Knee

EOR | VOLUME 6 | NOVEMBER 2021
DOI: 10.1302/2058-5241.6.200150
www.efortopenreviews.org

EFORT open reviews

Higher rates of surgical and medical complications and mortality following TKA in patients aged ≥ 80 years: a systematic review of comparative studies

Olivier Courage[1]
Louise Strom[2]
Floris van Rooij[2]
Matthieu Lalevée[1,3]
Donatien Heuzé[1,3]
Pierre Emanuel Papin[1,3]
Michael Butnaru[1,3]
Jacobus Hendrik Müller[2]

- The purpose of this systematic review was to synthesize studies published since the last systematic review in 2015 that compare outcomes of primary total knee arthroplasty (TKA) in older patients (≥ 80 years) and in younger patients (< 80 years), in terms of complication rates and mortality.
- An electronic literature search was conducted using PubMed, Embase®, and Cochrane Register. Studies were included if they compared outcomes of primary TKA for osteoarthritis in patients aged 80 years and over to patients aged under 80 years, in terms of complication rates, mortality, or patient-reported outcomes (PROs).
- Thirteen studies were eligible. Surgical complications in older patients ranged from 0.6–21.1%, while in younger patients they ranged from 0.3–14.6%. Wound complications in older patients ranged from 0.5–20%, while in younger patients they ranged from 0.8–22.0%. Medical complications (cardiac, respiratory, thromboembolic) in older patients ranged from 0.4–17.3%, while in younger patients they ranged from 0.2–11.5%.
- Mortality within 90 days in older patients ranged between 0–2%, while in younger patients it ranged between 0.0–0.03%.
- Compared to younger patients, older patients have higher rates of surgical and medical complications, as well as higher mortality following TKA. The literature also reports greater length of stay for older patients, but inconsistent findings regarding PROs. The present findings provide surgeons and older patients with clearer updated evidence, to make informed decisions regarding TKA, considering the risks and benefits within this age group. Patients aged over 80 years should therefore not be excluded from consideration for primary TKA based on age alone.

Keywords: elderly; geriatric; length of stay; mortality; nonagenarian; octogenarian; outcomes; TKA; total knee arthroplasty

Cite this article: *EFORT Open Rev* 2021;6:1052-1062.
DOI: 10.1302/2058-5241.6.200150

Introduction

The elderly population continues to grow globally,[1] increasing the overall prevalence of osteoarthritis (OA).[2] It is estimated that 17.7% of this population suffer from end-stage OA of the knee,[3] resulting in a rising demand for total knee arthroplasty (TKA), which is forecast to increase exponentially for this group of patients up to 2050.[4]

The success of TKA for patients aged over 80 years is a matter of controversy, as prior studies have reported inconsistent associations between advanced age and outcomes. Whereas some studies found patient-reported outcomes (PROs) following TKA in older patients to be comparable to those in their younger counterparts,[5–7] others reported them to be significantly inferior in elderly patients.[8,9] Furthermore, some studies reported higher complication rates, length of stay (LoS) in hospital, and mortality following TKA in older patients,[6,10–12] whilst other studies argued that these outcomes depend more on morbidities and health status, rather than age per se.[13–15]

Moreover, McCalden et al[8] reported lower revision rates for TKA at five and 10 years for patients aged over 80 years, compared to younger patients.

In 2018, Murphy et al[16] published a systematic review on the outcomes of total hip arthroplasty and TKA, and found higher risks of complications and mortality in older patients. In 2016, Kuperman et al[17] published a meta-analysis of comparative studies performed over the two preceding decades and concluded that primary TKA had comparable risks and similar improvements in outcomes in both older and younger populations. In both the systematic review and the meta-analysis, much of the available data was deemed to be of poor quality, and some of the included studies are outdated in terms of implant design, surgical techniques and postoperative management. Both surgeons and patients would benefit from clearer, updated evidence to make informed decisions regarding surgical intervention in end-stage OA of the knee. The purpose of the present systematic review was to synthesize studies published since 2015 that compare outcomes of primary TKA in older patients (≥ 80 years) and in younger patients (< 80 years) in terms of complication rates and mortality. The hypothesis was that older patients receiving TKA would have similar outcomes to younger patients.

Material and methods

The protocol for this systematic review was submitted to PROSPERO prior to commencement (registration number: CRD42020201381) and conforms to the principles outlined in the handbook of the Cochrane Collaboration,[18] along with the guidelines established by the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA).[19]

Search strategy

The authors conducted a structured electronic literature search using the PubMed, Embase®, and Cochrane Central Register of Controlled Trials databases, applying the keywords and medical subject heading (MeSH) terms presented in Appendix 1. The search was limited to articles published between 1 January 2015 and 3 August 2020, to ensure a contemporary systematic review in consideration of modernization of surgical techniques, implant design, and postoperative management strategy. After removal of duplicate records, two researchers (LS & FVR) each screened the titles and abstracts to determine the suitability for the review against predefined eligibility criteria:

Inclusion criteria

- Studies comparing patients aged 80 years and over to patients aged under 80 years, who received primary TKA for OA, and reporting one or more of the following outcomes: length of hospital stay, mortality, complication rates, or revision rates.

Exclusion criteria

- Narrative or systematic reviews, non-comparative case series, case reports, expert opinions, editorials or letters to editors.
- Studies published in languages other than English.
- Studies that reported aggregate outcomes of hip and knee arthroplasty, for which authors were contacted to obtain data specific to TKA, and for which no response was received after two reminders.

Study selection

Full-text review of studies meeting the criteria in the initial screening was carried out by two researchers (LS & FVR) and any disagreement about the final eligibility of studies was first discussed between the researchers, and, where required, a third researcher (JHM) resolved any disagreement. The reference lists of studies for full-text review were searched, and an expert in TKA (OC) was consulted to further establish relevant studies not captured by the database searches.

Data extraction and quality assessment

Data extraction was performed by two researchers (LS & FVR) independently and their results compared to ensure accuracy. Where there was disagreement in the documented value, the true value was ascertained by simultaneous review of the data in question by both researchers. The following data were extracted from the included studies: author(s), journal, year of publication, level of evidence, country in which the study was performed, conflicts of interest and funding declaration. Patient characteristics of the over 80 and under 80 populations were retrieved, including number of patients in each group, sex, age, body mass index (BMI), and American Society of Anesthesiologist (ASA) grade. Type and incidence of complications, mortality, LoS, and pre- and postoperative PROs were extracted where available. Methodological quality of the eligible studies was assessed by two researchers (LS & FVR) according to the Downs and Black Quality Checklist for Health Care Intervention Studies,[20] to appraise the reporting quality (10 items), external validity (three items), bias (seven items), confounding and selection bias (six items), and power (one item) of each study. Using modified scoring for power (1 – power calculated/recorded in study, 0 – power not calculated/reported) each study was given an overall score out of 28, and the quality of a study was rated as excellent (≥ 26); good (20–25); fair (15–19); or poor (≤ 14).[21] Where there was disagreement between the researchers, consensus was achieved by discussion and review.

Table 1. Study characteristics studies comparing patients aged > 80 and < 80 years following primary TKA

Author and year	Groups	Patients	Female sex	Age mean [median]	BMI	ASA grade I	ASA grade II	ASA grade III	ASA grade IV	Location	COI declared	Funding declared
Andreozzi et al 2020	>80 years	103	68%	83		16%	45%	39%		Italy	Yes	Yes
	<80 years	103	68%	64.6		43%	52%	5%				
Austin et al 2018[45]	>80 years	175	56%	>80						United States	Yes	Yes
	<80 years	2133	58%	<80								
Bovonratwet et al 2019[46]	>80 years	1005	53%	82.8	28.5	ASA 1 + 2: 44%		51%	2%	United States	Yes	Yes
	<80 years	17191	51%	64	32.2	ASA 1 + 2: 59%		40%	1%			
Cher et al 2018[44]	>80 years	209		82.1	26.4					Singapore	Yes	Yes
	<80 years	209		66.1	26.6							
Goh et al 2020[50]	>80 years	594	80%	81.5	26.4					Singapore	Yes	Yes
	<80 years	594	80%	69.7	26.3							
Klasan et al 2019[49]	>80 years	644	64%	83.3		3%	49%	47%	0%	Australia	Yes	
	<80 years	644	64%	69.9		3%	49%	47%	0%			
Kodaira et al 2019[48]	>80 years	679	77%	82	25.1					Japan	Yes	Yes
	<80 years	673	81%	71	27.0							
Maempel et al 2015[40]	>80 years	358		[83]						Scotland	Yes	
	75–80 years	694		[77]								
	<75 years	2092		[66]								
Murphy et al 2018[47]	>80 years	292	62%	83	30.4	1%	45%	52%	1%	Australia	Yes	Yes
	<80 years	2062	67%	67.8	33.7	3%	54%	42%	1%			
Sezgin et al 2019[7]	>80 years	22		92						Sweden		
	<80 years	1035		65-74								
Skinner et al 2016[41]	>80 years	31	61%	91	27.2					England		
	<80 years	36	36%	74.56	26.1							
Townsend et al 2018[42]	>79 years	24	54%	>79	29.0					United States	Yes	
	70–79 years	94	62%	70–79	31.6							
	60–69 years	138	69%	60–69	34.6							
	50–59 years	68	72%	50–59	35.7							
	<50 years	32	72%	<50	35.9							
Yun et al 2018[43]	>80 years	38	84%	82.8	25.6	0%	61%	34%	5%	Republic of Korea	Yes	
	<80 years	41	92%	67.9	25.8	0%	61%	39%	0%			

Note. TKA, total knee arthroplasty; ASA, American Society of Anesthesiologists; BMI, body mass index; COI, conflict of interest.

Statistical analysis

Heterogeneity was evaluated by visual inspection of the forest plots and quantified using the I^2 statistic to provide a measure of the degree of inconsistency across the studies.[22] Where possible, summary pooled estimates of proportions with 95% confidence intervals were calculated via logit transformation using inverse-variance weighting within a random effects model framework. Where the domains of studies were not sufficiently comparable to pool, results were displayed in a forest plot and the summary estimate withheld.[23] Statistical analyses were performed using R version 3.5.0 (R Foundation for Statistical Computing, Vienna, Austria) using the meta package.

Results

The systematic search returned 1421 records, of which 27 were duplicates, leaving 1394 for screening. A total of 1366 studies were excluded by examining their titles and/or abstracts, and a further 18 studies[9,12,24–39] were excluded after full-text review. A search of the reference lists of the 10 eligible studies, and a discussion with an expert on TKA, identified three additional studies. This left 13 studies[7,15,40–50] eligible for this systematic review, all of which were cohort or case-control studies (Table 1, Fig. 1). Due to substantial heterogeneity and insufficient information to further investigate this heterogeneity, pooling of results was not performed and only non-statistical syntheses was provided.

Surgical complications

Seven studies reported rates of surgical, and/or wound complications (Table 2).[15,40,43,45,47–49] The rate of surgical complications in older patients (≥ 80 years) ranged from 0.6–21.1%, while in younger patients (< 80 years) it ranged from 0.3–14.6%, with no heterogeneity ($I^2 = 0\%$) (Fig. 2). Wound complications in older patients ranged

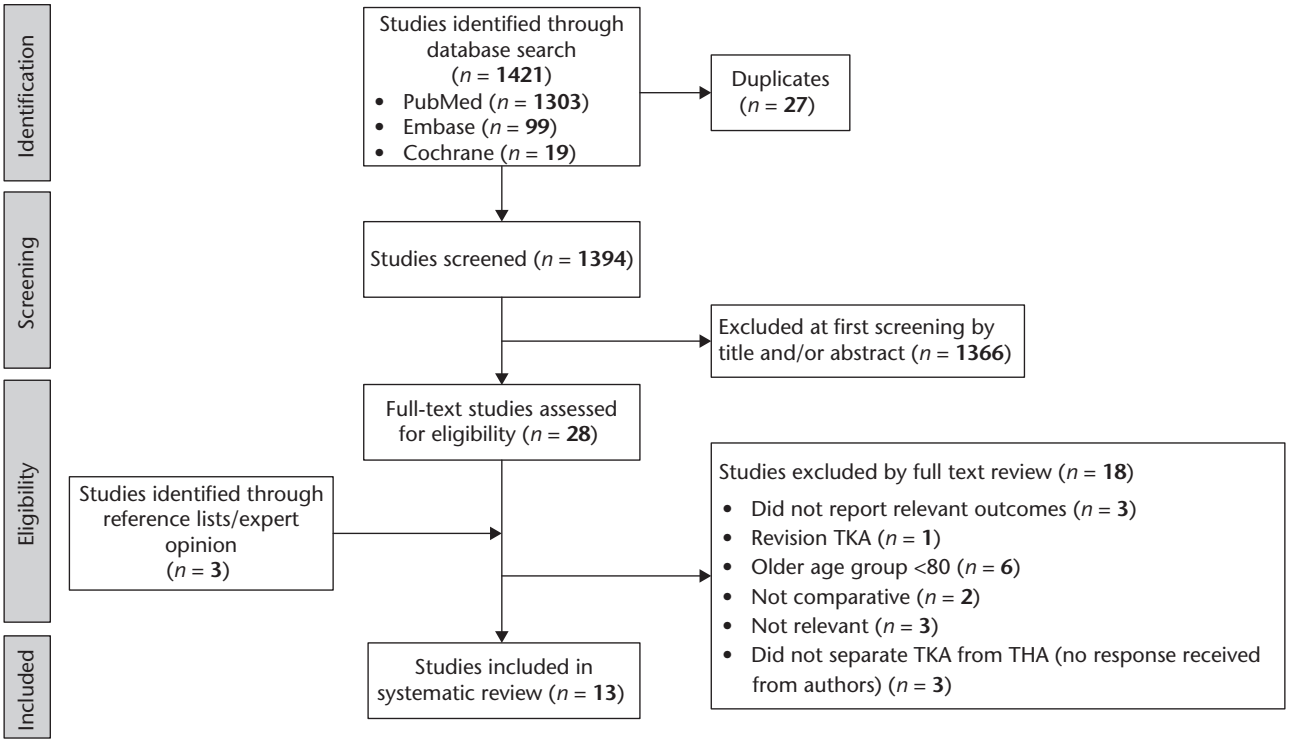

Fig. 1 Flowchart.

Note. TKA, total knee arthroplasty; THA, total hip arthroplasty.

Table 2. Complications in patients aged > 80 and < 80 years following primary TKA

Author	Groups	Surgical complications	Wound complications	Cardiac	Medical complications		Confusion/delirium
					Respiratory	Thromboembolic	
Andreozzi et al 2020[15]	>80 years	10.00%		4.00%	6.00%		12.00%
	<80 years	8.00%		2.00%	3.00%		5.00%
Austin et al 2018[45]	>80 years						
	<80 years						
Bovontarwet et al 2019[46]	>80 years		0.50%	1.44%	0.40%	1.29%	
	<80 years		0.78%	0.96%	0.20%	0.56%	
Klasan et al 2019[49]	>80 years	2.44%				2.00%	
	<80 years	2.27%				2.00%	
Kodaira et al 2019[48]	>80 years	0.60%	2.20%				11.70%
	<80 years	0.30%	2.20%				1.60%
Maempel et al 2015[40]	>80 years	1.70%		3.10%	1.60%	0.90%	3.10%
	75–80 years	2.00%		1.60%	2.30%	0.60%	2.20%
	<75 years	1.10%		1.40%	0.90%	1.00%	0.60%
Murphy et al 2018[47]	>80 years		20.00%	17.30%	3.30%	13.10%	11.10%
	<80 years		22.00%	11.50%	1.90%	9.40%	2.60%
Yun et al 2018[43]	>80 years	21.10%					10.50%
	<80 years	14.60%					4.90%

Note. TKA, total knee arthroplasty.

from 0.5–20%, while in younger patients they ranged from 0.8–22.0%, with no heterogeneity (I^2 = 1%).

Medical complications

Seven studies reported rates of medical (cardiac, respiratory, or thromboembolic) complications (Table 2).[15,40,43,45,47–49] Medical complications in older patients ranged from 0.4–17.3%, while in younger patients they ranged from 0.2–11.5%, with moderate heterogeneity (I^2 = 20 to 70%) (Fig. 3). Five studies reported on confusion or delirium, which in older patients ranged from 3.1–12.0%, while in younger patients ranged from 0.6–5.0%, with considerable heterogeneity (I^2 = 89%).[15,40,43,47,49] The overall risk of medical complications is 2% lower in younger patients.

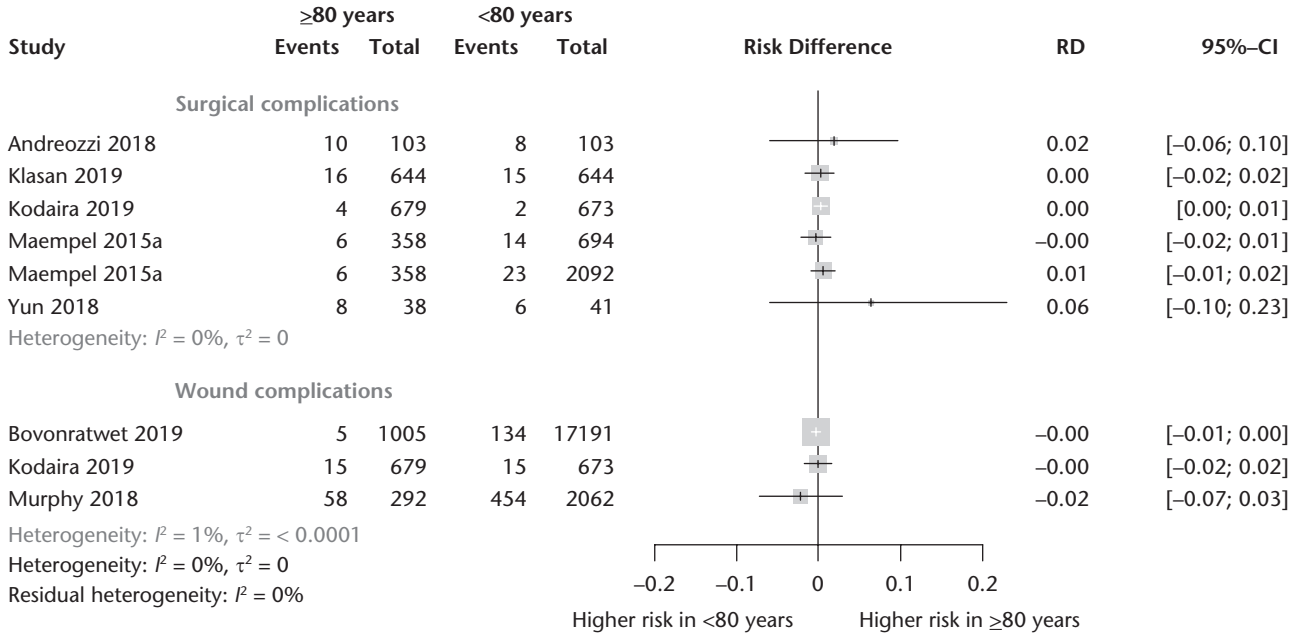

Fig. 2 Forest plot of the risk difference (RD) of surgical complications in patients aged > 80 years and < 80 years (a RD of 0.02 corresponds to a 2% higher risk for patients aged > 80).

Mortality

Six studies reported on mortality following primary TKA with rates varying across follow-ups (Table 3).[40,41,43,46,47,49] Mortality within 90 days in older patients ranged between 0–2%, while in younger patients it ranged between 0–0.03%.[15,43,46] Mortality within two years in older patients ranged between 3.2–12.9%, while in younger patients it ranged between 0–1.5%.[40,41] Mortality within 10 years in older patients ranged between 28–32%, while in younger patients it ranged between 7–12%.[47,49]

Length of stay in hospital

Eight studies reported LoS following primary TKA, all of which found a greater LoS for older patients (Table 4).[7,15,41–43,45,47,48] The mean LoS for older patients ranged from 2–20.9 days, while for younger patients it ranged from 1.5–14.4 days.

Patient-reported outcomes

Twelve studies assessed one or more PROs following primary TKA (Table 5). Six studies reported on Oxford Knee Score (OKS), four of which found 'no difference' between age groups,[15,41,42,44] while two found worse scores for older patients,[49,50] none of which exceeded the minimal clinically important difference (MCID) of 5.0 points.[51] Five studies reported on Knee Society Score (KSS), four of which reported 'no difference' between age groups,[15,43,44,50] while one reported better scores for older patients,[40] which did not exceed the MCID of 7.2 points.[52] Four studies reported on the function subcomponent of the KSS, two of which found 'no difference' between age groups,[15,44] while two found worse scores for older patients.[40,50] Two studies reported on Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC) scores, one of which found 'no difference' between age groups,[42] while the other found better scores for older patients,[43] which did not exceed the MCID of 10.8 points.[53]

Quality assessment

The overall level of quality was defined as good in two studies (15%), fair in 10 (77%), and poor in one (8%) (Table 6). Reporting quality was excellent (≥ 9) in seven studies (54%), and good (7–8) in six (46%). External validity was poor in seven studies (54%) suggesting that their findings may not broadly apply to the general population of patients undergoing TKA, and internal validity was good in all studies (100%), indicating these studies were methodologically appropriate. Power analyses were only performed in five studies (38%).

Discussion

The most important findings of this systematic review are that older patients (≥ 80 years) receiving TKA have higher rates of surgical and medical complications, as well as higher mortality, compared to younger patients (< 80 years). These findings therefore refute the hypothesis

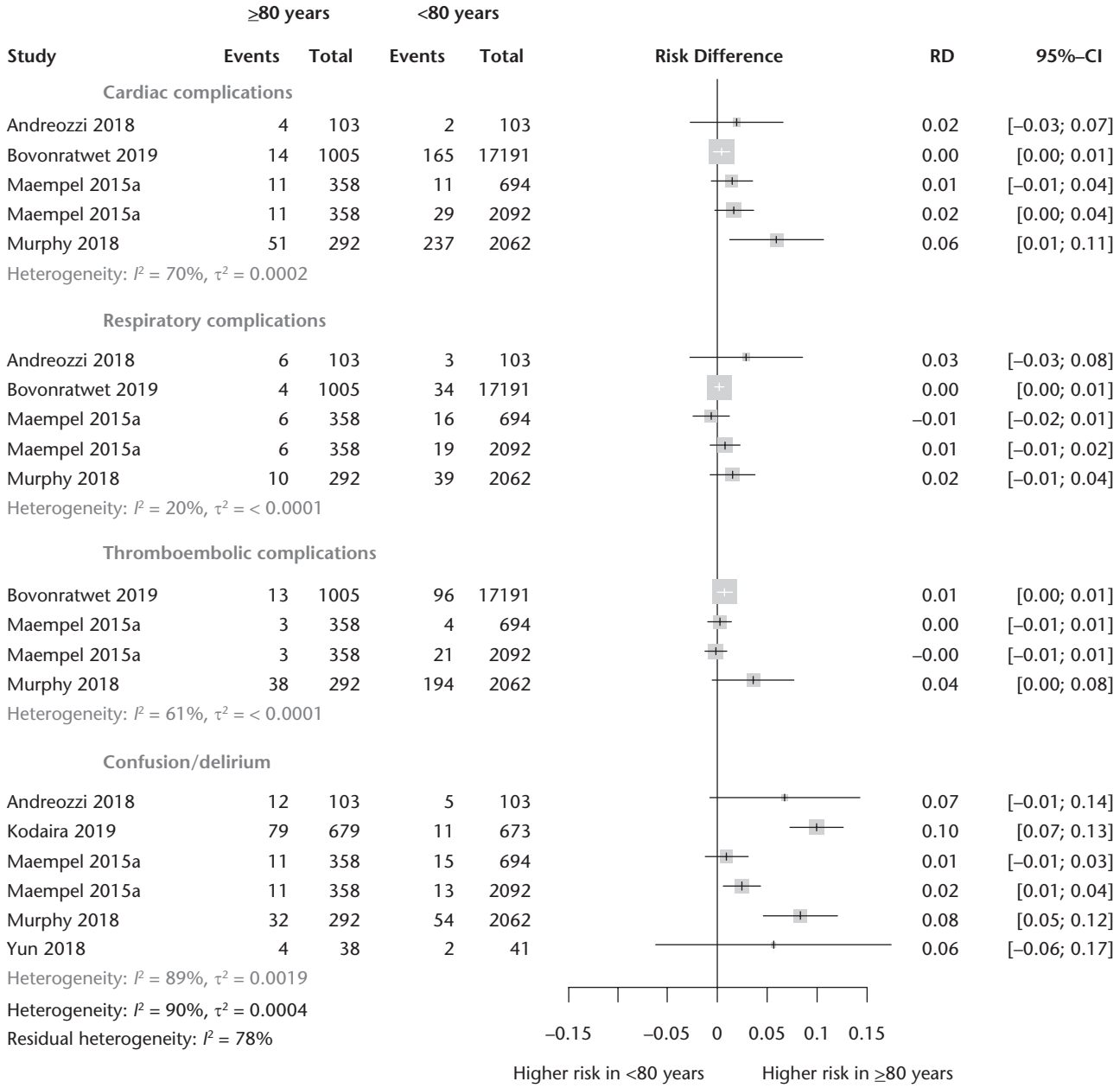

Fig. 3 Forest plot of the risk difference (RD) of medical complications in patients aged > 80 years and < 80 years (a RD of 0.02 corresponds to a 2% higher risk for patients aged > 80).

that older patients receiving TKA have similar outcomes to younger patients. The literature also reports greater LoS for older patients, but inconsistent findings regarding PROs. The majority of studies reported no difference in PROs between the two age groups, while some studies reported worse PROs in older patients, and fewer studies reported better PROs for older patients. It is worth noting that contrasting trends were reported for different PROs within three studies.[43,44,50]

In the present study, it was difficult to compare the rate of complications between older and younger patients due to differing definitions and groupings. This prohibited quantitative analysis of differences between these two groups, which is a barrier also experienced by Kuperman et al.[17] Additionally, drawing conclusions based on small differences in absolute numbers was deemed to have limited value. Furthermore, selection bias may exist, as patients with fewer comorbidities are more likely to be

Table 3. Mortality in patients aged > 80 and < 80 years following primary TKA

Author and date	Groups	Time	Mortality	p-value
Andreozzi et al 2020[15]	>80 years <80 years	Within 90 days	2.00% 0.00%	
Bovonratwet et al 2019[46]	>80 years <80 years	Within 90 days	0.20% 0.03%	0.108
Klasan et al 2019[49]	>80 years <80 years	Within 10 years	32.00% 12.00%	<0.001
Maempel et al 2015[40]	>80 years 75–80 years <75 years	Within 1 year	3.20% 2.00% 1.50%	
Murphy et al 2018[47]	>80 years <80 years	Within 10 years	28.00% 7.00%	
Skinner et al 2016[41]	>80 years <80 years	Within 2 years	12.90% 0.00%	
Yun et al 2018[43]	>80 years <80 years	Within 90 days	0.00% 0.00%	

Note. TKA, total knee arthroplasty.

Table 4. Length of stay (LoS) in patients aged > 80 and < 80 years following primary TKA

Author	Groups	LoS *(days)*	p-value
Andreozzi et al 2020[15]	>80 years	5.8	<0.001
	<80 years	4.1	
Austin et al 2018[45]	>80 years	3.3	
	<80 years	2.9	
Kodaira et al 2019[48]	>80 years	18.8	
	<80 years	16.8	
Murphy et al 2018[47]	>80 years	[5]	
	<80 years	[4]	
Sezgin et al 2019[7]	>80 years	6.2	
	<80 years	4.1	
Skinner et al 2016[41]	>80 years	8.4	0.001
	<80 years	5.6	
Townsend et al 2018[42]	>79 years	2.0	0.318
	70–79 years	1.7	
	60–69 years	1.5	
	50–59 years	1.9	
	<50 years	1.6	
Yun et al 2018[43]	>80 years	20.9	<0.001
	<80 years	14.4	

Note. TKA, total knee arthroplasty.

offered elective TKA.[54] Variations in peri- and postoperative management are rarely reported in the literature and may have an effect on complication rates; for example, physical therapy that commences soon after surgery, as well as prophylaxis strategies, can both decrease rates of deep vein thrombosis and pulmonary embolisms.[55]

The findings from the present systematic review revealed that the older population is at a much greater risk of suffering postoperative cognitive dysfunction, such as confusion or delirium, in comparison to the younger population. Some studies have found that general anaesthesia may increase the risk of early postoperative cognitive dysfunction, and recommended the use of regional anaesthesia where possible, particularly in more frail or vulnerable patients.[56,57] The present study also revealed similar rates of wound complications in both older and younger populations, which are more likely influenced by surgeon experience and technique. In contrast, older patients experienced higher rates of surgical and medical complications, which depend more on the physical condition of the patients. This finding was also reflected in a recent systematic review of total joint replacements by Murphy et al.[16] Older patients should therefore not be excluded from consideration for primary TKA based on age alone, but with consideration of preoperative physical condition.

Mortality outcomes are important when assessing the safety of joint replacement surgery for the elderly.[47] Overall, in the present study, mortality was consistently higher in the older population; however, the actual number of deaths within the first 90 days following TKA was relatively low, suggesting it is safe to offer TKA to the older population. Two studies[47,49] reported higher mortality within 10 years following TKA for older patients when compared to younger patients, which is in line with the life expectancy for patients over 85 years of age.[58] Furthermore, Skinner et al[41] reported high mortality in their nonagenarian population that received TKA, which was equal to that expected for the general population aged 90 years or older.

In the present systematic review, eight studies reported greater LoS for older patients compared to younger patients; however, only three studies found a statistically significant difference (range, $p < 0.001$ to $p = 0.001$), making it difficult to draw a definitive conclusion. Kupermen et al[17] pointed out that whilst greater LoS increases the direct cost of TKA, this additional expense should be weighed against the costs of ongoing support for patients with functional deficits if they do not undergo surgery. Compared to studies performed in North America, Europe, and Australia, studies from Asia have reported considerably greater LoS (ranging from 16.8 to 20.9 days) in both age groups, possibly because patients receive in-hospital postoperative physical therapy, and are only discharged when able to walk steadily.[48] A study by Pitter et al reported that fast-track TKA and THA is feasible in most patients aged ≥ 85; however, to prevent readmissions, clinicians should monitor postoperative anaemia and medical complications.[59]

In the present systematic review, most of the studies reported similar PROs following TKA in both older and younger patients. Although two studies reported significantly worse OKS for older patients ($p < 0.001$),[49,50] both studies found that the mean OKS for older patients was above the patient acceptable symptom state (PASS) of 37 points.[60] Furthermore, three studies reported KSS function and found worse scores in older patients,[15,40,50] likely because of comorbidities associated with advancing age,

Table 5. Clinical outcomes comparing patients aged > 80 and < 80 years following primary TKA

Author	Patient-reported outcome	>80		Comparator		p-value	Patient-reported outcome comparison
		Mean	±*SD*	Mean (range*)	±*SD*		
Andreozzi et al 2020[15]	OKS	40	2.6	41	2.7		No difference
	KSS	81.5	9.6	83.3	6.8		No difference
	KSFS	77.6	7.6	83.2	8.8	0.122	No difference
Austin et al 2018[45]	PCS	Not reported		Not reported			No difference
Cher et al 2018[44]	OKS	22.85		19.98			No difference
	KSS	84.4		86.2			No difference
	KSFS	55.77		73.44			No difference
	SF-36	49.59		46.41		<0.05	Better for >80
Goh et al 2020[50]	OKS	39.2	6.7	41.5	5.2	<0.001	Worse for >80
	KSS	83.1	12.3	82.2	11.9		No difference
	KSFS	57.7	19.6	69.8	19	<0.001	Worse for >80
	SF-36 PCS	45.2	11.1	48.1	10	0.001	Worse for >80
	SF-36 MCS	55	10.2	55.5	10.2		No difference
Klasan et al 2019[49]	OKS	38.9		41		<0.001	Worse for >80
Kodaira et al 2019[48]	JOA	82.8	0.4	87.4	0.3		No difference
Maempel et al 2015[40]	AKSK	93[a]		(92–93)[a]		0.001	Better for >80
	AKSF	65		80–80		<0.001	Worse for >80
Murphy et al 2018[47]	SF-12 PCS						No difference
Sezgin et al 2019[7]	KOOS					0.005 (symptoms)	Better for >80 (KOOS symptoms)
	EQ-VAS	76		78		0.700	No difference
Skinner et al 2016[41]	OKS					n.s.	No difference
Townsend et al 2018[42]	WOMAC	63.5		(53.0–64.4)			No difference
	OKS	26.5		(23.0–27.8)			No difference
Yun et al 2018[43]	WOMAC	28.7		21.7		0.009	Worse for >80
	KSS	68.34		64.83		0.130	No difference
	SF-36	51.3		59.5		0.022	Worse for >80

Note. TKA, total knee arthroplasty; OKS, Oxford Knee Score; KSS, Knee Society Score; KSFS, Knee Society Score (Function); KOOS, Knee injury and Osteoarthritis Outcome Score; JOA, Japanese Orthopaedic Association;

AKSK, American Knee Society Score (Knee); AKSF, American Knee Society Score (Function); PCS, Physical Component Socre; MCS, Mental Component Score; EQ-VAS, EuroQol Visual Analogue Scale; SF-36, Short Form 36; WOMAC, Western Ontario and McMaster Universities Osteoarthritis Index.

*The range is reported in case of multiple comparator groups.

[a]Median values.

Table 6. Assessment of methodological quality of clinical studies using an modified version of the checklist by Downs and Black

Author and year	Evaluated domain					Total (/28)	Total (%)
			Internal validity				
	Reporting (/11)	External validity (/3)	Study bias (/7)	Selection bias (/6)	Power (/1)		
Andreozzi et al 2020[15]	10	0	6	2	1	19	68%
Austin et al 2018[45]	11	2	5	3	0	21	75%
Bovonratwet et al 2019[46]	8	2	5	2	0	17	61%
Cher et al 2018[44]	10	1	5	2	1	19	68%
Goh et al 2020[50]	9	1	5	3	1	19	68%
Klasan et al 2019[49]	8	1	4	2	1	16	57%
Kodaira et al 2019[48]	7	1	4	2	0	14	50%
Maempel et al 2015[40]	7	2	5	3	0	17	61%
Murphy et al 2018[47]	9	2	5	4	1	21	75%
Sezgin et al 2019[7]	7	2	5	1	0	15	54%
Skinner et al 2016[41]	10	1	4	2	0	17	61%
Townsend et al 2018[42]	8	2	4	3	0	17	61%
Yun et al 2018[43]	10	1	4	3	0	18	64%

which can cause functional decline.[61] In fact, the older population have 'similar to worse' baseline functional scores compared to the younger population,[62] as older patients may delay or be denied surgery in the earlier stages of OA, on account of perceived surgical risks.[17] It is worth noting that in the last systematic review on the topic, Kuperman et al[17] found improvements in function to be similar for both older and younger patients.

The results of the present systematic review should be interpreted with the following limitations in mind. First, there is considerable heterogeneity in the characteristics of the included cohorts, which made quantitative comparisons between cohorts difficult. Second, although the overall level of quality was good to fair for the majority of studies, only two were prospective comparative studies (both Level II). Third, it is possible that selection bias may exist, as patients with fewer comorbidities are more likely to be offered elective TKA, and the results are not necessarily pertinent to the general older population. Fourth, while the PROs employed by the included studies evaluated pain as a component of their overall score (e.g. KSS, WOMAC, OKS), none comprehensively assessed pain in explicit detail. As pain is one of the primary indications for arthroplasty,[63] future studies should aim to quantify improvement in pain using standardized measures. Finally, only five out of the 13 studies performed a priori power analysis to determine the required sample size.

Conclusion

In comparison with younger patients (< 80 years), older patients (≥ 80 years) receiving TKA have higher rates of surgical and medical complications, as well as higher mortality. The literature also reports greater LoS for older patients, but inconsistent findings regarding PROs. The present findings provide both surgeons and older patients with clearer updated evidence, to help them make informed decisions regarding surgical intervention in end-stage OA of the knee, considering the risks and benefits within this age group. Older patients should therefore not be excluded from consideration for primary TKA based on age alone, but with consideration of preoperative physical condition.

AUTHOR INFORMATION

[1]Ramsay Santé, Hopital Prive de l'Estuaire, LeHavre, France.
[2]ReSurg SA, Nyon, Switzerland.
[3]Hôpital Charles Nicolle, CHU de Rouen, Rouen, France.

Correspondence should be sent to: Floris van Rooij, ReSurg SA, Rue Saint Jean 22, 1260 Nyon, Switzerland.
Email: Floris@resurg.com

ICMJE CONFLICT OF INTEREST STATEMENT

OC reports personal fees from Zimmer, personal fees from Arthrex, personal fees from Tornier-Corin, outside the submitted work. All other authors declare no conflict of interest relevant to this work.

FUNDING STATEMENT

No benefits in any form have been received or will be received from a commercial party related directly or indirectly to the subject of this article.

SUPPLEMENTAL MATERIAL

Supplemental material is available for this paper at https://online.boneandjoint.org.uk/doi/suppl/10.1302/2058-5241.6.200150

REFERENCES

1. **United Nations, Department of Economic and Social Affairs (Population Division).** *World population prospects 2019: highlights*. New York, NY: UN, 2019.

2. **Nemes S, Rolfson O, W-Dahl A, et al.** Historical view and future demand for knee arthroplasty in Sweden. *Acta Orthop* 2015;86:426–431.

3. **French HP, Galvin R, Horgan NF, Kenny RA.** Prevalence and burden of osteoarthritis amongst older people in Ireland: findings from The Irish LongituDinal Study on Ageing (TILDA). *Eur J Public Health* 2016;26:192–198.

4. **Krishnan E, Fries JF, Kwoh CK.** Primary knee and hip arthroplasty among nonagenarians and centenarians in the United States. *Arthritis Rheum* 2007;57:1038–1042.

5. **Hernández-Vaquero D, Fernández-Carreira JM, Pérez-Hernández D, Fernández-Lombardía J, García-Sandoval MA.** Total knee arthroplasty in the elderly: is there an age limit? *J Arthroplasty* 2006;21:358–361.

6. **Kennedy JW, Johnston L, Cochrane L, Boscainos PJ.** Total knee arthroplasty in the elderly: does age affect pain, function or complications? *Clin Orthop Relat Res* 2013;471:1964–1969.

7. **Sezgin EA, Robertsson O, W-Dahl A, Lidgren L.** Nonagenarians qualify for total knee arthroplasty: a report on 329 patients from the Swedish Knee Arthroplasty Register 2000–2016. *Acta Orthop* 2019;90:53–59.

8. **McCalden RW, Robert CE, Howard JL, Naudie DD, McAuley JP, MacDonald SJ.** Comparison of outcomes and survivorship between patients of different age groups following TKA. *J Arthroplasty* 2013;28:83–86.

9. **Pitta M, Khoshbin A, Lalani A, et al.** Age-related functional decline following total knee arthroplasty: risk adjustment is mandatory. *J Arthroplasty* 2019;34:228–234.

10. **Zicat B, Rorabeck CH, Bourne RB, Devane PA, Nott L.** Total knee arthroplasty in the octogenarian. *J Arthroplasty* 1993;8:395–400.

11. **Easterlin MC, Chang DG, Talamini M, Chang DC.** Older age increases short-term surgical complications after primary knee arthroplasty. *Clin Orthop Relat Res* 2013;471:2611–2620.

12. Fang M, Noiseux N, Linson E, Cram P. The effect of advancing age on total joint replacement outcomes. *Geriatr Orthop Surg Rehabil* 2015;6:173–179.

13. Preston SD, Southall AR, Nel M, Das SK. Geriatric surgery is about disease, not age. *J R Soc Med* 2008;101:409–415.

14. Jämsen E, Puolakka T, Eskelinen A, et al. Predictors of mortality following primary hip and knee replacement in the aged: a single-center analysis of 1,998 primary hip and knee replacements for primary osteoarthritis. *Acta Orthop* 2013;84:44–53.

15. Andreozzi V, Conteduca F, Iorio R, et al. Comorbidities rather than age affect medium-term outcome in octogenarian patients after total knee arthroplasty. *Knee Surg Sports Traumatol Arthrosc* 2020;28:3142–3148.

16. Murphy BPD, Dowsey MM, Choong PFM. The impact of advanced age on the outcomes of primary total hip and knee arthroplasty for osteoarthritis: a systematic review. *JBJS Rev* 2018;6:e6.

17. Kuperman EF, Schweizer M, Joy P, Gu X, Fang MM. The effects of advanced age on primary total knee arthroplasty: a meta-analysis and systematic review. *BMC Geriatr* 2016;16:41.

18. Higgins JP, Altman DG, Gøtzsche PC, et al; Cochrane Bias Methods Group; Cochrane Statistical Methods Group. The Cochrane Collaboration's tool for assessing risk of bias in randomised trials. *BMJ* 2011;343:d5928.

19. McInnes MDF, Moher D, Thombs BD, et al; and the PRISMA-DTA Group. Preferred Reporting Items for a Systematic Review and Meta-analysis of Diagnostic Test Accuracy Studies: the PRISMA-DTA statement. *JAMA* 2018;319:388–396.

20. Downs SH, Black N. The feasibility of creating a checklist for the assessment of the methodological quality both of randomised and non-randomised studies of health care interventions. *J Epidemiol Community Health* 1998;52:377–384.

21. Hooper P, Jutai JW, Strong G, Russell-Minda E. Age-related macular degeneration and low-vision rehabilitation: a systematic review. *Can J Ophthalmol* 2008;43:180–187.

22. Higgins JP, Thompson SG, Deeks JJ, Altman DG. Measuring inconsistency in meta-analyses. *BMJ* 2003;327:557–560.

23. Faber T, Ravaud P, Riveros C, Perrodeau E, Dechartres A. Meta-analyses including non-randomized studies of therapeutic interventions: a methodological review. *BMC Med Res Methodol* 2016;16:35.

24. Koh IJ, Kim GH, Kong CG, Park SW, Park TY, In Y. The patient's age and American Society of Anesthesiologists status are reasonable criteria for deciding whether to perform same-day bilateral TKA. *J Arthroplasty* 2015;30:770–775.

25. Pope D, El-Othmani MM, Manning BT, Sepula M, Markwell SJ, Saleh KJ. Impact of age, gender and anesthesia modality on post-operative pain in total knee arthroplasty patients. *Iowa Orthop J* 2015;35:92–98.

26. Yun SH, Park JC, Kim SR, Choi YS. Effects of dexmedetomidine on serum interleukin-6, hemodynamic stability, and postoperative pain relief in elderly patients under spinal anesthesia. *Acta Med Okayama* 2016;70:37–43.

27. Bayliss LE, Culliford D, Monk AP, et al. The effect of patient age at intervention on risk of implant revision after total replacement of the hip or knee: a population-based cohort study. *Lancet* 2017;389:1424–1430.

28. Feng B, Lin J, Jin J, Qian WW, Wang W, Weng XS. Thirty-day postoperative complications following primary total knee arthroplasty: a retrospective study of incidence and risk factors at a single center in China. *Chin Med J (Engl)* 2017;130:2551–2556.

29. Menendez ME, Greber EM, Schumacher CS, Lowry Barnes C. Predictors of acute ischemic stroke after total knee arthroplasty. *J Surg Orthop Adv* 2017;26:148–153.

30. Prattingerová J, Sarvikivi E, Huotari K, Ollgren J, Lyytikäinen O. Surgical site infections following hip and knee arthroplastic surgery: trends and risk factors of Staphylococcus aureus infections. *Infect Control Hosp Epidemiol* 2019;40:211–213.

31. Jamakorzyan C, Meyssonnier V, Kerroumi Y, et al. Curative treatment of prosthetic joint infection in patients younger than 80 vs. 80 or older. *Joint Bone Spine* 2019;86:369–372.

32. Inoue D, Xu C, Yazdi H, Parvizi J. Age alone is not a risk factor for periprosthetic joint infection. *J Hosp Infect* 2019;103:64–68.

33. Lenguerrand E, Whitehouse MR, Beswick AD, et al; National Joint Registry for England, Wales, Northern Ireland and the Isle of Man. Risk factors associated with revision for prosthetic joint infection following knee replacement: an observational cohort study from England and Wales. *Lancet Infect Dis* 2019;19:589–600.

34. Roger C, Debuyzer E, Dehl M, et al. Factors associated with hospital stay length, discharge destination, and 30-day readmission rate after primary hip or knee arthroplasty: retrospective cohort study. *Orthop Traumatol Surg Res* 2019;105:949–955.

35. Martinez-Carranza N, Pettas A, Razzaz D, Broström E, Hedström M. Younger age is associated with increased odds of manipulation under anesthesia for joint stiffness after total knee arthroplasty. *Orthop Traumatol Surg Res* 2019;105:1067–1071.

36. Yilmaz E, Poell A, Baecker H, et al. Poor outcome of octogenarians admitted to ICU due to periprosthetic joint infections: a retrospective cohort study. *BMC Musculoskelet Disord* 2020;21:304.

37. Klasan A, Putnis SE, Yeo WW, et al. Should sequential bilateral total knee arthroplasty be limited to patients younger than 80? A two-arm propensity matched study. *J Knee Surg* 2020. https://doi.org/10.1055/s-0040-1712100 [Epub ahead of print].

38. Brown MJ, Koh NP, Bell SW, Jones B, Blyth M. Age and gender related differences in infection, thromboembolism, revision and death in knee arthroplasty in a Scottish population. *Scott Med J* 2020;65:89–93.

39. Küçükosman G, Öztoprak H, Öztürk T, Ayoglu H. Factors associated with postoperative mortality in geriatric orthopedic surgery: a retrospective analysis of single center data. *Journal of Anesthesiol Reanim Special Soc* 2019;27:186–192.

40. Maempel JF, Riddoch F, Calleja N, Brenkel IJ. Longer hospital stay, more complications, and increased mortality but substantially improved function after knee replacement in older patients. *Acta Orthop* 2015;86:451–456.

41. Skinner D, Tadros BJ, Bray E, Elsherbiny M, Stafford G. Clinical outcome following primary total hip or knee replacement in nonagenarians. *Ann R Coll Surg Engl* 2016;98:258–264.

42. Townsend LA, Roubion RC, Bourgeois DM, et al. Impact of age on patient-reported outcome measures in total knee arthroplasty. *J Knee Surg* 2018;31:580–584.

43. Yun ST, Kim BK, Ahn BM, Oh KJ. Difference in the degree of improvement in patient-reported outcomes after total knee arthroplasty between octogenarians and sexagenarians: a propensity score matching analysis. *Aging Clin Exp Res* 2018;30:1379–1384.

44. Cher EWL, Tay KS, Zhang K, Tan SB, Howe TS, Koh JSB. The effect of comorbidities and age on functional outcomes after total knee arthroplasty in the octogenarian: a matched cohort study. *Geriatr Orthop Surg Rehabil* 2018;9:2151459318769508.

45. Austin DC, Torchia MT, Moschetti WE, Jevsevar DS, Keeney BJ. Patient outcomes after total knee arthroplasty in patients older than 80 years. *J Arthroplasty* 2018;33:3465–3473.

46. Bovonratwet P, Fu MC, Tyagi V, Gu A, Sculco PK, Grauer JN. Is discharge within a day of total knee arthroplasty safe in the octogenarian population? *J Arthroplasty* 2019;34:235–241.

47. Murphy BPD, Dowsey MM, Spelman T, Choong PFM. The impact of older age on patient outcomes following primary total knee arthroplasty. *J Bone Joint Surg [Br]* 2018;100-B:1463–1470.

48. Kodaira S, Kikuchi T, Hakozaki M, Konno S. Total knee arthroplasty in Japanese patients aged 80 years or older. *Clin Interv Aging* 2019;14:681–688.

49. Klasan A, Putnis SE, Yeo WW, Fritsch BA, Coolican MR, Parker DA. Advanced age is not a barrier to total knee arthroplasty: a detailed analysis of outcomes and complications in an elderly cohort compared with average age total knee arthroplasty patients. *J Arthroplasty* 2019;34:1938–1945.

50. Goh GS, Liow MHL, Chen JY, Tay DK, Lo NN, Yeo SJ. Can octogenarians undergoing total knee arthroplasty experience similar functional outcomes, quality of life, and satisfaction rates as their younger counterparts? A propensity score matched analysis of 1,188 patients. *J Arthroplasty* 2020;35:1833–1839.

51. Ingelsrud LH, Roos EM, Terluin B, Gromov K, Husted H, Troelsen A. Minimal important change values for the Oxford Knee Score and the Forgotten Joint Score at 1 year after total knee replacement. *Acta Orthop* 2018;89:541–547.

52. Lizaur-Utrilla A, Gonzalez-Parreño S, Martinez-Mendez D, Miralles-Muñoz FA, Lopez-Prats FA. Minimal clinically important differences and substantial clinical benefits for Knee Society Scores. *Knee Surg Sports Traumatol Arthrosc* 2020;28: 1473–1478.

53. Yeo MGH, Goh GS, Chen JY, Lo NN, Yeo SJ, Liow MHL. Are Oxford Hip Score and Western Ontario and McMaster Universities Osteoarthritis Index useful predictors of clinical meaningful improvement and satisfaction after total hip arthroplasty? *J Arthroplasty* 2020;35:2458–2464.

54. Jones CM, Ashrafian H, Darzi A, Athanasiou T. Guidelines for diagnostic tests and diagnostic accuracy in surgical research. *J Invest Surg* 2010;23:57–65.

55. Brander V, Stulberg SD. Rehabilitation after hip- and knee-joint replacement: an experience- and evidence-based approach to care. *Am J Phys Med Rehabil* 2006;85:S98–S118.

56. Mason SE, Noel-Storr A, Ritchie CW. The impact of general and regional anesthesia on the incidence of post-operative cognitive dysfunction and post-operative delirium: a systematic review with meta-analysis. *J Alzheimers Dis* 2010;22:67–79.

57. Zywiel MG, Prabhu A, Perruccio AV, Gandhi R. The influence of anesthesia and pain management on cognitive dysfunction after joint arthroplasty: a systematic review. *Clin Orthop Relat Res* 2014;472:1453–1466.

58. Murphy SL, Xu J, Kochanek KD. Deaths: final data for 2010. *Natl Vital Stat Rep* 2013;61:1–117.

59. Pitter FT, Jørgensen CC, Lindberg-Larsen M, Kehlet H; Lundbeck Foundation Center for fast-track hip and knee replacement collaborative group: postoperative morbidity and discharge destinations after fast-track hip and knee arthroplasty in patients older than 85 years. *Anesth Analg* 2016;122:1807–1815.

60. Keurentjes JC, Van Tol FR, Fiocco M, et al. Patient acceptable symptom states after total hip or knee replacement at mid-term follow-up: thresholds of the Oxford Hip and Knee Scores. *Bone Joint Res* 2014;3:7–13.

61. Palleschi L, De Alfieri W, Salani B, et al. Functional recovery of elderly patients hospitalized in geriatric and general medicine units. The PROgetto DImissioni in GEriatria Study. *J Am Geriatr Soc* 2011;59:193–199.

62. Cram P, Lu X, Kates SL, Singh JA, Li Y, Wolf BR. Total knee arthroplasty volume, utilization, and outcomes among Medicare beneficiaries, 1991–2010. *JAMA* 2012;308:1227–1236.

63. Gademan MG, Hofstede SN, Vliet Vlieland TP, Nelissen RG, Marang-van de Mheen PJ. Indication criteria for total hip or knee arthroplasty in osteoarthritis: a state-of-the-science overview. *BMC Musculoskelet Disord* 2016;17:463.