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Is there a relationship between surgical volume and outcome for total elbow arthroplasty? A systematic review

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- *Purpose*: Total elbow arthroplasty (TEA) is rarely performed compared to other arthroplasties. For many surgical procedures, literature shows better outcomes when they are performed by experienced surgeons and in so-called 'high-volume' hospitals. We systematically reviewed the literature on the relationship between surgical volume and outcomes following TEA.
- *Methods:* A literature search was performed using the MEDLINE, EMBASE and CINAHL databases. The literature was systematically reviewed for original studies comparing TEA outcomes among hospitals or surgeons with different annual or career volumes. For each study, data were collected on study design, indications for TEA, number of included patients, implant types, cut-off values for volume, number and types of complications, revision rate and functional outcome measures. The methodological quality of the included studies was assessed using the Newcastle–Ottawa Scale.
- *Results:* Two studies, which included a combined 2301 TEAs, found that higher surgeon volumes were associated with lower revision rates. The examined complication rates did not differ between high- and low-volume surgeons. In one study, low-hospital volume is associated with an increased risk of revision compared to high-volume hospitals, but for other complication types, no difference was found.
- *Conclusions:* Based on the results, the evidence suggests that high-volume centers have a lower revision rate in the long term. No minimum amount of procedures per year can be advised, as the included studies have different cut-off values between groups. As higher surgeon- and center-volume, (therefore presumably experience) appear to yield better outcomes, centralization of total elbow arthroplasty should be encouraged.

Keywords
- hospital volume
- surgeon volume
- total elbow arthroplasty
- complications
- revisions
- outcomes

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Introduction

Total elbow arthroplasty (TEA) is rarely performed compared to other arthroplasties (1). According to the Dutch Arthroplasty register, TEA was performed 81 times in 2019 and total knee and hip arthroplasty were performed 25,859 and 33,248 times, respectively (1). The large difference in incidence could be because of small numbers of patients with an indication for TEA and perhaps also the lack of (personal) experience and unfamiliarity with this type of surgery. Through the years, TEA has undergone several changes concerning indications and operative technique, but the complication rate and the need for revision are still higher than after knee and hip arthroplasty (2, 3, 4, 5, 6).

For many surgical procedures, the literature shows better outcomes when these are performed by experienced surgeons and in high-volume hospitals. This includes several orthopedic procedures and arthroplasties (7, 8, 9, 10, 11, 12, 13). Besides, in 2011, Sanchez-Sotelo claimed

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that the success of TEA depends on the familiarity of the surgeon with the procedure (14). Unlike other procedures, the literature to support this statement is limited, with only the advice from the Scottish Arthroplasty register which has analyzed the revision rates of TEA with a cut-off point of 10 arthroplasties a year (12).

This study aimed to systematically review the literature on the relationship between surgical volume, which is the best available measure for surgeon experience, and patient outcomes following TEA. We hypothesized that patients undergoing TEA in lowest-volume hospitals or by lowest-volume surgeons would have higher revision and complication rates, when compared to higher-volume hospitals or higher-volume surgeons, respectively.

Methods

The review process was conducted according to the preferred reporting items for systematic reviews and meta-analyses (PRISMA) guidelines and not registered in PROSPERO.

Identification of studies

A systematic literature search was performed using the MEDLINE, EMBASE and CINAHL databases in May 2022 with the aid of a medical librarian (Table 1). Original studies comparing TEA outcomes among hospitals or surgeons with different annual or career volumes were included. Duplicate studies were removed and congress abstracts, case reports and review articles were excluded. In case of missing data, the corresponding authors were contacted. Reference lists of the included papers were manually searched for other potentially eligible reports (Table 1).

Study selection

Two authors (BK and AP) independently screened titles and abstracts and subsequently retrieved full-text articles for suitability. Disagreements were settled by discussion between these authors. No restrictions were applied regarding language, publication year, TEA manufacturer, reported outcome measures or length of follow-up. TEA was defined as any ulnohumeral prosthesis.

Data extraction

Data from the selected studies were extracted using a predefined database. In this database, patient groups were divided into low-surgeon volume, medium-surgeon volume and high-surgeon volume or into low hospital volume, medium hospital volume and high hospital volume. No cut-offs for these volumes were defined upfront as the chosen cut-offs differ between studies. Data extraction was performed by one author and checked by a second one. Disagreements were resolved by discussion between the two authors.

Table 1 Search terms used for the literature review.

MEDLINE
('Hospitals, High-Volume'[Mesh] OR 'Hospitals, Low-Volume'[Mesh] OR 'Surgery Department, Hospital'[Mesh] 'Orthopedic Procedures'[Mesh] OR 'Orthopedics'[Mesh] OR 'Surgeons'[Mesh] OR hospital volume*[tiab] OR surgical volume*[tiab] OR surgeon volume*[tiab] OR surgeons volume*[tiab] OR high volume*[tiab] OR low volume*[tiab] OR patient volume*[tiab] OR expertis*[tiab] OR experience*[tiab] OR surgeon*[ti] OR cases[ti] OR hospital*[tiab])
AND
('Elbow'[Mesh] OR 'Elbow Joint'[Mesh] OR 'Arthroplasty, Replacement, Elbow'[Mesh] OR elbow*[tiab]) AND ("Arthroplasty, Replacement"[Mesh] OR "Joint Prosthesis"[Mesh] OR arthroplast*[tiab] OR replacem*[tiab] OR prosthes*[tiab] OR TEA[tiab] OR TJP[tiab] OR TJA[tiab] OR TEP[tiab])
EMBASE
1. high volume hospital/ or low volume hospital/ or hospital department/ or orthopedic surgery/ or orthopedics/ or surgeon/ or orthopedic surgeon/
2. ((hospital* or surgical* or surgeon* or surgeon* or high* or low* or patient*) adj3 volume*).ti,ab,kw.
3. (expertis* or experience* or hospital*).ti,ab,kw. or (surgeon* or cases).ti.
4. 1 or 2 or 3
5. elbow/ or exp elbow replacement/ or elbow*.ti,ab,kw.
6. exp replacement arthroplasty/ or joint prosthesis/ or exp elbow prosthesis/ or (arthroplast* or replacem* or prosthes* or TEA or TJP or TJA or TEP). ti,ab,kw.
7. and 5 and 6
CINAHL
(MH 'Hospitals+') OR ((MH 'Orthopedics') OR (MH 'Specialties, Surgical')) OR (MH 'Surgeons') OR (TI (hospital volume* or surgical volume* or surgeon volume* or surgeons volume* or high volume* or low volume* or patient volume* or expertis* or experience* or hospital*) OR AB (hospital volume* or surgical volume* or surgeon volume* or surgeons volume* or high volume* or low volume* or patient volume* or expertis* or experience* or hospital*) OR TI (surgeon* or cases))
AND
(MH 'Elbow') OR (MH 'Elbow Joint') OR (MH 'Arthroplasty, Replacement, Elbow') OR (TI elbow* OR AB elbow*)
AND
(MH 'Arthroplasty, Replacement+') OR (MH 'Joint Prosthesis') OR (TI (arthroplast* or replacem* or prosthes* or TEA or TJP or TJA or TEP) OR AB (arthroplast* or replacem* or prosthes* or TEA or TJP or TJA or TEP))

For each study, data were collected on study design, country, indications used for TEA, number of included patients, implant types, cut-off values for low, medium and high volume, number and types of complications, revision rate and functional outcome measures. Revision was selected as the primary outcome, considering this is a firm endpoint, which is expected to be registered more accurately than patient-reported outcomes in databases used for studies on the present study question.

Quality of included studies

The methodological quality of the included studies was assessed using the Newcastle–Ottawa Scale (NOS). The NOS is a validated tool developed for evaluating observational studies, including eight items categorized into three groups (selection, comparability and outcomes) (15, 16). Two authors (BK and AP) conducted the quality assessment. A total score of five or less was considered low quality, whereas six or seven was considered moderate quality and 8 or 9 was deemed high quality.

Data synthesis

No synthesis of data was performed because of a high amount of heterogeneity in study design and outcome reporting.

Results

Study selection

Figure 1 shows the process of study selection. The literature search identified 1218 potentially eligible papers. Following abstract screening and full-text selection, five original studies were included. All were retrospective cohort studies and included a total of 12,094 patients.

Study characteristics

Table 2 summarized the characteristics of the five included studies. All articles were retrospective cohort studies. Of these studies, two focused on surgeon volume and three studies on hospital volume. The sample size varied between 912 and 7256 patients. The definitions for low, medium and high volume of either surgeon or hospital for all included studies are presented in Table 3.

Quality of included studies

The evaluation of the quality of the included studies using the NOS revealed high quality as can be seen in Table 4. All studies scored well on the NOS, considering they all used databases to assemble their cohorts. This allows us to say with certainty that approximately all performed TEAs are included in these registries and that the majority of complications of interest are registered as well. The period of inclusion and length of follow-up in the studies varied between 9 and 24 years and is an adequate length of time to detect revisions. This all leads to a relatively low risk of bias in the included studies.

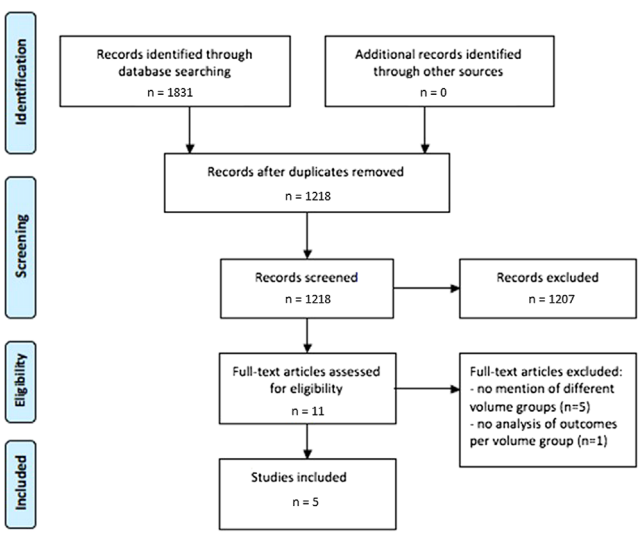

Figure 1
PRISMA flowchart.

Surgeon volume

The first study performed by Gay *et al.* (17) was performed in New York and used data from the Statewide Planning and Research Cooperative System database from the New York State Department of Health from 1997 to 2006. A total of 1155 TEAs were included in this study. The surgeries were performed by a total of 373 surgeons of which 90% had no prior documented case of TEA in the used database. Of the remaining 10%, half had performed 1–19 TEAs and the other half had performed over 20. The study found several differences between surgeons with no prior experience compared to surgeons with prior experience. It reports that surgeons without experience treated all patients who died and the revision rate was higher in the patient group treated by non-experienced surgeons (6.8% vs 2.8%; $P = 0.10$). These findings were not statistically significant. Furthermore, no difference was found in complication rates based on surgeon volume.

The second study performed by Jenkins *et al.* collected data from the Scottish national arthroplasty dataset from January 1991 to December 2008 (12). A total of 1146 TEAs were included in this study and 51 surgeons performed all registered TEAs. Of these surgeons, the mean amount of TEA procedures was calculated; 27 performed up to 4 procedures, 6 performed between 5 and 9 procedures and 18 surgeons performed more than 10 procedures annually. The study further specified that only two surgeons performed an average of more than ten TEA's per year consistently. As can be seen in Table 5, implant survivorship (measured with Kaplan–Meier) at 10 and 18 years differed between the three surgeon groups with the best results being found in the group of surgeons performing more than ten TEAs per year. No statistically significant differences were found regarding infection, dislocation or periprosthetic fracture following TEA between groups.

Hospital volume

The third included study performed by Krenek *et al.* included patients using California's Office of Statewide Health Planning and Development and included 1625 TEAs from 1995 to 2005 (18). Hospital volume was categorized by using the average number of TEAs performed annually. The categories are the top 20th percentile hospitals as the high-volume group, the next 40th percentile as the intermediate group and the lowest 40th percentile as the low-volume group. Within these groups, 146 TEAs were performed in the low-volume group, 467 in the intermediate group and 1012 in the high-volume group. The study reports complication rates which included

Table 2 Study characteristics

Reference	Data source	Country	Patients, *n*	Implant type	Indications
Gay *et al.* (17)	Statewide database	USA	1155	Not mentioned	All
Jenkins *et al.* (13)	National register	Scotland	1146	Not mentioned	All
Krenek *et al.* (18)	Statewide database	USA	1625	Not mentioned	All
Skytta *et al.* (19)	National register	Finland	912	Souter-Strathclyde	Rheumatoid arthritis
Poff *et al.* (20)	Nationwide readmissions database	USA	7256	Not mentioned	All

infection, revision, repeat surgery, pulmonary embolism and mortality but does not report these numbers for the different groups. The authors state that no relationship between complications and hospital volume was found using regression analysis.

The fourth included study performed by Skytta *et al.* derived their data from the Finnish Arthroplasty Register and included 1612 TEAs performed between 1982 and 2006 (19). A comparison was made between hospitals being specialized in the treatment of rheumatoid arthritis (considered high volume) and non-specialized hospitals (considered low volume). The study included a total of nine different TEA designs; however, our outcome of interest is only shown for the Souter-Strathclyde prosthesis ($n = 912$). The study found a 1.5-fold (95% CI: 1.1–2.2) increased risk of revision for low-volume hospitals compared to high-volume hospitals.

The fifth included study performed by Poff *et al.* extracted their data from the Nationwide Readmissions Database and included all TEAs performed from 2010 to 2017, performed from January to October (20). These months were selected to determine the correct 90-day readmission and complication rates. In this study, quartiles were made based on annual hospital volume, and using stratum-specific likelihood ratio, they calculated three strata for statistical purposes. All the groups were compared to each other for both stratifications. This study showed the lowest complication rate in the quartile with the highest annual TEAs (10%) as well as the highest stratum (>21 TEAs per year). No significant differences were clear for revisions, except that the third quartile (6–13 TEAs per year) had the lowest 180-day revision rate. Hospital stay of more than 2 days was also more frequent in higher-volume hospitals; both the fourth quartile (>13 TEAs per year) and highest stratum (>23 TEAs per year).

Discussion

This study systematically reviewed the literature for complications and revision rates after TEA and their relationship with surgeon and hospital volume. All included studies were large retrospective cohort studies with their data gathered from national or state databases.

Previous research has shown that regionalization of complex care and several kinds of orthopedic joint arthroplasty results in lower mortality and reduction in hospitalization time (21, 22, 23, 24, 25). This also leads to better value-based healthcare by lowering costs. With surgeon volume being an important factor resulting in better outcomes in several procedures including orthopedic joint replacements, it is important to examine this correlation in TEA as well. The current study found that higher surgeon volume is associated with a lower revision rate. This could be explained because of surgeon experience, as more procedures per year reflect surgeon experience. The examined complication rates did not differ between high- and low-volume surgeons. Low hospital volume is also associated with an increased risk of revision compared to high-volume hospitals, but for other complication rates, no difference was found.

These outcomes are not completely in line with our hypothesis. While we expected higher complication rates in patients being operated by low-volume surgeons and

Table 3 Results

Reference	Surgeon volume (cases/year)			Hospital volume	Results for different volume groups
	Low	Medium	High		
Gay *et al.* (17)	0	1–19	>19		OR: 2.8 for revision within 5 years for lower-volume surgeons
Jenkins *et al.* (13)	0–4	5–10	>10		18-year revision rates 17% vs 18% vs 11% for low-, medium- and high-volume surgeons. No difference in 10-year complication rate.
Krenek *et al.* (18)				Lowest 40th percentile; Middle 40th percentile; Highest 20th percentile*	No correlation with complication rate
Skytta *et al.* (19)				Specialized RA treatment; Non-specialized RA treatment	1.5-increased risk of revision within 12 years for low-volume hospitals
Poff *et al.* (20)				Quartiles	>21 TEA/year significantly less compications and non-home discharge compared to the other quartiles (<21/year); no differences in revisions.

*No further information provided on exact cut-off points; †only two groups (low- and high volume) are defined in this study.
OR, odds ratio.

Table 4 **Quality assessment** (Newcastle–Ottawa Scale)

Criteria	Reference				
	Gay *et al.* (17)	Jenkins *et al.* (13)	Krenek *et al.* (18)	Skytta *et al.* (19)	Poff *et al.* (20)
Representativeness	+	+	+	+	+
Selection of non-exposed cohort	+	+	+	+	+
Ascertainment of exposure	+	+	+	+	+
Outcome of interest not present at start	+	+	+	+	+
Comparability	1+	1+	1+	1+	1+
Assessment of outcome	+	+	+	+	+
Long enough follow-up	+	+	+	+	+
Adequacy of follow-up	+	+	+	+	+
Total number of allocated stars	8	8	8	8	8

in low-volume hospitals, most outcomes did not differ significantly. This could be explained by the low amount of high-volume surgeons. A second explanation could be the low number of included studies and the heterogeneity of the defined categories between studies and the absence of a uniform way to register complications. A third explanation could be that complex patients are referred to specialized centers.

As stated before, TEA is a rarely performed surgery and this results in difficulties in preparing young surgeons to perform this procedure. Originally, TEA was mostly performed in the treatment of rheumatoid arthritis. In recent years, this shifted to mostly being performed for traumatic and posttraumatic deformities (17, 26). This change is caused by the improved treatment of rheumatoid arthritis with disease-modifying anti-rheumatic drugs (DMARDs), which result in a subsequent decrease in the need to perform arthroplasty in this patient group. Therefore, the low incidence of TEA can be partially caused by unfamiliarity with the procedure. In trauma patients, TEA will continue to be performed as it has been shown that TEA results in better short-term and medium-term outcomes compared to ORIF in elderly trauma patients who suffered distal humeral fractures (27). However, TEA performed for rheumatoid arthritis is more prone to fail because of aseptic loosening, and TEA performed for trauma and traumatic sequelae is more prone to failing because of infections (26); that could make a difference in modes of failure between short-term complication (infection) and long-term revision rates (loosening). As both of these are used as outcome measures, interpretation of 'complications' is difficult.

A recent survey performed by Abdelmalek and Donaldson in the UK asked members of the British Elbow and Shoulder Society about the current treatment and possible improvements in the future (28). The majority of respondents agreed that an annual minimum number of performed TEAs should be required to continue performing TEA surgery. They suggested the use of a dedicated TEA surgeon per unit, a regional center or regional expert for TEA or a hub and spoke model to assure the best possible treatment for patients. When a good referral network is created for TEA, perhaps, more often, TEA will be considered as an option for elderly with comminuted fractures and usage of a TEA will become more common even more.

To the best of our knowledge, the current study is the first systematic review focusing on the effect of surgical volume of TEA on post-operative outcomes. The current study has some limitations that need to be considered. The first limitation is that the study was not able to perform a meta-analysis due to the limited amount of included studies and the heterogeneity of the collected data. Furthermore, all studies collected different data regarding complications and used different cut-off point to determine low, intermediate and high volume for either surgeons or hospital.

To improve studies regarding global trends and outcomes after TEA, registries should consist of a standardized set of complications. It is also important to pre-define subgroups to determine when a surgeon or hospital is considered low, intermediate or high volume. This can result in a better comparison between groups and the possibility of performing meta-analyses to provide a higher level of evidence to assess the outcomes after TEA. Another alternative is to extract data on surgeon or hospital volume from arthroplasty registers, when complications and outcomes are scored.

Table 5 **Implant survival** (Jenkins *et al.* (13))

	Implant, *n*	At 10 years	At 18 years	*P*-value
Average number of procedures per surgeon per year				
0–4	412	90 (86–93)	83 (75–91)	0.02
5–9	296	85 (79–91)	82 (73–90)	
>9	319	94 (91–97)	89 (84–95)	
Overall survivorship (%)*		90 (88–93)	85 (81–89)	

*Value presented with 95% CI.

Conclusions

This review found that higher surgeon volume is associated with a lower revision rate. Furthermore, the current study appears to show a trend toward better outcomes when surgery is performed by experienced surgeons or in high-volume hospitals. Exact cut-off values are unclear, yet, more than 10 procedures per surgeon annually and more than 20 procedures per center appear to have lower revision and complication rates, respectively. Optimizing outcomes after surgery also potentially reduce healthcare costs. This can be accomplished by implementing regionalization of complex, low-volume care like total elbow arthroplasty.

ICMJE Conflict of interest Statement
The authors declare that there is no conflict of interest that could be perceived as prejudicing the impartiality of the research reported.

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