SUPPLEMENTARY MATERIAL

Table i. Reported mortality after total hip replacement

Study Author	Year	Study period	Origin of study	No. Patients	Patient characteristics	Mortality (30 day)	Mortality(90 day)
Hunt[1]	2013	2003-2011	UK	409 096	Primary THR for OA.	NR	0.43%*
Jamsen[2]	2013	2002-2009	Finland	2559	Primary hip and knee >75 yrs. Mortality data includes both. No difference between hip and knees.	0.15%	0.35%
Bozic[3]	2013	1998– 2009	USA	53 252	5% sample Medicare database. Primary THR only.	NR	1.3%*
Aynardi[4]	2013	2000–2006	USA	8261	Uncemented THR. Partial hip arthroplasty were excluded.	NR	0.46%*
Jans[5]	2013	2010–2011	Denmark	5165	All primary THR or TKR patients. 2702 (52.3%) were THR and 2463 (47.7%) TKR. THR for #NOF were excluded.	NR	0.4%
Vulcano[6]	2012	2005–2011	USA	887	Primary elective hip replacement surgery with multimodal thromboprophylaxis. 887 THR, 645 TKR, 36 UKR.	NR	0.19%*
Suleiman[7]	2012	2005–2007	USA	584	Only hips. patients between 18 and 90 y of age who underwent TKR or THR. 1731 patients met the inclusion criteria, with 66% and 34% (584) undergoing TKR and THR	0.68%*	NR
Singh[8]	2012	1994–2008	USA	12 727	Institutional (Mayo Clinic) Total Joint Registry. Hip fracture patients were excluded from analysis. THR and TKR are separated for analysis.	0.24%*	0.46%*
O'Malley[9]	2012	2005–2008	USA	4281	American College of Surgeons National Surgical Quality Improvement Program database. THR in 4281 patients.	0.26%*	NR
Comba[10]	2012	1993–2006	USA	2453	Consecutive primary THR. joint registry at a single institution. 2453 elective surgeries and 779 surgeries were nonelective procedures due to displaced femoral neck fractures, analysed separately.	0.08%*	NR
Huddleston[11]	2012	2002–2007	USA	1809	Medicare Patient Safety Monitoring System in Medicare patients. Primary THR for degenerative arthritis.	1.00%*	NR
Bozic[12]	2012	1998–2007	USA	40 919	>65 years old. Medicare population.	NR	1.98%*
Pedersen[13]	2011	1995–2006	Denmark	44 558	All primary THR for OA, Danish Hip Arthroplasty Registry.	NR	0.67%*
Singh[14]	2011	1994–2008	USA	1195	Cohort of Olmsted County residents. After excluding those with fracture as the underlying diagnosis, the final sample consisted of 1195 THR and 1604 TKR patients.	NR	0.7%*
Singh[15]	2011	2001–2002	USA	10 187	Pennsylvania Health Care Cost Containment Council database to identify all elective primary THA and TKA surgeries performed in Pennsylvania. A total of 10 187 patients underwent hip replacement surgery, and 19,418 patients underwent knee replacement surgery.	0.52%*	NR
Malviya[16]	2011	2004–2009	UK	4500	Includes 2,502 TKRs analysed together.	0.37%	0.62%
Cram[17]	2011	2007–2008	USA	209 945	1 453 493 elective primary total hip arthroplasty procedures in Medicare patients. Acute fractures were excluded. However from 2007–2008 209 945 THRs were performed with 0.4% mortality at 30 days and 0.8% at 90 days	0.4%*	0.8%*

Table i. Reported mortality after total hip replacement

Study Author	Year	Study period	Origin of study	No. Patients	Patient characteristics	Mortality (30 day)	Mortality(90 day)
Paterson[18]	2010	2000–2004	Canada	20 290	Elective primary THR or total TKR. Data obtained from the Canadian Institute for Health Information. Joint replacements for cancer, fractures or trauma were considered unplanned and were excluded.	NR	0.6%*
Lie[19]	2010	1987–2005	Norway	188 110	50 to 80yrs old patients only. (THR and TKR included but no difference in mortality between the two). Data from the National Joint Replacement Registry of the Australian Orthopaedic Association and the Norwegian Arthroplasty Register.	0.20%	NR
Sierra[20]	2009	1988–2005	UK	9082	All cemented primary THAs from the local (Exeter) registry. #NOFs were excluded.	0.23%*	
Cusick[21]	2009	2002–2007	UK	2203	2203 primary THR and 2050 TKR. 4060 received aspirin only as chemical prophylaxis.		0.23%*
Aynardi[22]	2009	2000–2006	USA	6272	Consecutive series of uncemented total hip arthroplasty (THR) (6272 primary, 1206 revisions analysed seperately) performed under regional anesthesia. Institutional database.	0.13%*	0.41%*
Parry[23]	2008	2003–2006	UK	1549	All primary THR, with aspirin as chemical thromboprophylaxis and TED stockings.	0%*	0%*
Ramiah[24]	2007	1993–2004	UK	5831	All elective primary total hip replacements (mortality at 28 days).	0.4%*	
Gaston[25]	2007	1998–2004	UK	1744	All primary elective THA.	NR	0.90%*
Samama[26]	2007	June – July 2003	France	683	Prospective observational study of a cohort of consecutive patients hospitalized for total hip or knee replacement. 1080 patients (mean age68.0 years) were available; 63.2% were undergoing THR and 36.8% TKR.	NR	0.73%*
Tarity[27]	2006	1995–2002	USA	6258	All primary elective uncemented THR. Of those 6258 patients, 5725 (91%) underwent unilateral THR, whereas 533 (9%) patients received simultaneous bilateral THR.	NR	0.16%*
Blom[28]	2006	1993–1996	UK	1727	1,727 consecutive patients underwent primary THR.	0.41%*	0.98%*
Ibrahim[29]	2005	1996–2000	USA	6703	Data from the Veterans Administration National Surgical Quality Improvement Program database. 12 108 patients underwent primary TKR and 6703 patients who underwent primary THR.	NR	0.7%*
Nunley[30]	2003	1983–2001	USA	768	All, single surgeon, medium volume unit, includes revisions, fractures and cancer.	NR	0.65%
Miller[31]	2003	1970–1996	USA	4164	4164 primary THR and 803 revision cases. The primary group included 273 post-traumatic including pathologic fractures.	0.52%*	1.01%*
Mahomed[32]	2003	1995–1996	USA	61 568	United States Medicare population. Elective primary total hip replacements for a reason other than a fracture.	NR	0.97%*

*; includes only primary hip replacement. NR; data not recorded.

Table ii. Study characteristics

Study Author	Year	No. Patients	Patient characteristics	Statistical analysis	TKRs included?	How long is mortality elevated for?	Trends in mortality over time	Trends in co-morbidities	Common causes of mortality	Risk factors (age and gender)	Risk factors (co-morbidities)	Smoking?	BMI?	Revision v Primary	Hip v Knee	Cementless v cemented	Resurfacing v total	Hospital or surgeon volume
Hunt[1]	2013	409 096	Primary THR for OA	Uni and multivariate models with Kaplan-Meier estimates to describe the 90-day mortality of different sex and age groups. We used Cox proportional hazards models to investigate the effects of different patient and treatment factors, as well as time period, on the risk of death within 90 days.	No	✓ Approx 60 days	↓	NR	NR	Males ↑?Age ↑	Spinal anaesth↓ +/- combination↓, posterior approach↓, use of mechanical thromboprophylaxis↓, and thrombo prophylaxis with heparin with or without aspirin↓	NR	Being overweight at the time of surgery (body-mass index 26–30 kg/m^2) was associated with lower 90-day mortality (HR 0·76, 95% CI 0·62–0·92; p=0.006) ↓	×	×	×	×	×
Jamsen[2]	2013	2559	> 75 yrs Primary hip and knee. Mortality data includes both.. No difference between hip and knees	Kaplan-Meier survival analysis. The associations of the available patient-related, clinical, and operative variables with overall patient survival were analyzed by Cox regression analysis.	Yes 756 primary THRs and 1242 primary TKRs	NR	NR	NR	NR	Higher age↑, male sex↑,	American Society of Anesthesiologists risk score of > 2, use of walking aids, preoperative walking restriction (inability to walk or ability to walk indoors only, compared to ability to walk > 1 km), poor clinical condition preoperatively (based on clinical hip and knee scores or clinical severity of osteoarthritis), preoperative anemia, severe renal insufficiency, and use of blood transfusions were associated with higher mortality.	NR	High body mass index had a protective effect in patients after hip replacement.	×	×	×	×	×

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Bozic[3]	2013	53 252	5% sample Medicare database. Primary THR only.	Logistic regression using 29 comorbid conditions, age, sex, race, and SES were used as inputs to develop an electronic risk calculator	No	NR	NR	NR	NR	Highest risk in White women aged 65 to 69 years	White women aged 65 to 69 years with electrolyte disorder, hemiplegia/ paraplegia, hypertension, hypothyroidism, metastatic tumor, preoperative anemia, coagulopathy, cardiopulmonary (congestive heart failure, chronic pulmonary disease) and psychiatric (psychoses, depression) comorbidities,malignancies, and peripheral vascular disease were at highest risk for 90 day mortality.	NR	NR	×	×	×	×	×

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Aynardi[4]	2013	8261	Uncemented THR. Partial hip arthroplasty were excluded.	Univariate and multivariate analysis.	No	NR	NR	NR	26% of deaths were due to myocardial infarction. Cardiovascular causes were 32%, respiratory 20% PE 11% and other 37%.	Gender did not increase mortality	Univariate analysis of risk factors for early mortality found that increased age, ASA score greater than three, Charlson Index greater than three, the use of general anesthesia, and the presence of health insurance were potential demographic predictors of early mortality. Meanwhile, smoking, gender, race, type of surgery, and the use of cement did not increase the risk of mortality. Perioperative variables suggested to increase risk of early mortality were increased length of hospital stay, elevated pre- and postoperative blood glucose levels (fasting blood glucose ≥ 126mg/dl), elevated pre- and postoperative serum creatinine levels (serum creatinine ≥ 1.2mg/dl), elevated postoperative cardiac enzymes, abnormal postoperative cardiac studies, new onset atrial fibrillation postoperatively, the presence of preoperative anemia (hemoglobin ≤ 12.5 in males, ≤14 in females), history of coronary artery disease (CAD), peripheral vascular disease (PVD), and dementia. Estimated blood loss, operating room time, and the use of a beta blocker were not significant risk factors. Interestingly, nor was a past medical history of diabetes mellitus or renal disease predictive of early mortality. Multivariate analysis provided Charlson index greater than three,presence of PVD, elevated postoperative glucose, and abnormal postoperative cardiac studies as independent predictors of early mortality following THA	No diff in mortality	NR	×	×	Cement did not alter chance of mortality	×	×

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Jans[5]	2013	5165	All primary THR or TKR patients. 2702 (52.3%) were THR and 2463 (47.7%) TKR. THR for #NOF were excluded.	Multivariate logistic regression	Yes	NR	NR	NR			WHO defined anaemia was associated with increased mortality at 90 days ($p < 0.01$). In addition, age, hypertension, cardiac disease, pulmonary disease, cerebrovascular disease, and the use of walking aid before surgery were associated with both morbidity outcomes in the univariate analysis. Age, cerebrovascular disease, and the use of preoperative walking aid were also independently associated with both morbidity outcomes on multivariate analysis.	NR	NR	×	×	×	×	×
Vulcano[6]	2012	887	Primary elective hip replacement surgery with multimodal thromboprophylaxis. 887 THR, 645 TKA, 36 UKA.	No modelling	Yes	NR	NR	NR	3 Deaths, all likely cardiovascular (2 definitely)	NR	NR	NR	NR	×	×	×	×	×
Suleiman[7]	2012	584	Only hips. patients between 18 and 90 y of age who underwent TKR or THR. 1731 patients met the inclusion criteria, with 66% and 34% (584) undergoing TKR and THR	Multivariate regression was performed adjusting for age, BMI, gender, ethnicity, type of operation, and preoperative co-morbidities.	Y	NR	NR	NR	NR	NR	NR	NR	On comparison by different BMI categories, there were no differences in the rates of infection, respiratory, cardiac, renal, and systemic complications	×	There was no difference in mortality between the TKR and THR groups (0.68 *versus* 0.26, P = 0.189).	×	×	×

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Singh[8]	2012	12 727	Institutional (Mayo Clinic) Total Joint Registry. Hip fracture patients were excluded from analysis. THR and TKR are separated for analysis.	Logistic regression was used for univariate and multivariable-adjusted analyses of 90-day all-cause mortality	Yes, but analysised separately	NR	We did not observe any statistically significant timetrend in 90-day all-cause mortality in patients who underwent THR (P = .41)	NR	NR	Increasing age↑,	In multivariable-adjusted analyses of patients undergoing THA, older age, higher comorbidity index, and prior cardiac disease were significantly associated with higher 90-day mortality.	NR	NR	×	58 (0.5%) in the elective THR cohort died within the 90 days of their arthroplasty; similarly, 52 (0.4%) of 12 484 patients in the TKR cohort died within 90 days. Identical at 7 and 30 days.	×	×	×
O'Malley[9]	2012	4281	American College of Surgeons National Surgical Quality Improvement Program database. THA in 4281 patients.	multivariate model	No	NR	NR	NR	NR	NR	NR	NR	NR	NR	×	×	×	×
Comba[10]	2012	2453	Consecutive primary THR. joint registry at a single institution. 2453 elective surgeries and 779 surgeries were nonelective procedures due to displaced femoral neck fractures, analysed separately.	4-to-1 nested case– control study. Control cases were strictly matched by sex, age, surgeon, prosthesis fixation mode, and date of surgery. Conditional logistic regression was used to evaluate the-association of risk factors with mortality.	No	NR	NR	NR	7/11 deaths were due to CVD. 4/11 were fatal PEs.		American Society of Anesthesiologists (ASA) score III–IV increased the mortality risk 13 times (OR 13.7; 95 % CI 1.6–114.8). Cardiovascular disease increased the risk for mortality eight times (OR 8.83 (95 % CI 1.78–43.6). Time delay before surgery showed a trend towards significance (p=0.06). Aggressive vs. nonaggressive thromboembolism prophylaxis and the amount of blood transfusions required were not associated with a higher risk of death.	NR	NR	NR	×	×	×	×

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Huddleston[11]	2012	1809	Medicare Patient Safety Monitoring System in Medicare patients. Primary THA for degenerative arthritis.	bivariate analyses were conducted to compare patient characteristics, observed adverse events, and outcomes between the two periods	No		There were 14 deaths from 2002 to 2004 and four deaths from 2005 to 2007	When the patients were divided into two groups based on the year of their procedure (2002–2004 and 2005– 2007), patients who underwent THA were younger (p\0.023) in the later time period (74.1 ± 9.1 years *versus* 73.3 ± 8.8 years). The rate of obesity increased (p\0.041) from 10.5% (106 of 1014) in the period 2002–2004 to 13.6% (108 of 795) in the period 2005–2007	NR	NR	NR	NR	NR	NR	×	×	×	×
Bozic[12]	2012	40 919	> 65 years old. Medicare population	Cox regression, adjusted hazard ratios for all comorbid conditions, and the Wald chi-square statistic was used to rank the degree of association of each condition with postoperative mortality. The Bonferroni-Holm method was used to adjust for the multiple comparisons resulting from the number of comorbid conditions analyzed.	No	NR	NR	NR	NR	Age and gender were controlled for.	Comorbid conditions associated with an increased adjusted risk of ninety-day postoperative mortality (in decreasing order of significance, p < 0.05 for all comparisons) were congestive heart failure (HR = 2.11), metastatic cancer (HR = 3.14), psychosis (HR = 1.85), renal disease (HR = 1.98), dementia (HR = 2.04), hemiplegia or paraplegia (HR = 2.62), cerebrovascular disease (HR = 1.40), and chronic pulmonary disease (HR = 1.32).	NR	There was no association with obesity, but a tend towards lower mortality in the obese.	×	×	×	×	×

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Pedersen[13]	2011	44 558	All primary THR for OA, Danish Hip Arthroplasty Registry.	Patients matched at the time of surgery with three people from the general population. Therefore, all presented estimates were derived from the unstratified Cox's proportional hazards model.	No	There was a one-month period of increased mortality immediately after surgery among THR patients, but overall short-term mortality (0 to 90 days) was significantly lower (mortality rate ratio 0.8; 95% confidence interval 0.7 to 0.9). Long-term mortality was lower among THR patients than in controls (mortality rate ratio 0.7; 95% confidence interval 0.7 to 0.7)	No	No	THR patients with osteoarthritis had increased 90-day mortality from myocardial infarction and venous thromboembolism/pulmonary embolism than matched controls,	Men have higher mortality	NR	NR	×	×	×	×	×	×
Singh[14]	2011	1195	Cohort of Olmsted County residents. After excluding those with fracture as the underlying diagnosis, the final sample consisted of 1195 THA and 1604 TKA patients.	Separate logistic regression models were used for univariate and multivariable-adjusted analyses of 90-day cardiac events and 90-day thromboembolic events. A backward selection method was used to identify the significant variable in the multivariable models.	Yes but analysed separately.	NR	NR	signifi cant increases was noted in BMI (p<0.001),and the Deyo-Charlson index in the THR cohort during the study period (p = 0.02). For example BMI increased from 26.5 kg/m 2 in 1994–6 to 28.8 kg/m 2 in 2006–8 and Deyo–Charlson index increased from 2.0 in 1994–6 to 2.6 in 2006–8 in the THR cohort.	NR	NR	NR	NR	×	×	×	×	×	×

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Singh[15]	2011	10 187	Pennsylvania Health Care Cost Containment Council database to identify all elective primary THR and TKR surgeries performed in Pennsylvania. A total of 10 187 patients underwent hip replacement surgery, and 19 418 patients underwent knee replacement surgery.	logistic regression models and Kruskal-Wallis equality-of-populations rank test	Yes but analysed separately.	NR	NR	NR	Within 30 days, incident venous thromboembolism was observed in 0.42% of patients (43 of 10,187), myocardial infarction was observed in 0.40% (41 of 10,187), and infection was observed in 0.25% (25 of 10,187).	NR	NR	NR	×	×	×	×	×	Thirty-day mortality did not differ by hospital volume in the entire cohort or in those age 65 years. However, there was a statistically significant association between low hospital volume and higher 1-year mortality. Compared with patients whose surgeries were performed at very-high-volume hospitals (>200 procedures/year), patients who underwent elective primary THA procedures at hospitals with a very low volume (<25 procedures/year), a low volume (26–100 procedures/year), or a high volume (101–200 procedures/year) had higher multivariable-adjusted odds ratios (ORs) for venous thromboembolism (OR 2.0, 95% confidence interval [95% CI] 0.2–16.0), OR 3.4 [95% CI 1.4–8.0], and OR 1.1 [95% CI 0.3–3.7], respectively) and 1-year mortality (OR 2.1 [95% CI 1.2–3.6], OR 2.0 [95% CI 1.4–2.9], and OR 1.0 [95% CI 0.7–1.5], respectively).

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Malviya[16]	2011	4500	Includes 2,502 TKRs analysed together.	two-tailed unpaired t-test	Yes analysed together	NR	NR	NR	NR	NR	NR	NR	×	×	×	×	×	×
Cram[17]	2011	209 945	1 453 493 elective primary THR procedures in Medicare patients. Acute fractures were excluded. However from 2007-2008 209 945 THRs were performed with 0.4% mortality at 30 days and 0.8% at 90 days	We used analysis of variance for comparisons of continuous variables and the Mantel-Haenszel ? test for categorical variables. To account for the changing demographics of the primary and revision total hip arthroplasty populations over time, we calculated risk-standardized mortality ratios that adjusted for age, sex, and race.	No	NR	Between 1991 and 2008 unadjusted inhospital and 30-day mortality decreased from 0.5% to 0.2%	Between 1991 and 2008, the mean age for patients undergoing primary total hip arthroplasty increased from 74.1 to 75.1 years. The mean number of comorbid illnesses per patient increased from 1.0 to 2.0 for primary total hip arthroplasty.	NR	NR	NR	NR	×	×	×	×	×	×

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Paterson[18]	2010	20 290	Elective primary THR or total TKR. Data obtained from the Canadian Institute for Health Information. Joint replacements for cancer, fractures or trauma were considered unplanned and were excluded.	In the multivariable analyses, we used ordinal procedure volume variables to adjust the hospital volume analyses for surgeon volume and vice versa. We used the Kaplan–Meier approach to estimate failure-free survival and Cox proportional hazards models to adjust for patient and provider characteristics.	Yes, analysed seperately. 20 290 had a THR and 27 217 had a TKR	NR	NR	NR	NR	The death rates increased with age and Charlson comorbidity index >1, and the rates were higher for men than for women. The adjusted odds of death within 90 daysof operation confirm that age, sex andcomorbidity were strong predictors of 90-day mortality.	Charlson comorbidity index >1,	NR	×	×	In all, 122 hip patients (6.0 per 1000) and 144 knee patients (5.3 per 1000) died within 90 days of operation.	×	×	There were no associations between provider volume and mortality. Whereas there was some variation in crude rates for inhospital complications by provider volume category, after adjustment for potential confounders, complication rates were not related to hospital procedure volume (Table 5). In contrast, surgeons with the lowest quartile THR volumes had about 30% higher complication rates than surgeons in the higher-volume quartiles. However, no such relation was observed for TKR. There were slight trends toward decreasing mortality as hospital and surgeon volumes increased, but the reductions in the crude rates were small. neither hospital procedure volume nor surgeon procedure volume were significant predictors of death within 90 days of operation.

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Lie[19]	2010	188 110	50-80yrs old patients only. (THR and TKR included but no difference in mortality between the two). Data from the National Joint Replacement Registry of the Australian Orthopaedic Association and the Norwegian Arthroplasty Register.	Survival curves were calculated with use of the Kaplan-Meier method, with log-transformed 95% confidence intervals. The early postoperative mortality rate was calculated by means of kernel smoothing (with a normally distributed kernel and seven days' bandwidth) of the observed daily mortality rates. NB The baseline mortality was calculated with use of the average mortality between Day 100 and Day 200.	Yes. 81,856 patients with a total knee replacement and 106,254 patients with a total hip replacement.	We found that early postoperative mortality was increased for the first twenty-six postoperative days (95% confidence interval, twenty-two to forty-one days). The excess mortality, compared with a baseline mortality (calculated as the average mortality from Day 100 to Day 200), for these twenty-six days was estimated to be 0.12% (95% confidence interval, 0.11% to 0.14%).	NR	NR	NR	The most important risk factors for excessive early postoperative mortality were male sex and high age (more than seventy years of age).	NR	NR	×	×	×	×	×	×
Sierra[20]	2009	9082	All cemented primary THRs from the local (Exeter) registry. #NOFs were excluded.	None	No	×	×	×	21 deaths identified; CVD in 10, PE in 6, 1 fat embolism (cement related), 1 CVA, unknown in 3.	NR	NR	×	×	×	×	×	×	×
Cusick[21]	2009	4253	2203 primary THR and 2050 TKR. 4060 received aspirin only as chemical prophylaxis.	None	Yes	×	×	×	13 died within 90 days; 7 from CVD, 3 PEs, 1 cancer, 1 bleeding duodenal ulcer, 1 bowel infarction.	NR	NR	×	×	×	×	×	×	×

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Aynardi[22]	2009	6272	Consecutive series of uncemented total hip arthroplasty (THA) (6272 primary, 1206 revisions analysed seperately) performed under regional anesthesia. Institutional database.	None	No	×	×	×	Cardiovascular conditions were responsible for most deaths after THR. Cardiopulmonary arrest, acute coronary syndrome, stroke, pulmonary embolism, and arrhythmias were the listed causes of deaths (Table 1). Other causes of death included respiratory complications, malignancy, and sepsis.	Subjects less than 65 years old receiving primary elective THR had the lowest mortality of 0.03% (one of 3492), while those over 85 years old and receiving revision THR had the highest mortality of 6.25% (four of 64).	NR	×	×	When comparing primary and revision arthroplasty, primary hip repalcement was associated with the lowest 30-day mortality rate (0.13% [eight of 6272]) and 90-day mortality rate (0.41% [26 of 6272]). The perioperativemortality rate after revision arthroplasty was 0.83% (10 of 1206) and the 90-day mortality rate was 1.24% (15 of 1206). The death rate after primary and revision THR was proportionally higher by age group	×	×	×	×
Parry[23]	2008	1 549	All primary THR, with aspirin as chemical thromboprophylaxis and TED stockings.	None	No	NR	NR	NR	NR	NR	NR	×	×	×	×	×	×	×
Ramiah[24]	2007	5 831	All elective primary total hip replacements (mortality at 28 days).	Kaplan-Meier survival rates for life Expectancy compared with United Kingdom national statistics	No	NR	NR	NR	NR	standardised mortality rates were considerably higher for patients under 45 years, 20% higher for those between 45 and 64 years, and steadily reduced in patients aged 65 and over	NR	×	×	×	×	×	×	×

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Study Author	Year	No. Patients	Patient characteristics	Statistical analysis	TKRs included?	How long is mortality elevated for?	Trends in mortality over time	Trends in co-morbidities	Common causes of mortality	Risk factors (age and gender)	Risk factors (co-morbidities)	Smoking?	BMI?	Revision v Primary	Hip v Knee	Cementless v cemented	Resurfacing v total	Hospital or surgeon volume
Gaston[25]	2007	1744	All primary elective THR.	The association between mortality within three months and potential risk factors was assessed by chi-squared tests with Yates' correction or two-sample t-tests, and multiple logistic Regression. The association of risk factors with longer-term mortality amongst patients who survived more than three months was assessed by Cox proportional hazards regression	No	NR	NR	NR	NR	NR	Although the patients with a cardiac history were nearly twice as likely to die as those without (1.5% mortality rate in those with a cardiac history compared with 0.8% in those without), this difference was not statistically significant. The con dence intervals for the odds ratio of cardiac history as a risk factor alone were 0.58 – 5.65. This conclusion was not greatly altered by adjusting for the other factors in a multi-variate analysis, which gave a con dence interval for cardiachistory of 0.40 – 4.31. A history of hypertension similarly did not have a statistically significant effect on the risk of death within three months following THA in this study, with 1% mortality in those with hypertension, compared with 0.8% in those without, con dence intervals for odds ratio of 0.30 – 2.54. Sex or BMI also did not affect the early death rate following THA. Old age was the only statistically signi cant risk factor for early mortality amongst those studied (p<0.001), with increasing age resulting in higher mortality, particularly for the over 75s. In fact, we showed that the over 75 were nine times more likely to die following THR than the under 65s, with con dence intervals for the odds ratio for risk of death of 1.56 – 498 for the over 75s. We also examined the risk of three month mortality in relation to the preoperative ASA score. The ASA was only recorded in the database from January 2000 and was known for 1203 of the patients. Although ASA is not a 'risk factor' per se, it is interesting to see that an increasing ASA score has a highly statistically signi cant effect on death, with a P value of 0.009. When adjusted for age in a multiple	×	×	×	×	×	×	×

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Samama[26]	2007	683	Prospective observational study of a cohort of consecutive hip or knee replacement patients. 1080 patients were available; 63.2% were undergoing THR and 36.8% TKR.	Univariate analysis	Yes	NR	NR	NR	NR	NR	NR	NR	×	×	×	×	×	×
Tarity[27]	2006	6,258	All primary elective uncemented THR. Of those 6258 patients, 5725 (91%) underwent unilateral THA, whereas 533 (9%) patients received simultaneous bilateral THA.	Individual risk factors were analysed with either a Chi^2 test or Fisher exact test.	No	NR	NR	NR	Congestive heart failure 2, acute renal failure 1, Pulmonary embolus 1, Hypotensive event 1, Cerebrovascular accident 1, Mental status changes 1, Urinary tract infection 1, bowel obstruction, requiring surgical decompression	NR	NR	NR	×	×	×	×	×	×
Blom[28]	2006	1,727	1727 consecutive patients underwent primary THR.	None	No	NR	NR	NR	17 patients died within 90 days. 7 from ischemic heart disease, 4 died following cerebrovascular events, and 2 from pulmonary embolism. 4 patients died from non-vascular causes. Of the vascular deaths, ischemic heart disease outnumbered cerebrovascular events which, in turn, outnumbered pulmonary embolism (7 *vs*. 4 *vs*. 2)	The 90-day mortality was 0.2% in patients under 70 years of age, 1.3% in patients between 70 and 80, and 2.5% in those over 80.	NR	NR	×	×	×	×	×	×

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Ibrahim[29]	2005	6703	Data from the Veterans Administration National Surgical Quality Improvement Program database. 12 108 patients underwent primary TKR and 6703 patients who underwent primary THR.	Multinomial logistic regression	Yes, analysed separately	NR	NR	NR	NR	NR	NR	NR	×	×	The overall 30-daymortality was 0.6% following knee arthroplasty and0.7% following hip arthroplasty	×	×	×
Nunley[30]	2003	768	All, single surgeon, medium volume unit, includes revisions, fractures and cancer.	To compare the observed mortality with expected mortality, standardized mortality ratios (SMRs) with the associated 95% confidence intervals were used.	Yes 610 TKRs and 1108 THRs, of which 768 were primary procedures, and were analysed seperately.	Comparison of the mortality rate of these patients and the mortality rate from the general population at 90 days showed a SMR of 0.639 (7 deaths in the total hip and knee arthroplasty group compared with 10.98 expected deaths in the general population), but this was not statistically significant (*P* _ .05)	NR	NR	The 5 deaths in the first 90 days were because of coagulopathy secondary to chronic liver disease in 1 patient, myocardial infarction (autopsy proven) in 1 patient, metastatic lymphoma in 1 patient, and cerebrovascular accidents in 2 patients.	Mortality was standardised for age and gender	NR	NR	×	×	×	×	×	×

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Miller[31]	2003	4,164	4164 primary THR and 803 revision cases. The primary group included 273 post-traumatic including pathologic fractures.	Fisher's exact test was used to compare primary and revision cases with regard to age, year of death and comorbid conditions.	NR	NR	NR	NR	Cause of death within 90 days in primary cases: 12 myocardial infarction (0.28%), 12 pulmonary embolism (0.28%), 5 pneumonia (0.12%), 4 congestive heart failure (0.09%), 2 sepsis secondary to other infection (0.05%), 1 respiratory arrest (0.02%), 1 arrhythmia (0.02%), 1 renal failure (0.02 per cent), 1 lung carcinoma (0.02 per cent), 1 suicide (0.02 per cent), and 2 multifactorial (0.05 per cent). Myocardial infarction was the most common cause of death overall (30.6 per cent), with fatal myocardial infarctions occurring in 12 within the primary group (0.28 per cent) and 3 in the revision group (0.37 per cent). Cardiac related complications (myocardial infarction, congestive heart failure and arrhythmia) accounted for 40 per cent (17 of 42) of primary deaths.	In both the primary and revision situation and independent of co-morbidities, age greater than 70 years was significantly associated with increased risk for postoperative mortality ($p < 0.0001$), with 0.44% mortality in patients aged 70 years or younger (0.51 per cent primary and 0.00 per cent revision), and 1.45 per cent mortality in patients greater than 70 years of age (1.38 per cent primary and 1.86 per cent revision).	NR	NR	×	There was no difference in death rate in primary *vs.* revision cases ($p=0.825$).	×	×	×	×

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Mahomed[32]	2003	61 568	United States Medicare population. Elective primary total hip replacements for a reason other than a fracture	United States Medicare population. Elective primary total hip replacements for a reason other than a fracture.	No	The overall standard 90 day mortality ratio in the primary total hip replacement cohort was 0.9 (95% confidence interval, 0.8 to 1.0), indicating essentially equivalent (or slightly better) survival than was found in a Medicare cohort of comparable age, gender, race, and Medicaid buy-in status.	NR	NR	NR	The age-related risks were particularly pronounced for mortality: the odds of death were 5.8 (95% confidence interval, 4.2 to 8.0) for those between eighty-five and eighty-nine years of age compared with 1.0 for those between sixty-five and sixty-nine years of age. Men had a substantially greater risk of death and of hip dislocation than women	Patients with a Charlson index of one or more had a greater risk of adverse outcomes, particularly mortality (odds ratio, 1.7; 95% confidence interval, 1.5 to 2.1). Low-income patients (defined as those receiving Medicaid supplement) were also at high risk for death (odds ratio, 1.7; 95% confidence interval, 1.25 to 2.25)	NR	×	The ninety-day mortality rate after THR was 2.6%, after the primary THRs, the ninety-day risks were 1.0% for mortality	×	×	×	×

✓Data exists
×Data does not exist
↑This lowers mortality
↓This increases mortality
NR: Not recorded

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