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How much is enough? Finding the minimum annual surgical volume threshold for total knee replacement

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There is compelling evidence that the outcome of total knee replacement (TKR) depends on the annual caseload of the surgeon and the institution.[1–3] The fact that high-volume centres have better outcomes is so well known that patients themselves increasingly seek treatment at high-volume institutions.[4]

But how do we determine the surgical volume threshold that constitutes an acceptable risk?

In the recent article by Okoro *et al*, data from nearly 170 000 TKR recipient in Ontario, Canada, were analysed using a state of the art restricted cubic spline (RCS) analysis.[5] The authors identified an inflection point for increased probability for early revision or infection at 70 annual cases, after which the risk of complications plateaued. However, risk reduction continued even beyond an annual caseload of 70, highlighting the value of treatment by high-volume surgeons.

This method of identifying the surgical volume threshold differs from previous studies conducted in the last 10 years (table 1). While some papers fail to mention their methods for defining the volume groups, others have largely split the data by quartiles. This results in more or less arbitrary thresholds that are more dependent on local healthcare structure and population size than providing clinical meaningful volume categories. Due to varying methods for defining the volume groups, the lowest volume category in one study[6] would have been defined as the highest volume category in another.[7] Clearly, if the goal is to identify the annual caseload that reduces complications and produce meaningful thresholds that surgeons and institutions can aim to achieve, the volume categories should not be defined a priori. This methodological flaw is corrected by the RCS analysis, which uses the dataset to identify the inflection point to identify the actual caseload threshold where the risk of complications is reduced.

However, it is unlikely that the threshold of 70 annual cases to reduce risk of complications is universal. Like any surgery, TKR surgery is composed of teamwork and environmental factors, such as healthcare structure and population demographics, which influence the outcome. Okoro *et al* suggest that all communities with available real-world data perform similar RCS analysis to identify the caseload threshold relevant to their population. It should therefore be mentioned that Yu *et al* published a similar RCS analysis from Taiwan in 2019.[8] They found the inflection point to be somewhat lower in their population, at 50 cases per year, proving the point that the caseload threshold varies between populations. Differences in specialty training practices and best practices across nations affect volume threshold estimates. We predict that future research will produce new and different surgical volume thresholds to reduce complications, and it is unlikely that a definite answer will be possible to find. It is more likely that the true annual caseload threshold varies over time, as surgical training, implant design and population characteristics change.

Another challenge in determining acceptable caseload thresholds is that different complications will have different volume thresholds. Existing literature on the effect of surgical volume has used a spectrum of different outcomes, including 30-day readmission, revision rate, radiological implant alignment,[9] surgical site infection and length of hospital stay (table 1). Different complications will have different etiologies, not all related to the experience of the surgeon. Hospital environment, population characteristics, postoperative care and rehabilitation facilities all play a part in securing a good outcome after arthroplasty surgery. For example, length of stay is dependent on

Table 1 A literature review of publications in English from 2011 to 2021, with a minimum of 20 000 patients included, evaluating the effect of surgeon and/or hospital volume on total knee replacement outcome

Study	N	Setting	Volume thresholds					Definition of threshold	Outcome	Result	
Author year	No of TKRs	Data source, country	Low	Medium low	Medium high	High	Very High	(Method)	Type	Low versus high volume	OR (95 % CI) P value
Surgeon–volume relationship											
Namba etal[12] 2013a	64 017	Total Joint Replacement Registry, USA	1–9	10–49	≥50			Not explained	Aseptic revision	No difference	1.11 (0.66 to1.12) 0.690
Namba[13] 2013b	56 216	Total Joint Replacement Registry, USA	<20	20–49	≥50			Not explained	Surgical site infection	No difference	1.30 (0.90 to 1.88) 0.160
Wilson[2] 2016	289 976	Statewide Planning and Research Cooperative System (SPARCS), New York, USA	0–12	13–59	60–145	≥146		SSLR	CR and revision	Higher risk for low volume	1.85 (1.75 to 1.97) NR
Yu[8] 2019	30 828	Taiwan National Health Insurance Research Data base, Taiwan	1–49		≥50			RCSR	Readmission	Higher risk for low volume	1.44 (1.22 to 1.69) <0.001
Hospital–volume relationship											
de la Torre etal[14] 2019	36 316	Catalan Arthroplasty Registry, Spain	<125			>125		Previous studies	Revision	Higher risk for low volume	1.29 (1.16 to 1.44) NR
Badawy etal[7] 2013	26 698	Norwegian Arthroplasty Register, Norway	<25	25–49	50–99	100–149	≥150	Previous studies	Revision	No difference	0.81* 0.68
D'apuzzo etal[15] 2017	377 705	Statewide Planning and Research Cooperative System (SPARCS), New York, USA	1–89	90–235	236–644	≥645		SSLR	Readmission	Higher risk for low volume	1.32 (1.16 to 1.51) <0.001
Kurtz[6] 2016	952 593	Medicare 100% claims, USA	150–299	300–499	450–599	≥600		Not explained	Readmission	Higher readmissions for low volume	51.2%†
Meyer etal[16] 2011	43 180	Krankenhaus- Infektions-Surveillance System, Germany	1–50	51–99	>100			Previous studies	Surgical site infections	Higher risk for low volume	2.04 NR
Namba et al[12] 2013a	64 017	Total Joint Replacement Registry, USA	<100	100–199	≥200			Not explained	Aseptic revision	No difference	0.93 (0.59 to 1.48) 0.769
Namba[13] 2013b	56 216	Total Joint Replacement Registry, USA	<100	100–199	≥200			Not explained	Surgical site infection	lower risk for low volume	0.33 (0.12 to 0.90) 0.030
Pamilo et al[17] 2015	59 696	Perfect Knee Replacement database, Finland	1–99	100–249	250–449	>450		chosen arbitrarily	LOS, Readmission, MUA, revision	Higher readmission risk for low volume, no difference for revision	Readmission: 1.11 (1.03 to 1.19) NR Revision: 1.08 (0.93 to 1.26) NR

Continued

Table 1 Continued

Study	N	Setting	Volume thresholds					Definition of threshold	Outcome	Result	
Surgeon–volume relationship											
Author year	No of TKRs	Data source, country	Low	Medium low	Medium high	High	Very High	(Method)	Type	Low versus high volume	OR (95 % CI) P value
Singh *et al*[18] 2011	19418	Pennsylvania Healthcare Cost Containment Council database, USA	1–25	26–100	101–200	>200		Not explained	CR and MR	Higher risk for low volume	CR: 1.1 (0.8 to 1.6) NR MR: 1.0 (0.4 to 2.6) NR
Wilson[2] 2016	289976	Statewide Planning and Research Cooperative System (SPARCS), New York, USA	0–89	90–235	236–644	>645		SSLR	CR and revision	Higher risk for low volume	1.37 (1.32 to 1.42) NR
Yu[8] 2019	30828	Taiwan National Health Insurance Research Data base, Taiwan	1–74		≥75			RCSR	Readmission	No association	1.07 (0.90 to 1.28) 0.435

Search performed in Medline 9 April 2021 yielded 72 papers for screening.
*Relative risk,.
†Percentage difference.
CR, complication rate; LOS, length of stay; MR, mortality rate; MUA, manipulation under anaesthesia; NR, not reported; RCSR, Restricted Cubic Spline Regression; SSLR, Stratum-specific likelihood ratio.

multiple factors, not least the hospital capacity and the proximity of a potential rehabilitation facility or the home of the patient. A longer hospital stay in a rural hospital with low surgical volume may therefore not be an indication of poor quality. Furthermore, not all of these complications necessarily constitute a clinically meaningful difference for the patient (eg, implant alignment may not have clinical relevance). As such, the revision rate is probably the best outcome measure, representing a hard end-point with a clear consequence for the patient. However, even revision rates are subject to individual variation thresholds by the revision surgeon, and local traditions such as patella resurfacing or not. Defining the minimal surgical volume threshold is clearly not an easy task.

However, the true surgical volume threshold is perhaps not that important. The point is that there is little doubt that surgical volume matters, and the crucial question is what to do with this knowledge. Some authors have suggested that low-volume surgeons should either stop doing the procedure, or do more of it.[10] There are many arguments for centralisation, as TKR are nearly always an elective procedure that may be postponed. However, travelling for hours to receive care is not always possible, and removing TKR service from local hospitals reduces both the availability and the quality of care. Caring for patients operated by other surgeons is difficult, especially if the patient has had a type of surgery you do not perform yourself, and interrupts the continuity of a patient's care. Furthermore, patients treated at high-volume institutions differ from those of low-volume institutions,[11] meaning that changing the population flow might affect the caseload thresholds, which are probably constantly changing anyway.

Still, there is no denying the effect of surgical volume on outcome quality. The improved, and likely more accurate, caseload thresholds estimated by Okoro *et al* and Yu *et al* provide valuable information that can guide decision-makers when organising the arthroplasty service in the community. An effort to reach a minimum of caseload in most centres should be combined with efforts to improve the quality of the care in low-volume institutions, so that uniform healthcare and equity can be reached while preserving access to care.

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