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Shoulder arthroplasty volume standards: the more the better?

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Abstract

Introduction The wide use of hip and knee arthroplasty has led to implementation of volume standards for hospitals and surgeons. For shoulder arthroplasty, the effect of volume on outcome has been researched, but no volume standard exists. This review assessed literature reporting on shoulder arthroplasty volumes and its relation to patient-reported and functional outcomes to define an annual volume threshold.

Materials and methods MEDLINE and EMBASE were searched for articles published until February 2018 reporting on the outcome of primary shoulder arthroplasty in relation to surgeon or hospital volume. The primary outcome was predefined as any patient-reported outcome. The secondary outcome measures were length of stay, costs, rates of mortality, complications, readmissions, and revisions. A meta-analysis was performed for outcomes reported by two or more studies.

Results Eight retrospective studies were included and did not consistently show any associations of volume with in-hospital complications, revision, discharge to home or cost. Volume was consistently associated with length of stay (shorter length of stay for higher volume) and in-hospital complications (fewer in-hospital complications for higher volume). It was not consistently associated with mortality. Functional outcomes were not reported.

Conclusions There is insufficient evidence to support the concept that only the number of shoulder arthroplasties annually performed (either per hospital or per surgeon) results in better patient-reported and functional outcomes. Currently, published volume thresholds are only based on short-term parameters such as length and cost of hospital stay.

Keywords Shoulder arthroplasty · Surgeon volume · Guidelines · Hospital volume · Volume standards

Introduction

The use of shoulder arthroplasty has increased during the last decade [1]. In an effort to improve outcomes and decrease health care cost by centralizing orthopaedic surgical care, minimal volume standards for total knee arthroplasty and total hip arthroplasty have been proposed [2]. However, reported evidence-based volume thresholds are variable (28–35 hip and 12–50 knee arthroplasties per surgeon per year) [3–6]. Similarly, better outcomes for patients undergoing shoulder arthroplasty by higher-volume surgeons are reported and an annual volume of less than 5 procedures per surgeon has recently been suggested as low volume as it is associated with lower-quality outcomes [7]. These statements may hold important implications for national guidelines and health care policy, as orthopaedic units may be denied to perform arthroplasties when the annual surgeon or hospital volumes are below a certain threshold. Guidelines regarding shoulder arthroplasty volume are currently under preparation [8]. The present paper aimed to systematically review and meta-analyze if shoulder arthroplasty volume is related to patient-important outcomes and if it is possible to define an annual volume threshold for performing shoulder arthroplasty.

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Materials and methods

This study was conducted according to the PRISMA statement [9]. A literature search was performed for studies reporting on annual shoulder arthroplasty volume (both per hospital and per surgeon) and patient outcome. Shoulder arthroplasty comprised anatomic total shoulder arthroplasty (TSA), shoulder hemi-arthroplasty (SHA), shoulder surface replacement (SSR) and reverse shoulder arthroplasty (RSA). We also included stemless, short-stem and surface replacement designs. EMBASE and MEDLINE were searched from inception until February 2018 with the help of a medical librarian (Table 1). Based on title and abstract, two authors (BWK and MF) selected potentially relevant articles meeting the following inclusion criteria: (1) an original report (all study designs), (2) inclusion of patients treated with surgical procedures TSA, SHA, SSR or RSA, (3) report of surgeon or hospital volume, and (4) report of a clinical and/or patient-reported outcome. We excluded case reports and review articles. The bibliographies of all retrieved articles and reviews were manually searched for additional potentially relevant references. Discrepancies between investigators were resolved by discussion.

Outcomes were extracted in a predefined database and summarized. The predefined primary outcome was any patient-reported outcome. Secondary outcomes were length of stay (LOS), mortality, complications, readmissions, revisions, and costs. Volumes based on study period were converted to mean annual volumes. Additionally, the quality of all retrieved studies was assessed using the Newcastle–Ottawa Scale (NOS) [10]. The NOS is a validated tool developed for evaluating cohort studies, including eight items categorized into three groups (selection, comparability and outcomes) [11, 12]. Two authors (BWK and MF) conducted the quality assessments. A total score of five or less was considered low quality, of six or seven was considered moderate quality, and of 8 or 9 was deemed high quality.

A meta-analysis was performed for outcomes that were reported in more than one study. The outcomes of LOS, complications and mortality were considered as the most relevant. To explore whether low volume is associated with worse outcomes, we compared lowest-volume group to all other volume groups for each study in the meta-analysis. In case of missing data, authors of the corresponding studies were contacted. The data regarding length of stay could not be retrieved for one study [13]. Meta-analysis was performed using Revman software (version 5.3, Copenhagen: the Nordic Cochrane Centre, The Cochrane Collaboration,

Table 1 MEDLINE and EMBASE search strategy

#	Query
1	“Surgeons”[Mesh] OR “Hospitals”[Mesh] OR “Orthopedics”[Mesh] OR “Orthopedic Procedures”[Mesh]
2	Surg*[tiab] OR hospital*[tiab] OR center[tiab] OR centers[tiab] OR orthopedic*[tiab] OR orthopaedic*[tiab]
3	“Hospitals, High-Volume“[Mesh] OR “Hospitals, Low-Volume“[Mesh]
4	expertis*[tiab] OR experienc*[tiab] OR volume*[tiab]
5	#1 OR #2 OR #3 OR #4
6	“Shoulder“[Mesh] OR “Shoulder Joint“[Mesh]
7	Shoulder*[tiab]
8	#6 OR #7
9	“Arthroplasty, Replacement“[Mesh] OR “Joint Prosthesis”[Mesh]
10	arthroplast*[tiab] OR replacem*[tiab] OR prosthes*[tiab] OR TSP[tiab] OR TJP[tiab] OR TJA[tiab]
11	#9 OR #10
12	#5 AND #8 AND #11 (“Surgeons”[Mesh] OR “Hospitals”[Mesh] OR “Orthopedics”[Mesh] OR “Orthopedic Procedures”[Mesh] OR Surg*[tiab] OR hospital*[tiab] OR center[tiab] OR centers[tiab] OR orthopedic*[tiab] OR orthopaedic*[tiab] OR “Hospitals, High-Volume“[Mesh] OR “Hospitals, Low-Volume“[Mesh] OR expertise*[tiab] OR experienc*[tiab] OR volume*[tiab]) AND (“Shoulder“[Mesh] OR “Shoulder Joint“[Mesh] or Shoulder*[tiab]) AND (“Arthroplasty, Replacement“[Mesh] OR “Joint Prosthesis“[Mesh] OR arthroplast*[tiab] OR replacem*[tiab] OR prosthes*[tiab] OR TSP[tiab] OR TJP[tiab] OR TJA[tiab])
13	(“Hospitals, High-Volume“[Majr] OR “Hospitals, Low-Volume“[Majr] OR volume*[ti] OR experience*[ti] OR surgeon*[ti])
14	#12 AND #13 (“Surgeons”[Mesh] OR “Hospitals”[Mesh] OR “Orthopedics”[Mesh] OR “Orthopedic Procedures“[Mesh] OR Surg*[tiab] OR hospital*[tiab] OR center[tiab] OR centers[tiab] OR orthopedic*[tiab] OR orthopaedic*[tiab] OR “Hospitals, High-Volume”[Mesh] OR “Hospitals, Low-Volume”[Mesh] OR expertise*[tiab] OR experienc*[tiab] OR volume*[tiab]) AND (“Shoulder“[Mesh] OR “Shoulder Joint“[Mesh] or Shoulder*[tiab]) AND (“Arthroplasty, Replacement“[Mesh] OR “Joint Prosthesis“[Mesh] OR arthroplast*[tiab] OR replacem*[tiab] OR prosthes*[tiab] OR TSP[tiab] OR TJP[tiab] OR TJA[tiab]) AND (“Hospitals, High-Volume“[Majr] OR “Hospitals, Low-Volume“[Majr] OR volume*[ti] OR expertis*[ti] OR experienc*[ti] OR surgeon*[ti])

2014). For continuous data, we employed inverse variance random-effects models, producing mean differences. For dichotomous data, we employed Mantel–Haenszel random-effects models, producing odds ratios (OR). *P* values < 0.05 for effect sizes were considered statistically significant. Heterogeneity was assessed using the I^2 statistic.

Results

The literature search revealed 141 potentially eligible papers (Fig. 1). Following abstract screening and full-text selection, eight original studies were included [13–20]. All were retrospective cohort studies, including a total of 340,646 patients. The NOS quality scores are presented in Table 2. Three of the included studies were considered as low quality, four were considered as moderate quality, and one was considered as high quality. All studies chose volume thresholds arbitrarily, except for one [19] which chose thresholds based on differences in length of stay and cost. All studies followed patients until discharge only, except for one study on hospital volume, that recorded 60-day mortality and 2-year revision rates [16] No studies employed patient-reported outcomes.

Table 2 Quality assessment according to the Newcastle–Ottawa Scale [10]

	Number of stars from Newcastle–Ottawa scale[a]			
	Selection	Comparability	Outcome	Total
Hammond et al. 2003 [15]	2	1	1	4
Lyman et al. 2005 [16]	4	2	2	8
Jain et al. 2004 [17]	3	0	1	4
Jain et al. 2013 [18]	4	0	2	7
Singh et al. 2014 [20]	4	0	1	5
Singh and Ramachandran 2015 [13]	4	0	2	6
Day et al. 2015 [14]	2	0	2	6
Ramkumar et al. 2017 [19]	2	0	2	6

[a]Higher quality studies are reflected by higher numbers of stars in each category. The maximum possible star scores for each study criteria are 4 for selection, 2 for comparability, and 3 for outcome or exposure, with a total possible score of 9

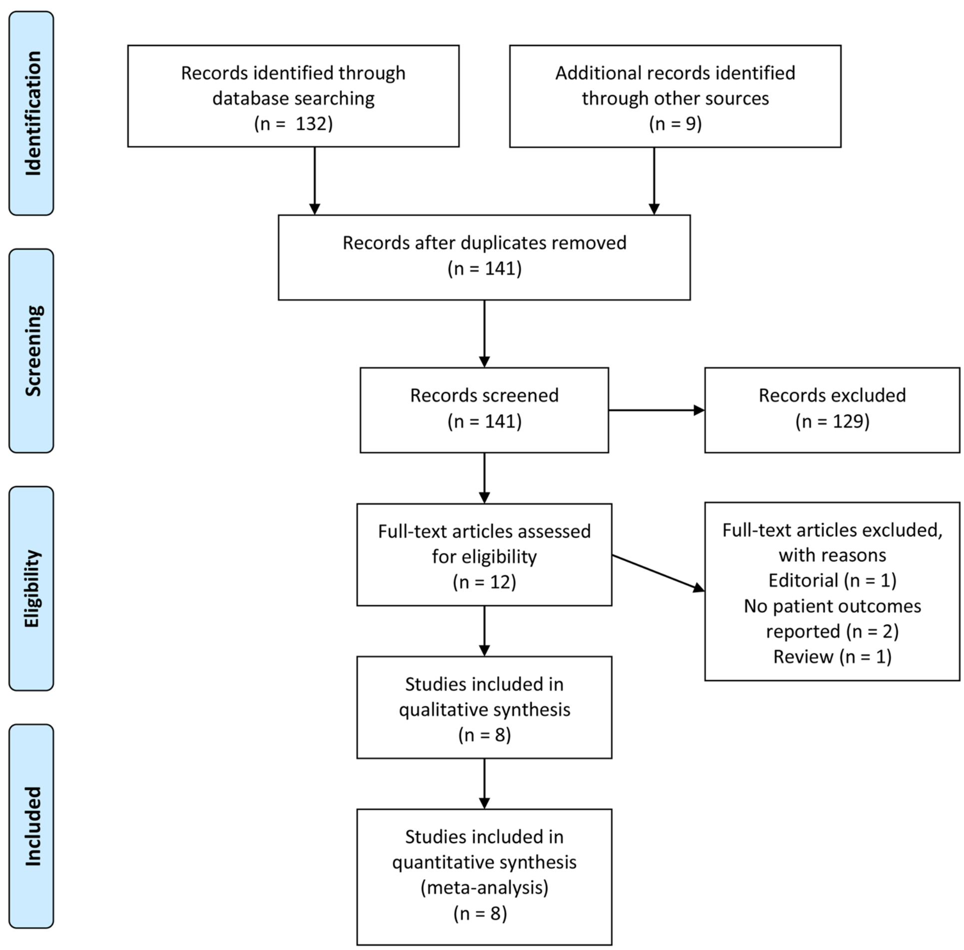

Fig. 1 PRISMA chart of the performed literature search

Hospital volume

Five studies evaluated hospital volume (Table 3) [13, 15–17, 19]. Definitions of low volume varied from ≤ 3 to ≤ 7 cases per year, whereas definitions of high volume varied from ≥ 10 to ≥ 25 cases per year.

The studies did not consistently show associations of volume with LOS, in-hospital complications, revision, and discharge to home, and cost. Compared to the lowest-volume groups, the higher-volume groups had shorter LOS (mean difference, 0.48 days, Fig. 2), fewer in-hospital complications (OR 1.40, Fig. 3), and fewer cases of in-hospital mortality (OR 2.02, Fig. 4). Yet, the absolute differences in complication rates (4.0% for the lowest-volume groups, 2.8% for the higher-volume groups) and mortality rates were very small (0.2 and 0.1%, respectively). Volume was associated with in-hospital complications; however, complications were lowest in the medium-volume group (8–13 cases per year) in one study,[15] while being highest in the medium-volume group (5–9 cases per year) in the other study [17]. The only study with post-discharge follow-up did not find differences in 2-year revision rates among different volume groups, but did find increased 60-day readmission rates in the low-volume hospitals [16]. For most outcome variables that were found to be associated with volume in individual studies (length of stay, 60-day readmission, revision during the primary hospital stay, intra-operative fracture, discharge to home, cost) the lowest-volume groups had worst outcomes.

Surgeon volume

Six studies evaluated the effect of surgeon volume (Table 4) [14, 15, 17–20]. Definitions of low volume varied from ≤ 0.8 to ≤ 5 cases per year, whereas definitions of high volume varied from ≥ 4.4 to ≥ 20 cases per year.

Table 3 Studies on hospital volume

Article (n)	Definition of annual volumes	Exclusion criteria	Follow-up	Outcome associated with hospital volume	Annual volume threshold for best outcome	Annual volume threshold for worst outcome	Outcome not associated with hospital volume
Hammond et al. 2003 [15] (*n* = 1868 TSA)	≤ 7 [a] 8–13 ≥ 14	None	No follow-up after discharge	Length of stay	8–13	≤ 7	Hospital costIn-hospital complications
Lyman et al. [16] (*n* = 1,307 TSA)	≤ 3 4–12 > 12	Trauma	24 months after discharge	60-day readmission	> 12	≤ 3	60-day mortality Revision within 24 months Length of stay Hospital cost
Jain et al. 2004 [17] (*n* = 12,494 TSA 17,252 SHA)	≤ 4 5–9 ≥ 10	None	No follow-up following discharge	TSA In-hospital complications SHA Discharge to home	TSA ≥ 10 SHA ≥ 10	TSA 5–9 SHA 5–9	TSA In-hospital mortality Discharge to home SHA In-hospital mortality In-hospital complications
Ramkumar et al. 2017 [19] (*n* = 9546 TSA/RSA/SHA)	≤ 3 4–14 ≥ 15	None	No follow-up after discharge	Length of stay Cost	≥ 15	≤ 3	None
Singh and Ramachandran 2015 [13] (*n* = 256,934 TSA)	≤ 4 5–9 10–14 15–24 ≥ 25	None	No follow-up after discharge	Discharge to home Length of stay Revision [b] Blood transfusion Post-arthroplasty fracture	≥ 25 ≥ 25 10–14 ≥ 25 15–24	≤ 4 ≤ 4 ≤ 4 ≤ 4 ≤ 4	Mortality

TSA total shoulder arthroplasty, *SHA* shoulder hemi-arthroplasty, *RSA* reversed shoulder arthroplasty

[a]Mean annual values based on 7-year totals

[b]Only revision during hospital stay after index operation

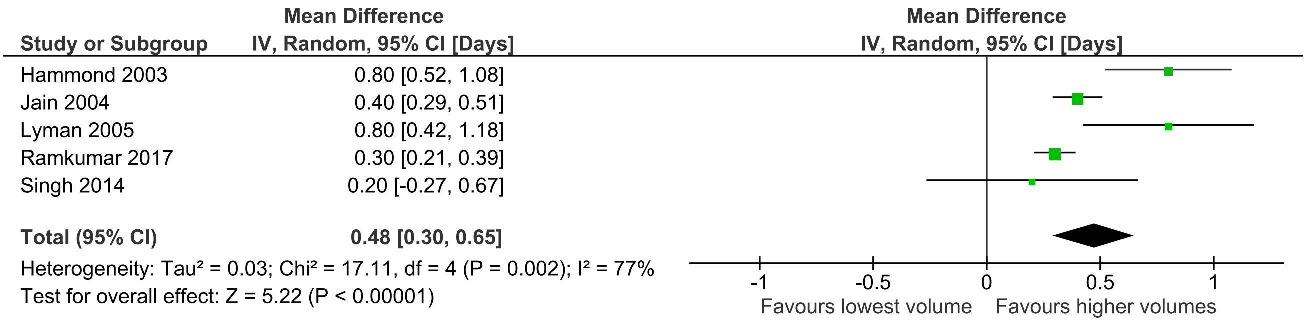

Fig. 2 Forest plot of length of stay for the lowest-volume groups (≤3 to ≤7 cases per year) versus higher-volume groups for studies on hospital volume

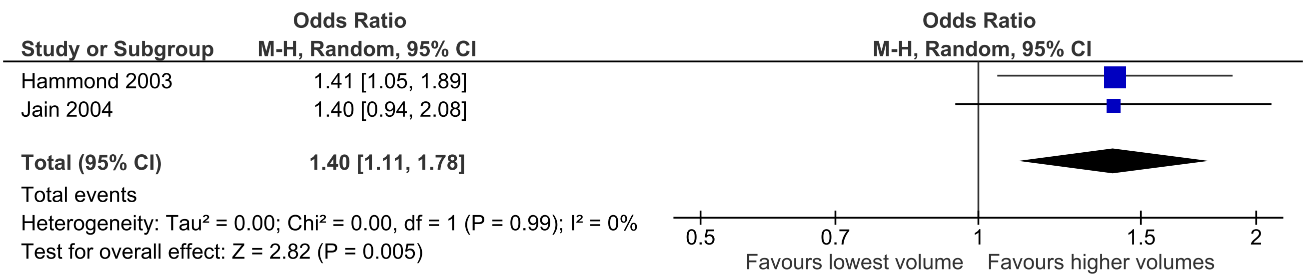

Fig. 3 Forest plot of in-hospital complications for the lowest-volume groups (≤3 to ≤7 cases per year) versus higher-volume groups for studies on hospital volume

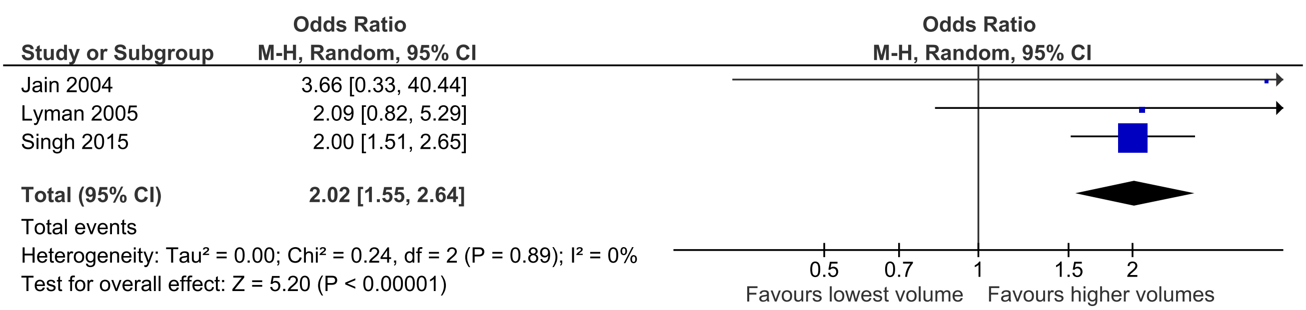

Fig. 4 Forest plot of in-hospital mortality for the lowest-volume groups (≤3 to ≤7 cases per year) versus higher-volume groups for studies on hospital volume

Compared to the lowest-volume groups, the higher-volume groups had shorter LOS (mean difference, 0.79 days, Fig. 5) and fewer in-hospital complications (OR 1.59, Fig. 6). There was a non-significant trend for fewer cases of in-hospital mortality in the higher-volume groups (OR 1.61, Fig. 7). Yet, the absolute differences in complication rates (3.2% for the lowest-volume groups, 2.3% for the higher-volume groups) and mortality rates were very small (0.5 and 0.3%, respectively). The studies did not consistently show associations of volume with discharge to home, and cost. For most variables that were found to be associated with volume in individual studies (length of stay, 60-day readmission, revision during the primary hospital stay, intra-operative fracture, discharge to home, blood loss, cost), the lowest-volume groups had worst outcomes.

Discussion

We reviewed the literature on the association of hospital and surgeon annual volume with outcome after shoulder arthroplasty. We found that the volume thresholds studied in the literature are variable and arbitrary, and that the relationship between volume and patient-important outcomes at

Table 4 Studies on surgeon volume

Article (n)	Definition of annual volumes	Exclusion criteria	Follow-up	Outcome associated with surgeon volume	Annual volume threshold for best outcome	Annual volume threshold for worst outcome	Outcome not associated with surgeon volume
Day et al. 2015 [14] (*n* = 31,002 TSA/RSA/SHA)	≤ 5 6–10 11–20 > 20	None	No follow-up after discharge	Length of stay	> 20	≤ 5	None
Hammond et al. 2003 [15] (*n* = 1868 TSA)	≤ 0.8[a] 0.9–4.3 ≥ 4.4	None	No follow-up after discharge	Length of stay Complications	0.9–4.3 0.9–4.3	≤ 0.8 ≤ 0.8	Cost
Jain et al. 2004 [17] (*n* = 12,494 TSA 17,252 SHA)	≤ 1 2–4 ≥ 5	None	No follow-up following discharge	TSA Length of stay SHA In-hospital complications Discharge to home Length of stay	TSA ≥ 5 SHA ≥ 5 ≥ 5 ≥ 5	TSA ≤ 1 SHA ≤ 1 2–4 ≤ 1	TSA In-hospital mortality In-hospital complications Discharge to home SHA In-hospital mortality
Jain et al. 2013 [18] (*n* = 9067 SHA)	≤ 4 5–14 ≥ 15	Non-trauma	No follow-up after discharge	Length of stay Hospital cost	≥ 15 ≥ 15	≤ 4 ≤ 4	Mortality In-hospital complications
Ramkumar et al. 2017 [19] (*n* = 9546 TSA/RSA/SHA)	≤ 4 5–14 ≥ 15	None	No follow-up after discharge	Length of stay-Cost	≥ 15 ≥ 15	≤ 4 ≤ 4	None
Singh et al. 2014 [20] (*n* = 711 TSA; 277 HSA; 188 RSA)	TSA ≤ 5 6–15 ≥ 16 HSA ≤ 1 2–4 ≥ 5 RSA ≤ 4 5–8 ≥ 9	Trauma	No follow-up after discharge	TSA Blood loss Operative time Length of stay SHA Length of stay Blood loss Operative time RSA Blood loss Operative time	TSA ≥ 16 ≥ 16 ≥ 16 SHA ≥ 5 ≥ 5 ≥ 5 RSA ≥ 9 ≥ 9	TSA ≤ 5 ≤ 5 6–15 SHA ≤ 1 ≤ 1 ≤ 1 RSA 5–8 ≤ 4	TSA None SHA None RSA Length of stay

TSA total shoulder arthroplasty, *SHA* shoulder hemi-arthroplasty, *RSA* reversed shoulder arthroplasty

[a]Mean annual values based on 7-year totals

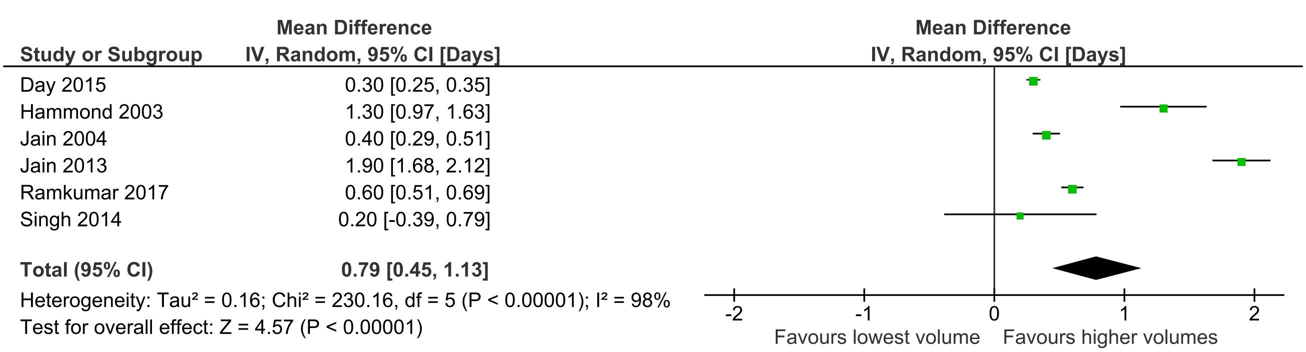

Fig. 5 Forest plot of length of stay for the lowest-volume (groups ≤ 0.8 to ≤ 5 cases per year) versus higher-volume groups for studies on surgeon volume

Fig. 6 Forest plot of in-hospital complications for the lowest-volume (groups ≤ 0.8 to ≤ 5 cases per year) versus higher-volume groups for studies on surgeon volume

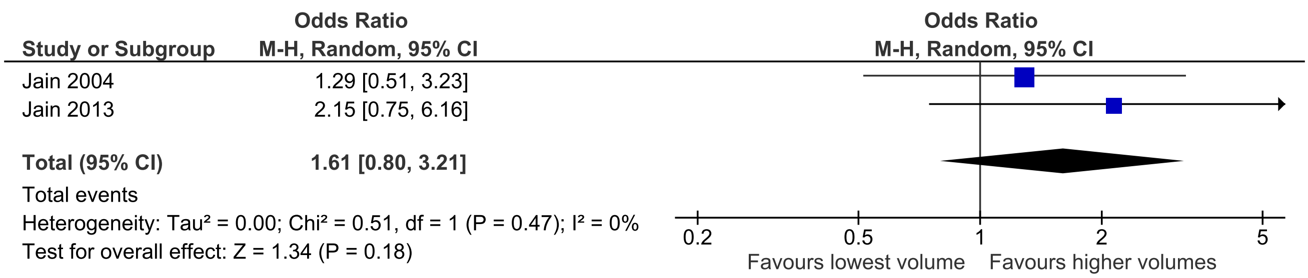

Fig. 7 Forest plot of in-hospital mortality for the lowest-volume (groups ≤ 0.8 to ≤ 5 cases per year) versus higher-volume groups for studies on surgeon volume

outpatient follow-up has not been studied. Unfortunately, all but one study examined only outcome parameters pertaining to the initial hospital stay and found a consistent relationship of shorter length of stay and decreased cost for high-volume surgeons. Complications and mortality rates were slightly higher for the lowest-volume hospitals and surgeons; however, these differences were not clinically significant.

Our paper has several limitations. First, most included studies did not follow the patients after discharge and did not record patient-reported outcome measures, functional outcome scores or complications such as deep infection, dislocation or loosening. This limits the ability to judge the value of applying volume standards to shoulder arthroplasty. Second, the included studies were generally low to moderate quality, probably resulting in similar quality of our data synthesis. Third, despite a strict methodology it is possible that our systematic search has still missed relevant studies.

Volume standards are used as health care quality indicators for ample elective operative procedures, including arthroplasties in orthopedics [2, 8]. Assuming there is a need for continued operative exposure to maintain technical skills, the effect of surgeon volume on patient outcome seems rational. A recent report suggested to define surgeon volume of less than five shoulder arthroplasties per year as low volume,[7] based on mostly the same surgeon volume studies as reviewed here. However, we caution against defining volume thresholds based on studies without patient-important outcomes and without follow-up beyond patient discharge. After all, it is the long-term outcome that matters to patients and that influences re-operations, total cost and, thus, health care value. In contrast to shoulder arthroplasty, studies on hip and knee arthroplasty have used patient-reported outcomes and longer follow-up to support the importance of volume [5, 21, 22].

Given the absence of a proven relation of surgeon volume with eventual patient outcome, applying solely a volume minimum to ensure health care quality does not seem to be justified. Apart from the annual number of cases per surgeon, technical success and patient outcome may be determined by learning curve, dexterity and total number of career cases [23]. Additionally, it is suggested that a completed formal fellowship training is likely to further improve surgical technique [24]. Also, although not supported by any data, a low-volume shoulder arthroplasty surgeon who performs other open shoulder operations, in high volume may be well fitted to perform a shoulder arthroplasty due to familiarity with the surgical anatomy of the shoulder. Even performing total hip arthroplasties may be more useful than performing shoulder arthroscopies, as the former more closely resembles shoulder arthroplasty.

Compared to surgeon volume, hospital volume as a parameter may even better encompass the familiarity of a shoulder unit as a whole to care for shoulder arthroplasty patients. As such, one might expect 'hospital volume' to reflect quality of care, including nursing, specialized physical therapy, and logistics [25] better than 'surgeon volume'. Still, hospital volume did not show better correlations with outcome than surgeon volume.

Until better evidence becomes available to estimate volume thresholds for shoulder arthroplasty, surgeons in shoulder units should measure and compare the outcomes of their patients. Although this concept is not supported by comparative data, mentorship of underperforming surgeons by well-performing surgeons may enhance surgical performance and outcomes for patients of the entire unit [26]. Comparing outcomes, including patient-reported outcomes, [27] among surgeons and among hospitals may very well be facilitated by national shoulder arthroplasty registries [28].

In conclusion, currently available literature does not provide sufficient evidence to support the concept that performing more shoulder arthroplasties annually (either per hospital or per surgeon) results in better patient-reported and functional outcomes. Currently published volume thresholds are only based on short-term parameters such as length and cost of hospital stay. Therefore, we are unable to define a volume threshold for shoulder arthroplasty, neither at the level of individual surgeons nor at the level of individual hospitals.

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Compliance with ethical standards

Conflict of interest Dr. Kooistra, dr. Flipsen, dr. van den Bekerom, dr. van Raaij, dr. Gosens and dr. van Deurzen declare that they have no conflict of interest.

Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors.

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