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Anatomical shoulder replacements in young patients: A systematic review and meta-analysis

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Abstract

Introduction: Increasing numbers of young patients receive shoulder replacements. Greater information on outcomes is needed to inform implant choice. The aim of this study was to investigate the survivorship and clinical effectiveness of hemiarthroplasty and anatomical total shoulder arthroplasty (TSA) in patients younger than 65 years.
Method: A systematic review was performed of MEDLINE, EMBASE, CENTRAL, The Cochrane Database of Systematic Reviews and National Joint Registry reports. The primary outcomes were implant survival and change in perioperative shoulder scores.
Results: Meta-analysis of implant survivorship was performed of six studies reporting on 416 patients. Implant survival was 86.1% (72.1,100) at 10 years for hemiarthroplasty and 82.3% (64.6,100) for TSA. 20 year survival was 80.0% for hemiarthroplasty (72.5,87.4) and 75.0% (56.9,93.1) for TSA. Ten studies were included in the meta-analysis of shoulder scores, multiple instruments were used. The standardised mean difference between pre-operative and post-operative shoulder scores was 2.15 (1.95, 2.35) for TSA at 4.2–4.9 years, and 2.72 (1.98,3.47) for hemiarthroplasty at 3.8–6 years.
Conclusion: Over 80% of shoulder replacements last more than 10 years, and 75% last more than 20 years. Significant improvements in shoulder scores are shown at all time points.

Keywords

shoulder, replacement, arthroplasty, survival, patient reported outcome measures

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Introduction

Management of end stage arthritis in young patients is particularly challenging due to concern regarding implant survivorship and the physical demands placed on the joint.

Conservative management options include analgesia and physical therapy, steroid injections, sodium hyaluronate therapy, and nerve blocks.[1] These are typically temporising measures.[1] Arthroscopic debridement can improve symptoms and shoulder function in the short term, however glenohumeral joint arthroplasty remains the definitive surgical management.[2]

Arthroplasty options in young patients with an intact rotator cuff include total shoulder arthroplasty (TSA) and hemiarthroplasty. Either implant may be considered in the absence of advanced or asymmetrical glenoid wear.[3] The use of reverse arthroplasty has expanded dramatically but remains controversial in this population. The evidence to guide practise in young patients is limited, and patient's expectations regarding function can be high.[4] TSA addresses degenerative disease in both the glenoid and humeral head and is associated with good post-operative function and relief of symptoms.[5] Hemiarthroplasty is less destructive of the native glenoid and avoids the additional concern of glenoid implant loosening in this high demand population.

Biological resurfacing of the glenoid is described in combination with arthroscopic debridement or shoulder hemiarthroplasty. This typically involves placing an autograft or allograft across an eroded glenoid. Grafts include

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This work is not based on a previous communication to a society or meeting.

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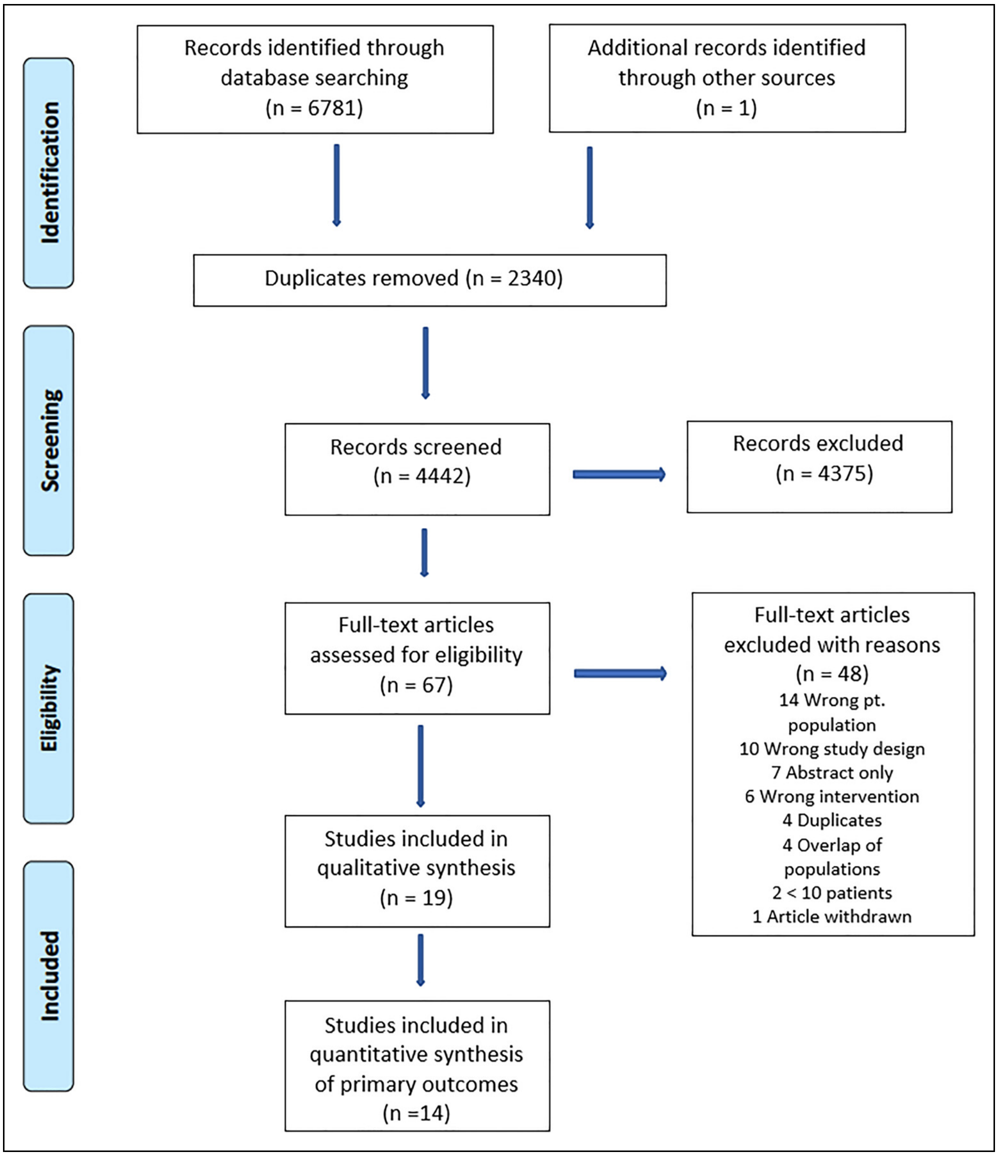

Figure 1. PRISMA study flow diagram.

acellular dermal matrix, Achilles tendon or fascia lata allograft, and autografts from the fascia lata or anterior shoulder joint capsule.[6] A review of biological resurfacing alongside hemiarthroplasty reported a high risk of complications (36.2%), and high risk of revision (22.7%), the majority within 2.5 years.[6] Biological resurfacing will not be considered further in this review.

A recent Cochrane review synthesised research comparing total shoulder replacement and hemiarthroplasty, however we were unable to find a summary of current evidence in the younger population.[7] The aim of this systematic review is to answer the following question: In patients younger than 65 years who undergo an anatomical shoulder replacement, what improvement in function and risk of revision arthroplasty is expected following surgery?

Method

The review was registered on the International prospective register of systematic reviews (PROSPERO). The report is structured according to the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, please see the appendix. An initial scoping review was performed to estimate the availability of current literature and direct the search criteria.

The search was performed on; MEDLINE (OvidSP, 1946 to present), Embase (OvidSP, 1974 to present), CENTRAL and the Cochrane Database of Systematic Reviews from inception until April 2021. Nine national joint registries report on shoulder replacements, annual reports were reviewed for outcome data stratified by age.[8]

Table 1. Study characteristics.

Study	Implant	Number shoulders	Mean age	Mean follow-up	Shoulder Scores	Included in survival analysis	Included in analysis of shoulder scores
Bailie[16] 2008	HA	38	42.3 (28–54)	38.1 months	ASES	No	Yes
Bartelt[17] 2011	TSA HA	46 20	49 (21–55) 49 (26–55)	6 years 9.3 years	None	Yes	No
Brewley[18] 2020	TSA	142	68 (<65 subgroup)	4.2 years	ASES	No	Yes
Denard[19] 2013	TSA	52	50.5 (35–55)	9.6 years	Constant	Yes	Yes
Eichinger[20] 2016	TSA	54	44 (29–50)	4.9 years	SSV	Yes	Yes
Garcia[4] 2017	TSA	72	48.9 (25–55)	5.1 years	ASES	No	No
Gauci[21] 2018	TSA TSA	46 23	55 (40–60) 53 (35–60)	1 year 1 year	Constant, SSV	No	Yes
Hammond[22] 2013	HA	25	33.9 (17–50)	3.8 years	Constant, ASES, SST	No	Yes
Iagulli[23] 2014	HA	52	48 (21–59)	6 years	UCLA	No	Yes
Kany[24] 2021	TSA HA	77 62	44 (31–50) 44 (29–47)	7.9 years	Constant	No	No
Kusnezov[25] 2016	TSA	26	45.8 (35–54)	1.8 years	None	No	No
Levy[26] 2015	TSA HA	17 37	38.9 (22–50)	14.5 years	Constant	Yes	No
Neyton et al.[27] 2019	TSA HA	202 31	55.7 (36–60) 52.5 (38–60)	9 years 8.7 years	Constant, SSV	No	No
Patel[28] 2019	TSA	118	50 (31–55)	4.2 years	Constant, ASES, UCLA, SPADI	No	Yes
Rasmussen[29] 2014	HA	165	Not stated	Not stated	WOOS	No	No
Schoch[30] 2015	TSA HA	19 56	41 (22–50) 39 (19–50)	21.6 months 20.8 months	None	Yes	No
Sowa[31] 2017	TSA	24	55 (37–60)	13 years	Constant	No	Yes
Sperling[32] 2004	TSA HA	36 78	41 (not stated) 39 (19–50)	18.6 years 15.3 years	None	Yes	No
Tsitlakidis[33] 2021	HA	20	52.8 (29–65) Subgroup (max. 55)	24.3 months	Constant	No	No

ASES: American Shoulder and Elbow Score, Constant: Constant-Murley Score. SSV: Subjective Shoulder Value, SST: Simple Shoulder Test, UCLA: The University of California at Los Angeles Shoulder Score, SPADI: Shoulder Pain and Disability Index, WOOS: Western Ontario Osteoarthritis of the Shoulder Index.

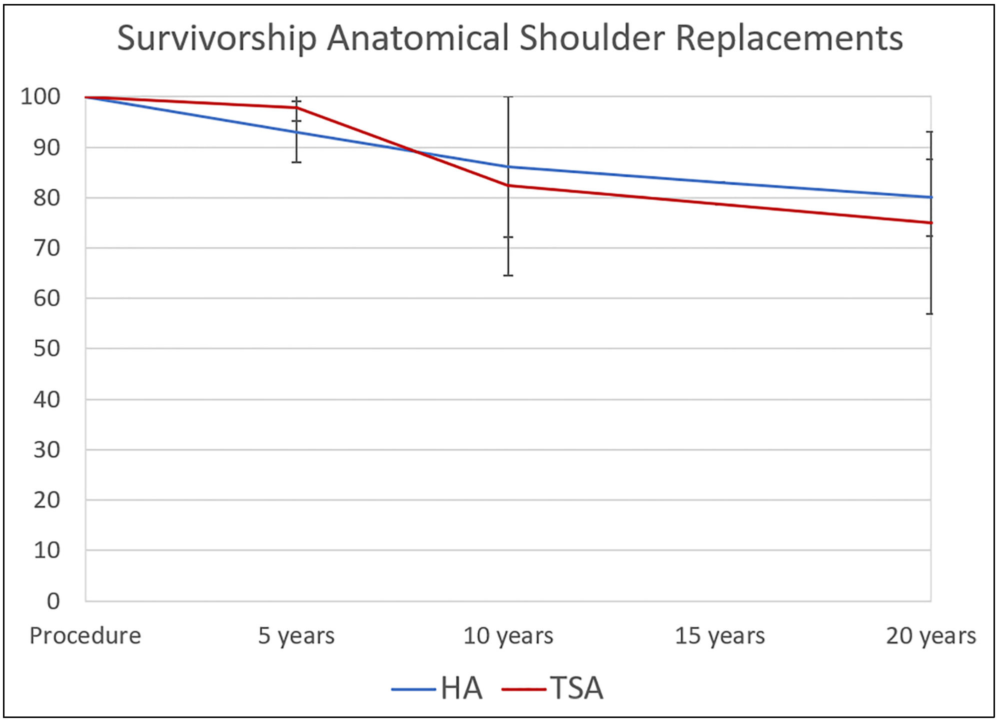

Figure 2. Survivorship: hemiarthroplasty (HA) and total shoulder arthroplasty (TSA) in patients 55 years or less.

Population

The inclusion criteria were as follows; adult patients younger than 65 years at the time of surgery who received an anatomical shoulder replacement for end stage arthritis and had a normal or attenuated rotator cuff. All implant types were accepted (resurfacing, stemless, stemmed). All studies reported outcome data following an anatomical shoulder replacement. This includes randomised and non-randomised studies, case series and registry reports.

We excluded studies reporting on reverse TSA, surgery for juvenile idiopathic arthritis, case studies, case series of less than 10 patients, editorials, reviews and conference abstracts. Studies were also excluded if the majority of replacements were performed following trauma. For cohort studies and registry data, the outcomes of both implants were reported separately. Studies reporting on hemiarthroplasty along with a ream and run, or glenoid resurfacing procedure were excluded.

Outcomes

The primary outcome measures were implant survival and shoulder scores. Shoulder scores included patient reported outcomes measures (e.g. Oxford Shoulder Score) and combined shoulder scores with functional and patient reported components (e.g. Constant-Murley Score). Implant survival was defined as the time from the primary procedure to revision arthroplasty, reported at a minimum of 5 years. Secondary outcomes were pain scores and quality of life scores.

Data extraction

Two reviewers independently selected studies according to the inclusion criteria. A third reviewer was available to manage any discrepancies. Search results were organised using Covidence® systematic review management software. Initial screening of titles and abstracts was performed by two authors independently, followed by full text review of relevant papers. There was no disagreement between the two reviewers after discussion. Registry reports were reviewed separately. Only the Australian joint registry reported outcomes stratified by patient age.

Data was extracted independently by two authors onto a pre-specified data collection table. Data was collected on the study setting, study population, patient demographics, study design, funding source, surgical indication, protheses, loss to follow-up and the outcomes of interest A full description of extracted data is available in the appendix. Where multiple papers have been published using the same population, the most comprehensive article was included. Studies reporting subgroups of patients less than 65 years of age were included if patient ages were clearly defined. Where articles reported on multiple procedures, those that met the inclusion criteria were included.

Shoulder scores were extracted where they reported both pre-operative and post-operative scores, including means (+/- standard deviations). Standard deviations were estimated from confidence intervals according to the Cochrane handbook.[9] Data was extracted on survival where it was published alongside 95% confidence intervals, we did not extract data from figures.

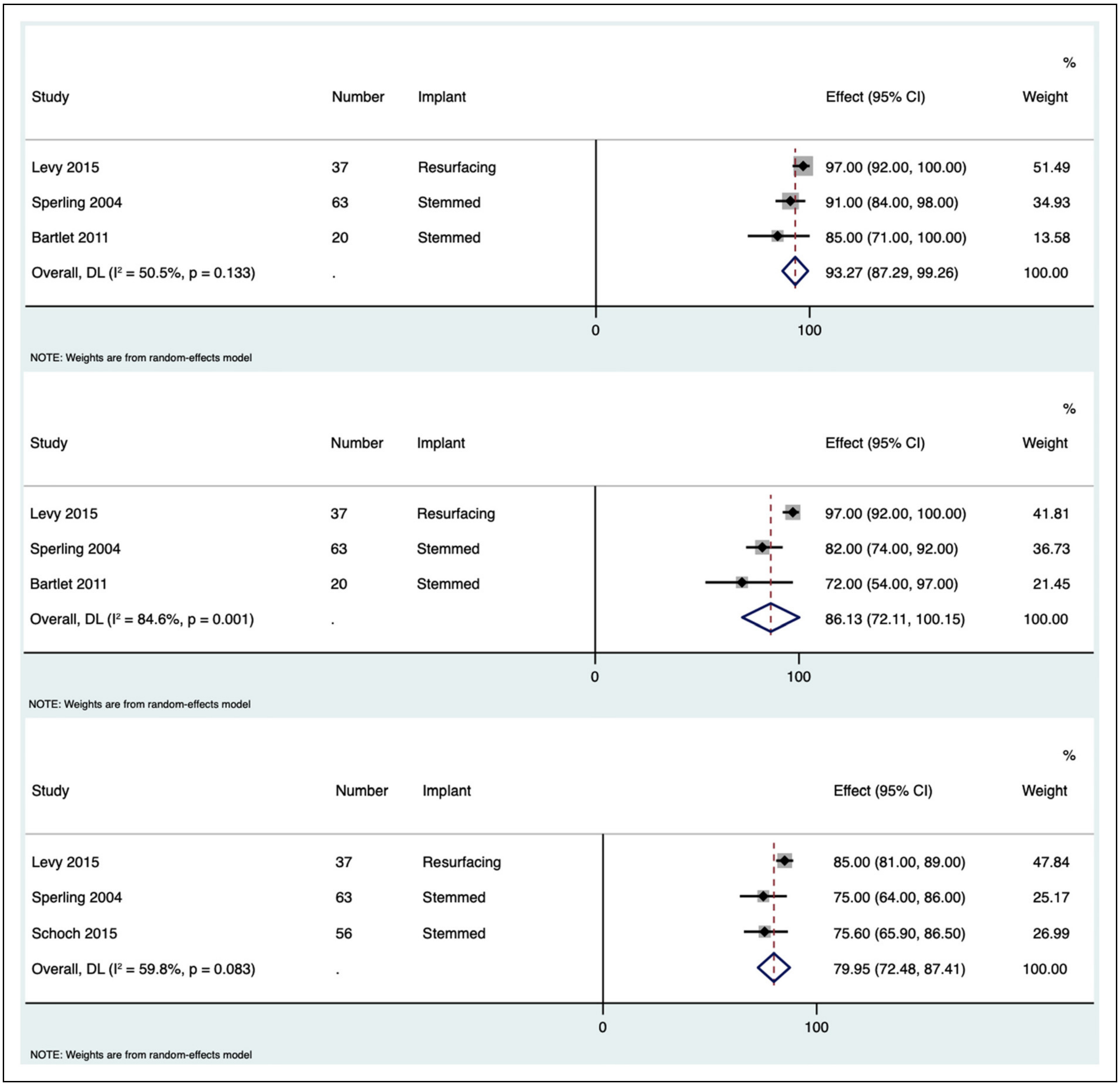

Figure 3. Survivorship of hemiarthroplasties at 5, 10 and 20 years.

Data analysis

A meta-analysis was performed of shoulder scores and survival estimates. Several shoulder scores were used across studies. The standardised mean difference (SMD) is a summary statistic that is used to facilitate meta-analysis when different measurements are used for the same outcome.[9] We applied the SMD in our analysis to compare the difference between the pre-operative and post-operative shoulder scores across studies.

The SMD of shoulder scores were pooled using Revman® meta-analysis software and weighted according to sample size and the standard deviation of the scores. A random effects model was applied on the assumption that the studies estimated different intervention effects.[10] All studies reported shoulder scores at a single time point post operatively. Studies were grouped according to the post-op duration at which the shoulder scores were reported. A sensitivity analysis was performed regarding the outcome duration of these groups. Previous work has shown shoulder scores may improve up to three years following an anatomical shoulder replacement.[11]

A meta-analysis of survival estimates was performed on STATA version 16. Studies were weighted according to standard error, calculated from confidence intervals.[9] A subgroup analysis was performed of implant survivorship in patients with stemmed prostheses. These may have a lower risk of revision compared to stemless and

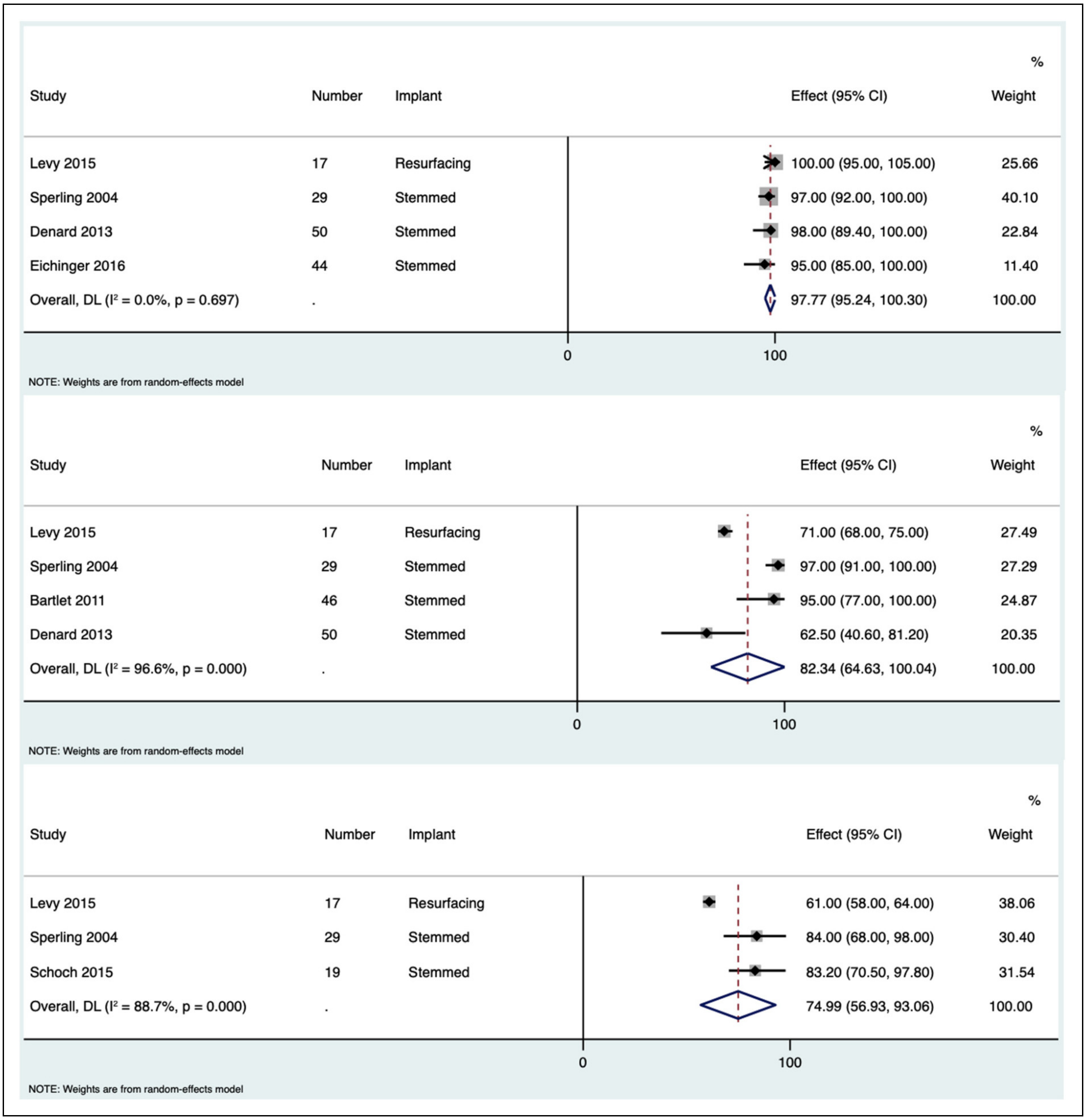

Figure 4. Survivorship of total shoulder arthroplasty at 5, 10 and 20 years.

resurfacing implants, however current reports are inconclusive.[12,13]

Risk of bias was assessed using the MINORS instrument.[14] This includes an eight-item assessment for non-comparative studies. This decision was made following publication of the protocol as the instrument was considered more suitable than the Newcastle Ottawa Quality Assessment Scale for the non-comparative studies included in this review.[15] Two authors independently documented the risk of bias according to the instrument, the results are included in the appendix. After discussion there were no inconsistencies. The results from case series and registry reports were compared to identify potential reporting bias.

Results

The database search identified 6781 studies; one further article was found on review of reference lists. The PRISMA flow diagram is shown in Figure 1. Following removal of duplicates, the abstracts of 4442 articles were screened. Full text review was performed of 67 articles and 19 met our inclusion criteria.

The characteristics of the 19 included studies are listed in Table 1.[4,16–33] Where studies reported on alterative procedures such as hemiarthroplasty with glenoid resurfacing, these groups were omitted from the table. Seven studies reported outcomes for both TSA and hemiarthroplasty, seven studies reported on

Table 2. Summary of survivorship of stemmed implants.

Implant	5 year	10 year	20 year
Hemiarthroplasty	89.87 (83.56, 96.17)	81.87 (72.80, 90.93)	75.32 (67.80, 82.84)
Total shoulder arthroplasty	97.00 (94.06, 99.94)	88.10 (73.38,102.82)	83.56 (73.47, 93.66)

Table 3. Summary of data from the Australian joint registry of survivorship for primary anatomical shoulder replacements for OA, stratified by age.[34]

Implant	Age	Number	5 years	10 years
Hemi resurfacing	<55	326	89.5 (84.7,92.8)	72.9 (64.7, 79.5)
	55–64	408	84.6 (80.3, 88.0)	78.0 (72.5, 82.5)
Hemi stemmed	<55	156	84.7 (76, 90.5)	Not reported
	55–64	289	88.6 (83.7, 92.1)	84.3 (79.2, 89.8)
Total stemmed	<55	626	88.8 (85.8, 91.3)	79 (73.6, 83.3)
	55–64	3037	90.9 (89.7, 92)	83.9 (81.7, 85.8)

TSA alone and five studies reported on hemiarthroplasty alone. The outcomes of 1539 shoulders were reported in 1530 patients. One study reported data from the Danish Joint Registry, however this was not included in the meta-analysis of survivorship or shoulder scores due to a lack of published confidence intervals.[29]

Survivorship

Survivorship data from case series and the Australian Joint Registry were available. Six studies reporting on 416 patients provided sufficient data for meta-analysis of survival outcomes. Despite the inclusion criteria of patients less than 65 years of age, the maximum age of patients in these pooled case series was 55. The pooled survivorship of hemiarthroplasty and anatomical TSA from case series is summarised in Figure 2. The forest plots are shown in Figures 3 and 4.

The majority of studies included stemmed implants. Survivorship was calculated for stemmed implants alone as a subgroup. There was insufficient outcome data for stemless and resurfacing implants to warrant dedicated subgroup analyses. The forest plots are included in the appendix and summarised in Table 2.

Of the nine national joint registries reporting outcomes in shoulder arthroplasty, only the Australian registry contains survivorship outcomes stratified by age, implant type and implant indication.[8,34] A further article reported on outcomes from the Danish Joint Registry, however these data were not included in the meta-analysis due to an absence of confidence intervals.[29] Survivorship was reported separately for several different age groups and implant types in the Australian National Joint Registry. Relevant age groups were patients less than 55 years and patients aged 55–64 years. Implant types included primary stemmed and resurfacing hemiarthroplasty for osteoarthritis, and primary total stemmed shoulder replacement for osteoarthritis. The results are summarised in Table 3.

Shoulder scores

Ten studies reported sufficient data for meta-analysis of shoulder scores. The duration of follow-up ranged from two years to 13 years, all studies reported outcomes at a single time point. Given the limited number of studies, the outcome duration was grouped into mid-term and long-term follow-up. For hemiarthroplasty the range of mid-term follow-up was 3.8–6 years, and 4.2–4.9 years for TSA. The SMD between pre-operative and post-operative scores at mid-term follow-up are shown in Figures 5 and 6.

Two further studies reported shoulder scores at a mean of 2 years for hemiarthroplasty.[16,33] These were not included in the primary analysis, previous work has shown shoulder scores may improve for several years post-operatively.[11] A sensitivity analysis was performed with their inclusion in the mid-term follow-up group. The SMD was 3.22 (2.24,4.21), the full results are included in the appendix.

Three studies reported shoulder scores at a mean of 9.6–13 years following TSA (Figure 7). These were grouped as long-term follow-up. The improvement in shoulder scores was maintained. There were no studies reporting long-term follow-up in the hemiarthroplasty group.

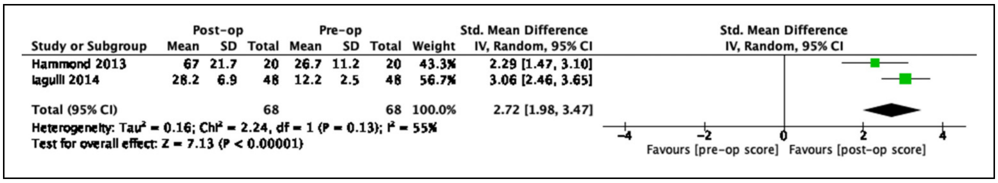

Figure 5. Standardised mean difference in shoulder scores at mid-term follow-up for hemiarthroplasty.

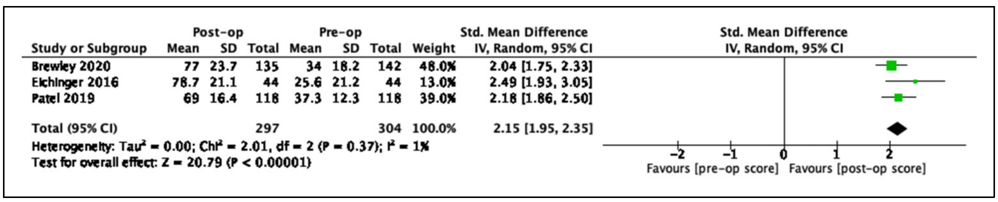

Figure 6. Standardised mean difference in shoulder scores at mid-term follow-up for TSA.

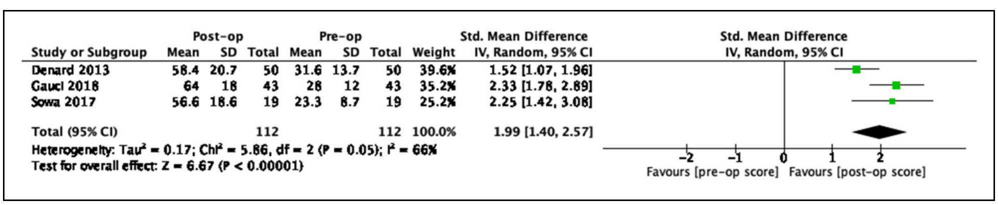

Figure 7. Standardised mean difference in shoulder scores at long-term follow-up for TSA.

Pain and quality of life scores

Pain scores were reported in 16 studies, and both pre-operative and post-operative scores were reported in 15 studies. Each demonstrated significant improvement in pain following surgery. Standard deviations were provided alongside pain scores in 4 studies on hemiarthroplasty, and 5 studies on TSA, these are tabulated in the appendix. No studies reported quality of life scores at any time point.

Risk of bias

Risk of bias was assessed using the MINORS instrument, the full results are included in the appendix.[14] All studies had a clear aim and the majority included consecutive patients. 17 of the 19 studies were of a retrospective design. Despite 84% of studies clearly reporting the size of the initial population, only five studies had a loss to follow-up of less than 5%.

Discussion

Despite our inclusion criteria of patients younger than 65 years, the maximum age of patients in the survival analysis was 55 years. In this age group, 80% of replacements last 10 years, and 75% remained unrevised at 20 years. Subgroup analyses from the Australian Joint Registry indicates survivorship in the hemi-resurfacing group may be lower.[34] There was a substantial improvement in mean shoulder scores following anatomical shoulder replacement at mid-term follow-up in patients less than 65 years of age.

As expected, the overall survivorship is lower than reported in a previous study using case series and registry data in patients of all ages.[35] Previous work using a national health service database in the United Kingdom showed the lifetime survivorship of 76.4% in patients aged 55–59 receiving a shoulder replacement.[36] Patients were not stratified according to implant type; hemiarthroplasty, TSA or reverse arthroplasty. The lower quartile for the age of patients undergoing a reverse shoulder replacement in the UK is 71 years, and so a higher proportion of these will likely be anatomical shoulder replacements rather than a reverse replacement.[12]

The Australian registry reports outcome data for each implant type separately. In order to compare outcomes between case series and registry data we performed a subgroup analysis of the survivorship of stemmed implants. Survivorship was greater for TSA from case series at 5 years and 10 years, however the uncertainty demonstrated by the broad confidence intervals makes meaningful comparison difficult. The registry reports are limited by the duration of follow-up. This is improving, however case series currently provide the longest available outcome data.

A recent meta-analysis of case series and cohort studies demonstrated similar shoulder scores and a higher revision rate in the resurfacing group.[13] The duration of follow-up was mixed, and the loss to follow-up was unclear. In the National Joint Registry of England Wales and Northern Ireland, the stemless hemiarthroplasty may have the greatest revision rate compared to resurfacing or stemmed replacements at 5 years across all ages.[12] However, the confidence intervals overlap.

In the Australian registry there was no significant difference in survivorship between resurfacing hemiarthroplasty, stemmed hemiarthroplasty and stemmed TSA at 5 years.[34] Survivorship data at 10 years in the Australian registry indicates the revision rate may be higher in the resurfacing hemiarthroplasty group in younger patients.[34] These revision rates are all unadjusted for age, gender, patient co-morbidities and other variables that many influence outcomes.

Several surgical indications were accepted in this review. Further restriction would have resulted in fewer included studies, and on balance we felt there was greater value in a wider review. The age limit of 65 was chosen as compromise between a summary of outcomes in a more specific population and large number of included studies. The most common indication for revision of an elective anatomical shoulder replacement in the UK is cuff failure.[12] In Australia this is true for TSA, however glenoid erosion is the most common indication for revision of an elective hemiarthroplasty, and cuff failure is the most common reason for TSA. Indications for revision are not stratified by age. Instability and loosening are more common indications in patients with an American Society of Anaesthesiologists score of 1, this group may be more active. The clinical decision to revise a hemiarthroplasty can be more straightforward compared to TSA. Shoulder pain in a hemiarthroplasty and evidence of glenoid wear is a clear indication, however a patient with ongoing pain following a TSA may be revised less readily. A rationale for using hemiarthroplasty in younger patients is reduced disruption of native glenoid anatomy. Furthermore, loosening of the glenoid component of a TSA may lead to additional bony destruction.

An important question is whether revision of a hemiarthroplasty to a total or reverse shoulder replacement leads to superior outcomes compared to revision of a total shoulder replacement. Data from the Australian National Joint Registry demonstrates the majority of hemiarthroplasties are revised to rTSA.[34] Sheh et al. found fewer hemiarthroplasty patients revised to rTSA required bone grafting compared to the TSA group.[37] Similarly, a greater number of TSA patients required re-revision at 5 years.[37] Overall satisfaction levels following revision of a hemiarthoplasty to TSA may be modest. Two case series demonstrate dissatisfaction in 16%–47% of patients undergoing revision of a hemiarthroplasty. Insertion of a glenoid implant may be more challenging due to asymmetric glenoid wear.[38,39] Ceiling effects have been shown in hip and knee scores and may occur using shoulder scores, this is particularly true in the highest functioning patients.[40–42]

Patients wish to be well informed about arthroplasty surgery, and have high expectations about return to function.[43] Participation in sport, pain relief and the ability to continue work are priorities.[43] However patients may be less concerned about the risk of revision surgery or adverse events, particularly in the younger population.[44] This distinction is important when counselling patients about implants. A fast return to high function may be a greater concern in a younger patient, rather than whether they may need a revision in later life.

This review has limitations. Our inclusion criteria were broad, and outcomes may differ by surgical indication. A subgroup analysis was performed for the survivorship of stemmed implants alone. We were unable to perform further analyses according to other implant types, such as resurfacing or stemless hemiarthroplasty and TSA. We did not stratify by implant brand as this is known to influence revision rates.[35] This may lead to an overestimate of revision risk when the underperforming implants are included. For example Levy et al. used metal-backed glenoid components.[26] The earlier metal-backed glenoids were shown to have a higher failure rate compared to polyethelene components, however this may not be true of the more modern metal backed glenoids.[45,46] On a national scale, differences in revision risk for stemmed, short stemmed and resurfacing implants did not reach statistical significance.[12] We assessed survivorship according to 1-Kaplan-Meier rather than using a competing risks method. This does not incorporate the risk of patient death into the analysis, and it is arguably a more appropriate method of presenting implant failure.[47] Given the age of the population and size of the groups in this review this is likely to have a very limited effect.

The improvement in shoulder scores occurred in patients who reached the follow-up period and did not undergo a revision procedure, which may result in an overestimation of the true effect. We were unable to estimate the rate of post-operative improvement in shoulder scores. Speed of recovery may be of particular importance to younger patients who are keen to return to employment and sports. Further investigation in this area is warranted.

Conclusion

The number of young patients undergoing shoulder replacements is increasing. This review provides a summary of the best available evidence to guide patients and clinicians. Significant improvement in post-operative shoulder scores were seen in both hemiarthroplasty and TSA at mid-term follow-up in patients younger than 65 years. Case series data revealed 80% of hemiarthroplasties and 75% of TSA lasted 20 years**.**

Contributorship

All authors were directly involved in planning the review. AD & TL performed the search, study selection and analysis. SS provided additional input on study selection. AD wrote the first draft of the manuscript. All authors reviewed and edited the manuscript and approved the final version of the manuscript.

Declaration of conflicting interests

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