, comprehensive, consecutive series of shoulder arthroplasty cases from a single centre with no cases excluded. It must be stated however that the numbers are small when compared to large national population level studies from the USA. The limitations are that this was a retrospective study based on case note and medical record review and the numbers may have been too small to detect all significant associations on multivariate analysis. Patients in the study underwent different procedures with a variable physiological burden which may influence mortality. These cases were performed in a high-volume centre so may not be generalisable to all centres performing shoulder arthroplasty. The study here is designed to demonstrate an association between considered variables, but is not able to prove causation.

Conclusion:

This study reports 30-day, 90-day and 1-year mortality of 0%, 0.16% and 2% in 640 patients undergoing shoulder arthroplasty for all indications. Patients undergoing procedures for traumatic indications had a hazard ratio 5.3 for 1-year mortality. 1-year mortality was predicted by presence of malignancy, liver failure, cardiac failure, peptic ulcer, trauma surgery, revision surgery, peri-operative complication, transfusion and increased length of stay. This study provides useful single centre data in a shoulder arthroplasty population, and highlights the need for a larger in depth population level study of mortality in patients undergoing shoulder arthroplasty.

Word count: 2821

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Table 1. Patient Demographic Data

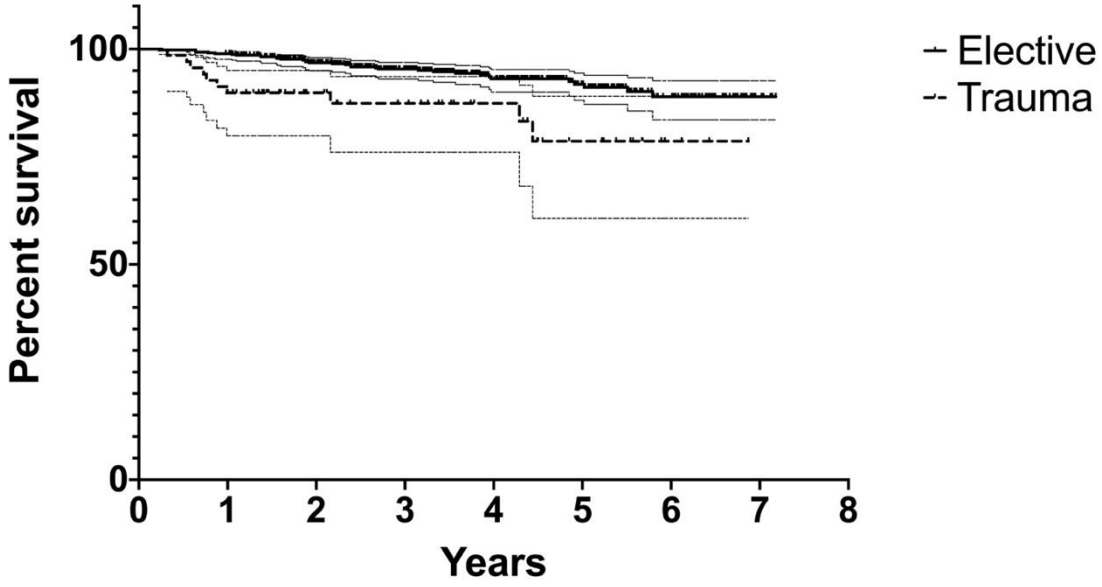
	All Patients	Alive	Died	
			Died <1yr post op	Died >1yr post op
Number	640	596	13	31
Age				
Mean (SD)	72 (+-10)	71 (+-10)	80 (+-4)	75 (+-11)
Min	24	24	72	31
Max	95	95	86	87
Gender				
Male	189	178	2	9
Female	451	418	11	22
ASA				
1	52	48	0	4
2	314	307	0	7
3	265	237	12	16
4	9	4	1	4
Charlson Score				
Mean (SD)	3.3 (±1.4)	3.3 (±1.4)	5.5 (±1.9)	4.2 (±2.0)
Min	0	0	3	0
Max	9	8	9	8
Procedure				
Anatomic	262	246	0	16
Reverse	287	269	8	10
Hemi	36	32	1	3
Revision	55	49	4	2
Indication				
OA	297	278	0	19
RA	36	33	0	3
Cuff arthropathy	160	154	2	4
AVN	18	18	0	0
Trauma	22	18	4	0
Trauma sequelae	49	44	3	3
Revision	55	49	4	2
Infection	2	2	0	0
Elective vs Trauma				
Elective	569	535	6	28
Trauma	71	59	7	3
Side				
Right	351	332	4	15
Left	289	264	9	16
Length of Stay				

Median (IQR)	2 (2-4)	2 (2-4)	14 (2-23)	3 (2-5)
Min	0	0	1	1
Max	71	71	27	38
Previous Surgery				
Yes	95	91	1	3
No	545	505	12	28

Table 2: Multiple regression model investigating factors that significantly predict mortality by 1 year following shoulder arthroplasty.

Variable	Multiple regression model estimate	95% confidence interval	t value	p value
Age	0.0008	-0.0005 to 0.0020	1.226	0.2207
Gender	0.0147	-0.0073 to 0.0368	1.311	0.1903
ASA 1-2 or 3-4	-0.0166	-0.0395 to 0.0063	1.426	0.1545
Diabetes	-0.0184	-0.0495 to 0.0127	1.164	0.2450
Liver failure	0.8653	0.6191 to 1.111	6.904	<0.0001
Malignancy	0.0729	0.0505 to 0.0954	6.382	<0.0001
CKD	-0.0114	-0.0549 to 0.0321	0.515	0.6070
CCF	0.0598	0.0111 to 0.1086	2.409	0.0163
MI	0.0137	-0.0363 to 0.0636	0.537	0.5916
COPD	0.0129	-0.0222 to 0.0479	0.722	0.4707
PVD	0.0007	-0.1091 to 0.1104	0.012	0.9906
CVA	-0.0487	-0.1009 to 0.0036	1.828	0.0680
Connective tissue	-0.0386	-0.0740 to -0.0033	2.146	0.0323
Peptic ulcer	0.1034	0.0417 to 0.1652	3.290	0.0011
Trauma or elective	0.0761	0.0306 to 0.1216	3.285	0.0011
Primary or revision	0.0978	0.0298 to 0.1659	2.823	0.0049
Indication: OA	-0.0052	-0.0447 to 0.0343	0.257	0.7977
Indication: cuff tear arthropathy	-0.0115	-0.0529 to 0.0299	0.545	0.5860
Year 2011-4 or 2015-7	-0.0143	-0.0356 to 0.0070	1.321	0.1870
Hemiarthroplasty	0.0006	-0.0524 to 0.0536	0.021	0.9835
Anatomical TSR	0.0204	-0.0172 to 0.0581	1.065	0.2874
Reverse TSR	0.0102	-0.0097 to 0.0301	1.004	0.3156
Side	0.0322	-0.0110 to 0.0753	1.465	0.1434
Hand dominance	0.0235	-0.0076 to 0.0545	1.482	0.1388
Anaesthetic (GA vs. GA+block)	0.0018	-0.0209 to 0.0245	0.154	0.8775
Operating surgeon grade	0.0059	-0.0340 to 0.0458	0.290	0.7720
Previous arthroscopy	-0.0745	-0.1585 to 0.0095	1.743	0.0819
Previous ORIF	-0.0543	-0.1225 to 0.0137	1.569	0.1172
Previous arthroplasty	-0.0203	-0.0498 to 0.0093	1.344	0.1795
Humeral fixation	0.0532	0.0172 to 0.0893	2.899	0.0039
Peri-operative complication	0.0859	0.0325 to 0.1393	3.159	0.0017
Postoperative transfusion	0.0023	0.0004 to 0.0042	2.360	0.0186
Length of stay	0.0137	0.0111 to 0.1086	1.226	0.2207

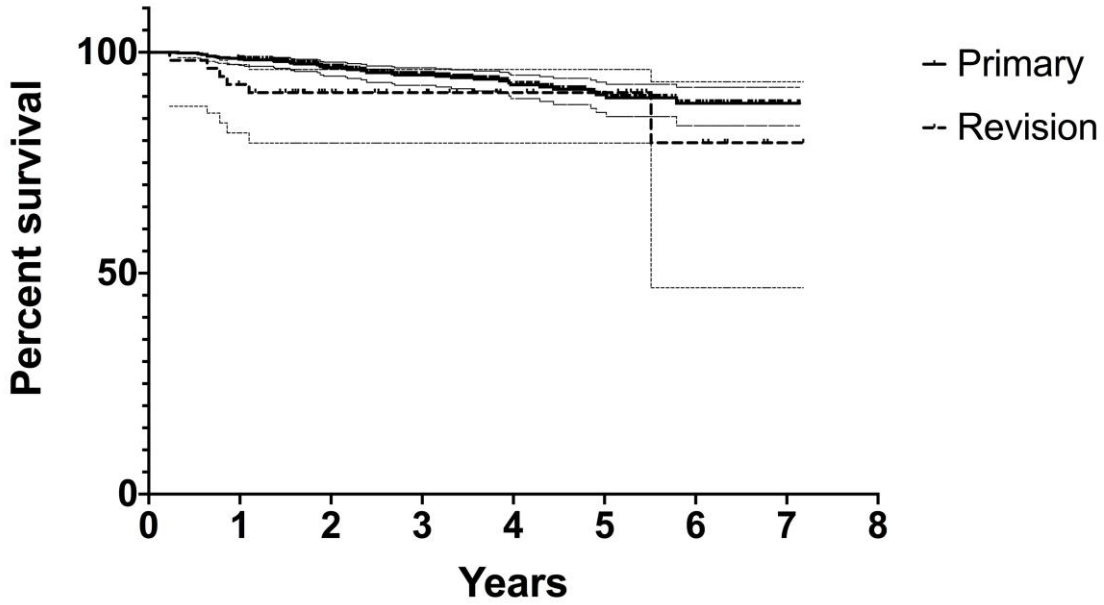
Figure 1: Survival following shoulder arthroplasty: elective compared to trauma procedures



Numbers at risk:

Elective:	571	565	463	336	212	136	65	7
Trauma:	69	61	40	32	22	14	5	1

Figure 2: Survival following shoulder arthroplasty: primary compared to revision procedures



Numbers at risk:

Primary:	585	574	464	339	214	135	61	6
Revision:	55	51	39	29	20	15	8	2