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Early Postoperative Mortality Following Joint Arthroplasty: A Systematic Review

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Abstract

Objective—To perform a systematic review of 30- and 90-day mortality rates in patients undergoing hip or knee arthroplasties.

Methods—Five databases were searched for English-language studies of mortality in hip or knee arthroplasties and the following data were extracted: patient characteristics (age, gender, ethnicity), arthroplasty characteristics (unilateral vs bilateral, hip vs knee), system factors (hospital volume and surgeon volume), year of study, etc... Mortality rates were compared across variable categories; proportions were compared using relative risk ratios and 95% confidence intervals.

Results—Out of 650 titles and abstracts, 80 studies qualified for data inclusion. 35%, 34% and 31% studies provided 30-, 90- and >90-day mortality rates. Overall 30-day mortality rates published across all types of arthroplasties were 0.3%, 90-day: 0.7%. For those reports with specific rates, 30-day mortality was significantly higher in men than women (1.8% vs 0.4%; relative risk (RR): 3.93, 95% confidence interval (CI), 3.30–4.68) and bilateral vs unilateral procedures (0.5% vs 0.3%; RR, 1.6, 95% CI:1.49–1.72), but no differences were noted by the underlying diagnosis of osteoarthritis vs rheumatoid arthritis (0.4% vs 0.3%; RR 0.77, 95% CI:

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0.48–1.24). 90-day mortality showed non-significant trends favoring women, osteoarthritis as the underlying diagnosis, and unilateral procedures.

Conclusions—Several demographic and surgical factors were associated with higher 30-day mortality rates following knee and hip arthroplasties. More studies are needed to examine the effect of body mass index, comorbidities, and other modifiable factors, in order to identify interventions designed to lower mortality rates following arthroplasty procedures.

Keywords

Mortality; Total Knee Arthroplasty; Total Hip Arthroplasty; Short-term mortality

Introduction

Knee and hip joint replacements are generally successful surgical treatments primarily for patients with osteoarthritis (OA) or rheumatoid arthritis (RA) (1–3). Hip and knee arthroplasties are generally elective procedures. Those that are non-elective occur following trauma, including fractures, cancers or joint infections.

While common, non-serious, complications are reported during and after hip and knee arthroplasties, mortality is rare. Due to the elective nature of most joint replacements, despite its rarity, estimation and correlates of mortality are nonetheless important to both patients and surgeons. Knee and hip arthroplasties are among the most common elective procedures currently performed in the U.S., with an increased estimated occurrence by 2030 of 1.5 times for hip and 6 times for knee, respectively (4). Improvements in surgical techniques and operative room sterility have significantly reduced their mortality risk. Due to their increasing prevalence, it is important to estimate associated mortality rates and their correlates.

One of the main objectives of the Knee and Hip Arthroplasty Special Interest Group (SIG) is to standardize assessment and reporting of benefits and risks of these procedures. In addition to cardiac and thromboembolic complications that may occur in the early post-operative period following arthroplasties, all cause mortalities that are events of extreme importance. One of the first steps in this process is to assess what is important for outcomes reporting from clinical trials of arthroplasty and whether measures for these outcomes meet the OMERACT filter of truth, discrimination and feasibility. Death ascertainment is commonly done using National Death Index or reporting of death by family members to a physician practice, and these would meet the filters of truth and feasibility. It is well-known that the small sample size and short duration of most clinical trials (which are known limitations of clinical trials) limit the power to detect differences in harms, such as mortality, between interventions. Thus, discrimination ability for mortality may be limited outside the realm of simple, large clinical trials. However, measurement of this outcome is part of every clinical trial for most interventions, due to its inherent importance. This systematic review was designed to estimate risks for the most severe consequences associated with arthroplasties; including deaths occurring immediately post-operatively.

The objective was to assess overall mortality rates and their variation according to important characteristics. A systematic review of published studies in the English language of mortality in patients undergoing hip or knee joint replacement was performed, specifically to examine 30- and 90-day mortality rates by patient characteristics (age, gender, race/ethnicity, body mass index and comorbidity), surgeon and hospital procedure volume (high versus medium versus low), hospital type (community center versus referral center), setting (US/Canada versus other countries), and type of procedure (total joint versus partial; knee versus hip; primary versus revision). Particular emphasis was placed on 30- and 90-day mortality rates, reasoning that deaths within that time frame were more likely related to the surgical procedure and immediate postoperative care than those occurring months or years after surgery.

Methods

Literature Search and Study Selection

A librarian performed the literature search (J.B.) on 9/01/2009 using the terms “arthroplasty”, “joint replacement” or “arthroscopy” AND “mortality”, “fatal outcome” or “death”. The following databases were searched: (1) Cochrane Central Register of Controlled Trials (CENTRAL), via *The Cochrane Library*, Wiley InterScience (www.thecochranelibrary.com), current issue; (2) OVID MEDLINE, 1966- ; (3) CINAHL (via EBSCOHost), 1982- ; (4) OVID SPORTdiscus, 1949- ; and (5) Science Citation Index (Web of Science) 1945- .

Two reviewers (JK and JAS) independently examined all publication titles and abstracts for inclusion. Inclusion criteria were: (1) study of mortality in patients with joint replacement; (2) fully published original study in English language, not an abstract, review of editorial. Consensus was achieved by discussion between reviewers. All full text articles were reviewed by one co-author (J.K.), who was trained by the senior epidemiologist (JAS). Those meeting inclusion criteria were selected, in agreement with the senior author (JAS).

Data Abstraction and Analyses

For all studies selected for full text review, data were abstracted (J.K.) using a structured data abstraction form. The elements abstracted included study characteristics (study type, type of joint replacement, length of study), setting (country, community hospital- versus referral/tertiary hospital), patient characteristics (age, gender, race/ethnicity, BMI, comorbidity) and system characteristics (hospital volume, surgeon volume). Reports which did not provide information regarding elective vs non-elective procedures were considered and analyzed as including all-comers and were analyzed as such.

Overall 30- and 90-day mortality rates were calculated as the number of patients who died divided by those at risk (number undergoing arthroplasties). If and when standardized mortality rates were presented, they were extracted. It was anticipated that a small subset of studies would provide mortality rates according to variables of interest. Mortality rates were compared by important patient characteristics (gender), surgery type (primary vs revision; unilateral vs bilateral) and whether surgery was unilateral or bilateral. Realizing that health

care reimbursement, delivery systems, population health and access to arthroplasty procedures vary by country, differences between US/Canada and other countries (European countries, Israel and Singapore) were compared as a hypothesis-generating exercise.

Mortality rates were compared between categories of variables using relative risk ratios, which were calculated using www.pedro.org.au/wp-content/uploads/CIcalculator.xls.

Results

Search Strategy and Study Selection

Search strategy is shown in Appendix 1 and search results are summarized in Figure 1. Of 650 titles reviewed, 145 studies underwent a full review, of which 80 were assessed to have usable data (Figure 1). 56 (70%) studies summarized data from primary arthroplasty patients, three (4%) included those with surgical revisions and 21 (26%) both. 78 (98%) studies included total joint arthroplasty patients and 2 both total and partial joint replacements. 48 studies (60%) summarized only patients with hip arthroplasties, 22 (23%) only knee arthroplasties, and nine (11%) either knee and/ or hip (wrist arthroplasties were excluded from further analyses, being the only non-hip, non-knee study). The majority included primary arthroplasty procedures: of 48 hip studies, 34 (74%) were primary; nine reporting both knee and hip, six (67%) included primary arthroplasties; and of 22 knee studies, 16 (73%) were primary. In the majority of reports, 61/80 (76%), all-comer mortality in subjects undergoing hip or knee joint arthroplasties was reported; few reported mortality in those undergoing elective arthroplasties, 16/80 (20%) or in non-elective procedures, 3/80 (4%).

Overall Mortality

Of the 80 studies, 28 (35%) reported 30-day mortality rates, 27 (34%) 90-day rates and 25/80 studies (31%) >90-day rates post-procedure. Overall 30- and 90-day day post-operative mortality rates across all arthroplasty groups were 0.3% (15,856/4,991,811) and 0.7% (4,865/651,448) respectively.

Socio-demographic characteristics of patients included in the studies are summarized in Table 1. The majority of the patients were Caucasian with an underlying diagnosis of OA; 53–61% were women with a mean age of 68 years for both 30- and 90-day mortality estimates.

Association of gender, underlying diagnosis, bilaterality and type of arthroplasty with 30- and 90-day mortality

A subset of studies provided mortality rates for these variables. Men had significantly higher 30-day mortality rates compared with women (1.8% vs 0.4%); 90-day rates were similar in both (1.1% vs 1.0%) (Table 2). As might be expected, bilateral procedures were associated with higher 30-day mortality compared with unilateral arthroplasties (0.5% vs 0.3%) (Table 2). However, 90-day mortality did not differ significantly between unilateral versus bilateral arthroplasty. Data regarding mortality rates according to body mass index (BMI) and

associated comorbidities were not included in the reviewed studies, and therefore could not be analyzed.

To understand differences in mortality rates by arthroplasty type, site (knee vs hip) and primary surgery vs revision were analyzed for 30-day (Table 3) and 90-day mortality (Table 4). Pooled 30-day mortality rates were 0.63% for hip and 0.29% for knee arthroplasties (Table 3) and 90-day rates 0.9% for hip and 0.62% for knee (Table 4). Although some studies reported rates for elective surgery, the majority reported mortality for all-comers (Tables 3 and 4).

Only one study provided data for 30-day mortality rates among subjects undergoing revision arthroplasties and two studies reported 90-day mortality rates. Revision procedures were associated with similar 30- and 90-day mortality rates as primary arthroplasties. In subjects undergoing elective procedures, revisions were associated with significantly higher 90-day mortality rates despite significantly lower rates at 30-days (Table 5).

Due to reporting of mortality data by different age categories and lack of studies providing mortality by ethnicity, body mass index or comorbidity, summarizing mortality data according to these variables was not possible.

Differences by Region (US/Canada versus other countries)

For all-comers undergoing primary hip and knee arthroplasties, 30-day mortality rates were significantly higher in US/Canada and 90-day rates significantly lower compared with other countries (Table 6).

Analyses for System factors (Surgeon volume, hospital volume, setting) and Time Trends

As there were an insufficient number of studies reporting data by system factors, and the categories were different between studies, these data could not be summarized. The surveillance time periods in several studies overlapped more than a decade, therefore time trend analyses could not be performed.

Discussion

This report presents a systematic review of all published English-language studies including mortality data for patients undergoing elective or non-elective hip or knee arthroplasties. Socio-demographics of this study population, typical for subjects undergoing knee and hip arthroplasties included a mean age of 68 years; the majority being women and those with an underlying diagnosis of OA.

In the context of the OMERACT filter, mortality has received little attention, but a renewed focus on safety in the OMERACT and our groups' focus on benefit/risk profiles of arthroplasty should encourage consideration of additional outcomes such as mortality. The current version of the OMERACT filter was designed to assist in selection of outcome measures to define /efficacy and effectiveness. It is likely that next version of the filter can/ will take potential risks into account – and thus assessment of outcomes following TJR may assist in this effort.

Certain aspects of mortality assessment require further analyses: distinguishing between all-cause versus specific-cause mortality, despite the challenges posed by differentiating these in the context of chronic inflammatory diseases. In the absence of a life-threatening condition, the surgical procedure and perioperative stress are partially or mostly responsible for 30- and to some extent 90-day mortality. Nonetheless, explicit definitions regarding specific-cause mortality need to be developed. In future OMERACT work, the focus of this group will be to develop standardized measures of mortality, including comparisons to overall age-gender-adjusted mortality rates etc. The challenge remains to define the type of mortality, what is most important to study of a specific condition, and why? Should the focus be on all cause or specific mortality? Should we focus on early and late mortality or just early mortality? Assigning causality is particularly challenging, since most patients undergoing arthroplasty are elderly and may have multiple underlying conditions, likely to contribute to both early and later mortality. Another challenge will be to determine how mortality fits into the overall risk/benefit profile, determining number needed to treat vs potentially harm. Another important issue is whether it is possible to assess these differences with traditional sample sizes for arthroplasty trials (300–1500 typically for randomized controlled trials).

Several important observations from these analyses deserve further attention. First, overall 30- and 90-day mortality rates were 0.3% and 0.7%. These findings may not be easy to make broad generalizations, as studies included patients undergoing knee and/or hip arthroplasties and the majority were performed in the Western hemisphere (US, Canada and Europe). Nonetheless, summary estimates of mortality will be useful to patients, providers and policy makers, as comparative effectiveness becomes increasingly important, and both benefits and potential risks of arthroplasty procedures are compared with other interventions.

Second, men undergoing hip or knee arthroplasties had significantly increased 30-day mortality rates, compared with women. This is important, and confirms similar observations from previous arthroplasty studies with large sample sizes, most/all of which were included in this analysis. Higher prevalence of pre-operative cardiac morbidity, as well as higher peri-operative cardiac complications in men may explain the higher mortality rate, although more data are required to test this hypothesis.

Third, as expected, mortality rates were significantly higher in all-comers undergoing revisions vs primary arthroplasties: likely related to older age, more comorbidities and surgical complexity. Higher complication rates (5) and poorer health-related quality of life outcomes (6–7) have been reported following joint replacement revisions, compared with primary arthroplasty. These are likely reflective of higher comorbidity and poorer general health in revision candidates and at least partially explains the higher mortality rate for surgical revision procedures. A lower 30-day mortality rate in elective revisions compared with elective primary arthroplasty procedures is unexpected; as only one study provided data, these estimates may not be representative and may change with availability of more data.

Fourth, subjects undergoing bilateral procedures had higher 30-day mortality rates compared with those undergoing unilateral arthroplasties. Because of higher 30 day mortality rates, risks of simultaneous bilateral versus unilateral arthroplasty procedures need to be balanced against their potential benefits. Interestingly, 90-day rates were not significantly different between unilateral versus bilateral procedures. This may be due to the lack of power to detect these differences at 90-days (sample size 80–100 times higher for 30- versus 90-day sample) or the slight increase in higher mortality in early post-operative period in bilateral cases, relative to unilateral arthroplasty balanced by similar mortality in the later period (between 30- and 90-days) in patients undergoing arthroplasty, unrelated to laterality (unilateral vs bilateral).

Fifth, no significant differences in mortality rates between OA and RA patients may be due to improved treatment for RA in recent years, which may have reduced disease associated mortality and co-morbidities. However, this finding needs to be interpreted with caution due to the small number of events and small sample sizes of subjects with RA: 20 mortality events among 7,174 at 30-days and four events among 481 patients at 90-days.

Another hypothesis-generating observation were differences in mortality rates between US/ Canada and other countries – potentially attributable to differences in the proportion of primary vs revision procedures, variability between health care systems, and access to arthroplasty and post procedure rehabilitation. Future research should focus on determinants of mortality rates across countries, to ascertain potential insights explaining this variability in mortality rates.

Regarding system factors such as surgeon and hospital volume, several studies have found an association between higher procedure volume, better outcomes, lower revision rates (8–10) and lower mortality (9). We were unable to summarize data from the included studies since the definitions of low versus high volume differed between studies; however the results favored high-volume hospitals. Since they were reproducible, these results are widely accepted as valid and no additional studies were available to allow meta-analysis.

This study has several strengths and limitations. This was a comprehensive literature search, data were abstracted using standardized methods, and analyzed according to important clinical characteristics. Despite a large number of studies, results regarding revision arthroplasties are limited and may have led to Type II errors, i.e., missing an important difference due to lack of adequate power. Multivariable-adjusted analyses could not be performed due to small sample size and several candidate variables, due to concern for over-adjustment. Thus, these comparisons between crude rates should be interpreted with caution. Additionally, reported studies were of variable duration from one week to several months, and a prior decision to analyze mortality rates in categories of 30 days and 90-days (clinically meaningful) may have resulted in under- or over-estimation. Most studies originated from single or group practices, and although several utilized validated datasets such as Medicare and National Inpatient sample and National Hospital Discharge Summary, the sources of mortality were variable. We doubt that ascertainment of death could vary significantly between studies, but small ascertainment errors are possible. As study sample sizes varied, it is expected that larger studies impacted overall mortality rates more than

smaller studies. Another limitation included the relative lack of availability of studies reporting results in subjects undergoing non-elective procedures, as well as revision arthroplasties. Analyses by body mass index (BMI) and associated comorbidities could not be performed due to lack of relevant data. We combined US and Canadian populations as compared to other countries for country comparisons, but caution must be exercised interpreting these results, since there are differences in these health care systems between countries which we lumped together. The risk of mortality may differ based on differences in patient selection, comorbidity load and mortality risk in the general population in each country.

In summary, this systematic review quantified mortality rates following hip or knee arthroplasties. Significantly higher mortality rates were noted in women vs men, revision vs primary and bilateral vs unilateral procedures. Studies examining associations of BMI and baseline comorbidities with mortality rates have not been reported – despite the fact that many of these factors are modifiable. It is expected that a better understanding of the potential role of these factors in affecting overall outcomes will help to better reduce mortality in patients undergoing hip or knee arthroplasties. Several questions related to mortality assessment and reporting following arthroplasty remain unanswered, such as how to standardize the reporting, what adjustments are needed, how to measure differences and assessment of cause-specific versus all-cause mortality. These areas need further study and our group plans to address some of these challenges in the coming years.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1. Study flow chart

Table 1

Study population characteristics

	30-day mortality cohort	90-day mortality cohort
	Mean (SD) or %	Mean (SD) or %
Mean Age (SD)	67.4 (7.0)	68.0 (6.8)
% Female	52.8%	61.3%
% Caucasian	80.5%	91.2%
% Osteoarthritis	65.1%	82.5%
Mean BMI	28.9 (1.6)	28.1 (2.7)

SD, standard deviation, BMI, body mass index

Table 230- and 90-day mortality rates by gender, underlying diagnosis, and laterality^a

	30-day mortality		90-day mortality	
	n/N (%)	Relative Risk (95% CI)	n/N (%)	Relative Risk (95% CI)
Gender				
Female	156/32,612 (0.4%)	Reference	382/37,392 (1.0%)	Reference
Male	635/33,797 (1.8%)	3.93 (3.30–4.68)	195/18,382 (1.1%)	1.04 (0.87–1.23)
Underlying diagnosis				
OA	114/31,504 (0.4%)	Reference	78/13,686 (0.3%)	Reference
RA	20/7,174 (0.3%)	0.77 (0.48–1.24)	4/481 (0.8%)	1.46 (0.53–4.00)
Laterality				
Unilateral	10,711/3,739,900 (0.3%)	Reference	199/28,988 (0.6%)	Reference
Bilateral	765/167,069 (0.5%)	1.60 (1.49–1.72)	22/2,916 (0.7%)	1.13 (0.73–1.76)

^aSince only a few studies provided numbers separately for gender, underlying diagnosis and laterality, the mortality rates may differ from the overall rates, since these studies were a subset of all studies included

Table 3

30-day mortality stratified by the type of joint (hip versus knee versus both) and type of arthroplasty (primary versus revision versus both)^a for elective surgery and all-comers

	# studies ^a	All Studies Combined	Underlying indication for arthroplasty	
			Elective	All-comers ^b
Hip arthroplasty		2,602/411,675 (0.63%)		
Primary hip	11 studies		48/6,703 (0.71%)	2,224/352,708 (0.63%)
Revision hip^d	6 studies		22/7,371 (0.29%)	24/2,402 (1.0%)
Primary and revision combined	5 studies		90/30,714 (0.29%)	234/21,327 (1.1%)
Knee arthroplasty		13,233/4,569,617 (0.29%)		
Primary Knee	8 studies		75/12,108 (0.62%)	1,277/372,444 (0.34%)
Revision knee^d	1 study		--	4/4,375 (0.1%)
Primary and revision combined	7 studies		11,881/4,185,030 (0.28%)	0/35 (0%)

^a Since only a few studies provided numbers separately for knee and hip arthroplasty, the mortality rates may not be reflective of overall rates, these studies being a subset of all studies included

^b One study could provide data for more than 1 group

^c All-comers included studies where all patients were included and those in which there was no clear description of included patients

^d Revision numbers were often a subset of the mortality for the entire sample, frequently with primary arthroplasty constituting a large majority of cohort and high proportion of all deaths.

Table 4

90-day mortality stratified by underlying type of joint (hip versus knee versus both) and type of arthroplasty (primary versus revision versus both)^a for elective surgery and all-comers

	# studies ^b	Overall (all studies)	Underlying indication for arthroplasty	
			Elective	All-comers ^c
Hip arthroplasty		2,126/236,104 (0.9%)		
Primary hip	2 studies		395/46,007 (0.86%)	744/100,058 (0.74%)
Revision hip^d	8 studies		327/15,229 (2.15%)	38/3785 (1.0%)
Primary and revision combined	6 studies		884/73,750 (1.19%)	103/16,289 (0.63%)
Knee arthroplasty		2,432/393,540 (0.62%)		
Primary Knee	8 studies		508/78,745 (0.65%)	1,921/313,586 (0.61%)
Revision knee^d	1 study		--	1/132 (0.76%)
Primary and revision combined	1 study		--	3/1,209 (0.25%)

^aSince only a few studies provided numbers separately for knee and hip arthroplasty, the mortality rates are not reflective of overall rates, these studies being a subset of all studies included

^bOne study could provide data for more than 1 group

^cAll-comers included studies where all patients were included and those in which there was no clear description of included patients

^dRevision numbers were often a subset of the mortality for the entire sample, frequently with primary arthroplasty constituting a large majority of cohort and high proportion of all deaths.

Table 5
Comparison of primary and revision arthroplasty for studies including all-comers and elective arthroplasty

	30-day mortality		90-day mortality		Relative risk (95% CI)
	Primary	Revision	Primary	Revision	
All-comers	3,501/725,152 (0.5%)	28/6,777 (0.4%)	2,681/415,213 (0.6%)	47/6,190 (0.8%)	1.18 (0.88–1.57)
Elective	123/18,811 (0.6%)	22/7,371 ^b (0.3%)	1,126/135,496 (0.8%)	320/13,128 (2.4%)	2.93 (2.59–3.31)

^aRelative risk is for mortality in the revision arthroplasty with primary arthroplasty as the reference group
^bData from one study only with very low mortality risk for revision arthroplasty

Table 6

30- and 90-day mortality rates by region

	30-day mortality			90-day mortality		
	U.S./Canada	Other countries	Relative risk (95% CI)	U.S./Canada	Other countries	Relative risk (95% CI)
Primary Hip-all comers	893/69,819 (1.28%)	1,331/2,82889 (0.47%)	2.72 (2.50–2.96)	37/8,885 (0.42%)	707/9,1173 (0.78%)	0.54 (0.39–0.75)
Primary Knee-all comers	522/111,385 (0.43%)	755/26,1059 (0.29%)	1.62 (1.45–1.81)	1,733/28,9094 (0.60%)	188/2,4492 (0.77%)	0.78 (0.67–0.91)