Evidence check

28 August 2020

Rapid evidence checks are based on a simplified review method and may not be entirely exhaustive, but aim to provide a balanced assessment of what is already known about a specific problem or issue. This brief has not been peer-reviewed and should not be a substitute for individual clinical judgement, nor is it an endorsed position of NSW Health.

Resuming elective surgery – Volume-outcome relationships in surgery

Evidence check question

What is the evidence regarding a volume-outcome relationship for surgical interventions?

In brief

- For some surgical procedures, there is evidence of a volume-outcome relationship – a correlation between lower number of cases and poorer outcomes.(1)
- Volume-outcome relationships have been evaluated at both a surgeon and hospital level. For procedures with a shorter length of stay and specific intraoperative processes and skills, the volume of procedures performed by the surgeon are more likely to influence outcomes; while for procedures with longer lengths of stay, the volume of procedures performed at the hospital is more likely to be important.(2)
- Definitions of what constitutes a 'low volume' varies across studies, countries and conditions. Reporting of definitions of volumes is often inadequate and not consistent across studies.(2)
- Outcomes reported include mortality, postoperative complications, length of stay, cost of hospital stay, and readmissions and reoperations/revisions.
- The quality of studies and strength of association between volumes and outcomes varies.
- Conditions where a volume-outcome relationship has been reported in systematic reviews include: pancreaticoduodenectomy, colon, rectal and colorectal cancer, bariatric surgery, breast cancer, abdominal aortic aneurysm, spinal surgery, cystectomy, oesophageal cancer, stomach cancer, head and neck cancer, lung cancer, radical prostatectomy, gynaecology surgery, carotid endarterectomy, paediatric heart surgery, AIDS, hysterectomy, thyroidectomy, transcatheter aortic valve implantation, nephrectomy, hernia, acute aortic syndrome, revascularisation of the lower limbs, hip and shoulder arthroplasty.(2-31)
- Conditions where volume-outcome relationship has not been clearly established include liver resections, Norwood procedure, adrenocortical carcinoma and thoracic aortic aneurysms,(2, 32-35)
- There is mixed evidence across reviews regarding percutaneous coronary intervention, hernia, trauma and injury, and coronary artery bypass grafting.(36, 37)

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Limitations

This evidence check is limited to systematic reviews, and any studies not yet evaluated in a review would not be included. In the in brief section the terms higher and lower have been intentionally used, terminology used in the source articles are reflected in the results table. The reporting of definitions of volumes is often inadequate and not consistent across studies.(2) While we can't define of what constitutes a lower or higher volume centre or surgeon, volumes should be interpreted in the context of disease prevalence.

Background

A volume-outcome relationship is a correlation between volume and outcome quality in procedures, where a lower-case volume is associated with poorer outcomes. Many studies and reviews indicate a positive relationship between hospital and surgeon volume with clinical outcomes for different surgical procedures

The designation of 'higher' and 'lower' volume in surgical procedures varies across jurisdictions and contexts. In NSW, the NSW Government's Canrefer site lists recommended specialist hospitals for the treatment of some cancers.

Methods (Appendix 1)

A systematic review of systematic reviews was published in 2016.(2) This evidence check updates this review by searching for systematic reviews from 2016 onwards, and including the addition of hospital volume. Only peer reviewed systematic reviews and meta-analyses were included.

Results

Table 1

Source	Summary
Peer reviewed sources	
Reviews of multiple surgical procedures	
Association of Hospital and Surgeon Volume With Mortality Following Major Surgical Procedures: Meta-analysis of Meta-Analyses of Observational Studies Hoshijima, et al. 2019 (38)	• Included 20 meta-analyses including 4,520,720 patients • 19 types of surgical procedures for hospital volume and 11 types of surgical procedures for surgeon volume were included • Nominally significant reductions were found in odds ratio in 82% to 84% of surgical procedures in both hospital and surgeon volume-mortality associations. • Only one surgical procedure (pancreaticoduodenectomy) fulfilled the criteria of class I and II for both hospital and surgeon volume and mortality relationships, with a decrease in OR for hospital (0.42, 95% CI: 0.35-0.51) and for surgeon (0.38, 95% CI: 0.30-0.49), respectively. • Most surgical procedures resulted in having weak or 'non-significant' evidence, including total knee replacement, thyroidectomy, bariatric surgery, radical cystectomy, and rectal and colorectal cancer resections.

Volume and Health Outcomes: Evidence From Systematic Reviews and From Evaluation of Italian Hospital Data
 	
Amato, et al. 2017 (3)
	• Eighty reviews were included on 48 different clinical areas
	• The literature found a positive association with clinician and surgeon outcomes for 21 conditions including:
	  ○ 9 consider surgery for cancer: bladder, breast, colon, colon rectum, pancreas, prostate, rectum, stomach, and head and neck
	  ○ 5 consider the cardiocerebrovascular area: ruptured and nonruptured abdominal aortic aneurysm, carotid endarterectomy, paediatric heart surgery, and revasculariSation of the lower limbs
	  ○ 2 consider the orthopaedic area: knee and hip arthroplasty
	  ○ 5 consider other areas: AIDS, bariatric surgery, hysterectomy, intensive care unit, and thyroidectomy.

Relationship Between Surgeon Volume and Outcomes: A	• Thirty-two reviews reporting on 15 surgical procedures and conditions were included for the systematic review on the surgeon volume-outcome relationship. Most reviews tend to support the presence of a

Source	Summary
Peer reviewed sources	

Systematic Review of Systematic Reviews
 	
Morche, et al. 2016 (2)
	surgeon volume-outcome relationship. This is most clear-cut in colorectal cancer, bariatric surgery, and breast cancer, where reviews of high-quality show large effects. Based on the included systematic reviews, this association tends to be stronger for hospital volume than for surgeon volume regarding some procedures and conditions.
	• A tendency or trend of surgeon volume-outcome relationship was found for abdominal aortic aneurysm, cystectomy, oesophageal cancer, head and neck cancer, lung cancer, pancreatic surgery, radical prostatectomy, and total knee arthroplasty.
	• The relationship between surgeon volume and outcomes is rated as unclear for:
	  ○ off-pump coronary artery bypass grafting, as the methodological quality of the review is flawed
	  ○ Percutaneous Coronary Intervention (PCI), as the pooled results for major adverse cardiac events are statistically very heterogeneous
	  ○ trauma, as the included primary studies are more than 10 years old and the review does not have enough information to justify another rating
	  ○ Norwood procedure, as the body of evidence is not sufficient and results are heterogeneous.

The Combined Effect of Surgeon and Hospital Volume on Health Outcomes: A Systematic Review Vecchi, et al. 2019 (39)	• Sixteen studies were included. Due to the heterogeneity of studies, it was not possible to perform a quantitative analysis. • Heath outcomes are worse when high surgeon volumes operating in low hospital volumes vs high hospital volumes, for the majority of the conditions (colorectal cancer, cystectomy, liver resection, mitral valve surgery, pancreatico-duodenectomy). • Results for low surgeon volumes are better when operating in high hospital volumes vs low hospital volumes for patients undergoing pancreatic-duodenectomy for mortality, 30 days complications and length of stay. • Results for low surgeon volumes are worse vs high surgeon volumes when operating in high hospital volumes for most considered conditions. • Results were in favour of higher surgeon volumes vs low surgeon volumes when operating in low hospital volumes for digital replantation success after injuries, 30 days mortality and complications after pancreaticoduodenectomy. • The available evidence is limited. It is necessary to increase the monitoring of the association between surgeon volumes and hospitals volumes in which they operate, to ensure fairness and accuracy of care for better health outcomes.

Source	Summary
Peer reviewed sources	
Spinal surgery	
Does Hospital Volume Affect Outcomes in Spine Surgeries? A Systematic Review Adkins, et al. 2019 (4)	• 12 studies were included in the review. • Studies were variable in defining hospital volume thresholds. • Higher hospital volume was associated with statistically significant lower risks of postoperative complications, a shorter length of stay, lower cost of hospital stay, and a lower risk of readmissions and reoperations and revisions.
Relationship Between Surgeon Volume and Outcomes in Spine Surgery: A Dose-Response Meta-Analysis Li, et al. 2018 (5)	• Eleven studies with 1,986,545 patients were included. • Pooled estimate indicated that a higher surgeon volume was associated with lower postoperative morbidity (OR, 0.62; 95% CI: 0.52-0.75; I2=93.9%), lower mortality (OR, 0.76; 95% CI: 0.66-0.87; I2=0), shorter length of hospital stay (WMD, -7.07; 95% CI: -7.08 to -7.06; I2=100%), less readmission (OR, 0.78; 95% CI: 0.72-0.85; I2=93.1%), and lower hospital costs (WMD, -25,497.47; 95% CI: -25,528.43 to -25,466.51; I2=100%). • Dose-response analysis suggested a nonlinear relationship between surgeon volume and postoperative morbidity (p for nonlinearity less than 0.00001).
The Impact of Surgeon Volume on Patient Outcome in Spine Surgery: A Systematic Review Malik, et al. 2018 (6)	• Nine studies comprising 954,007 patients included anterior cervical discectomy and fusion (ACDF), anterior/posterior cervical fusion, laminectomy/decompression, anterior/posterior lumbar decompression with fusion, discectomy, and spinal deformity surgery (spine arthrodesis). • Despite significant variability in defining surgeon volumes, there was a general trend towards better outcomes in terms of length of stay, cost of stay, and postoperative complications with a lower risk of readmissions and reoperations/revisions when surgeries were done by a high volume surgeon rather than a low volume surgeon.
Hernia	
Relationship Between Volume and Outcome for Surgery on Congenital Diaphragmatic Hernia: A Systematic Review Morche, et al. 2020 (32)	• Included five cohort studies on hospital volume. • Results for in-hospital mortality, one-year mortality and length of stay are inconclusive. • The certainty of the evidence was very low for all outcomes due to risk of bias, inconsistency and imprecision. • No studies were identified on surgeon volume.

Source	Summary
Peer reviewed sources	
What Is the Influence of Simulation-Based Training Courses, the Learning Curve, Supervision, and Surgeon Volume on the Outcome in Hernia Repair?- A Systematic Review Kockerling, 2018 (28)	• Eighty-one studies were included (not all were on volume outcomes). • Surgeons with a low caseload was associated with increased reoperation rate, have significantly higher recurrence and pain on exertion and were more likely to experience a major complication than patients with high volume surgeons. • Definition of what constitutes high and low volume varied across the studies.
Pancreatic surgery	
The Impact of Surgeon Volume on Outcomes After Pancreaticoduodenectomy: A Meta-analysis Macedo, et al. 2017 (7)	• Eleven studies met the inclusion criteria comprising 36,449 patients. • Among these patients, 12,512 (34.3%) pancreaticoduodenectomies were performed by high volume surgeons and 23,937 (65.7%) by low volume surgeons. Meta-analysis of included studies showed that high volume surgeons had significantly lower mortality rates than low volume surgeons (2.4 vs 6.7%, OR 2.88; 95% CI: 2.51-3.27, p<0.001). • High volume surgeons also had significantly lower overall complication rates (36.3 vs 50.3%, OR 1.71; 95% CI: 1.62-1.81, p<0.001), hospital costs (range $10,818-141,322 vs $12,114-198,678, OR 0.13; 95% CI: 0.07-0.19, p<0.001), and length of stay (range 11-35 vs 14-38 days, OR 2.86; 95% CI: 2.03-3.68, p<0.001).
Effect of Hospital Volume on Surgical Outcomes After Pancreaticoduodenectomy: A Systematic Review and Meta-analysis Hata, et al. 2016 (8)	• Thirteen studies based on nationwide databases from 11 countries, including 58,023 patients, were included in this study. Variations in high volume hospital cut-off values across studies majorly influenced the overall heterogeneity. • The overall pooled odds ratio (OR) for mortality favouring the high volume hospital group was 2.37 [95% CI: 1.95-2.88] with high heterogeneity (I=63%). • All included studies were classified into categories according to the cut-off values for high volume hospital as defined in each individual study. • The pooled OR for each category of 1 to 19, 20 to 29, and ≥30. Pancreaticoduodenectomies per year was 1.94, 2.34, and 4.05, respectively. There were significant differences among these categories (I=58.9%, P=0.09). The two former categories showed no statistical interstudy heterogeneities. The data did not suggest publication bias. These trends persisted in all subgroup analyses. Postoperative length of stay in the high volume hospital group was significantly shorter with mild interstudy heterogeneity.

Source	Summary
Peer reviewed sources	
	• The meta-analysis included studies from different countries with disparate healthcare systems and provided strong evidence for an inverse association between higher hospital volume and lower mortality after pancreaticoduodenectomy.
Esophagectomy	
Hospital Esophagectomy Volume and Postoperative Length of Stay: A Systematic Review and Meta-Analysis Giwa, et al. 2018 (40)	• Nineteen observational cohort studies reporting on the relationship between hospital esophagectomy volume and length of stay among 75,383 patients were included. • High hospital esophagectomy volume was associated with reduced postoperative length of stay (mean of 3 days; 95% CI: 2.8, 3.2) and risk of prolonged length of stay (RR: 0.80, 95% CI: 0.74, 0.87) in a dose-response fashion.
Cardiac surgery	
Meta-Analysis of Hospital-Volume Relationship in Transcatheter Aortic Valve Implantation Ando, et al. 2019 (9)	• Ten publications included in the meta-analysis. • Results showed that in both the highest (OR 0.66, 95% CI: 0.53-0.83, p=0.0003, I2=78%) and intermediate (OR 0.85, 95% CI: 0.79-0.92, p<0.0001, I2=0%) volume hospitals, there was a statistically significant volume-outcome relationship for short-term mortality compared with the lowest volume hospitals. • Included patients were mainly high-risk cohorts. • The high heterogeneity in this relationship between the highest and the lowest volume hospitals warrant cautious interpretation. Whether this relationship remains significant in low-risk cohort requires further study.
Annual Case Volume on Mortality After Coronary Artery Bypass Grafting: A Dose-Response Meta-Analysis Tie, et al. 2019 (10)	• Twenty-five studies including 3,492,101 participants. • The pooled estimate revealed that both hospital and surgeon annual case volumes were inversely associated with mortality in patients after coronary artery bypass grafting (CABG) (OR for hospital: 0.62, 95% CI: 0.56-0.69; P<0.001; OR for surgeon: 0.51, 95% CI: 0.31- 0.83; P<0.001) with high heterogeneity. • The relationship remained consistent and robust in most subgroup and sensitivity analyses.

Source	Summary
Peer reviewed sources	
	• Our meta-regression analysis of time suggested that the strength of the negative associations between volume and mortality for both hospitals and surgeons remained unattenuated over time even though the CABG mortality gradually decreased over time. • The dose-response analysis suggested a non-linear relationship between both hospital and surgeon annual case volumes and mortality (both P non-linearity =0.001).
Aortic Centres Should Represent the Standard of Care for Acute Aortic Syndrome Mariscalco, et al. 2018 (11)	• Thirty studies including 79,131 adult patients were included. • No randomised studies were identified. • Pooled unadjusted ORs showed that patients treated in high volume centres or by high volume surgeons were associated with lower mortality rates (OR 0.51; 95% CI: 0.46-0.56, and OR 0.41, 95% CI: 0.25-0.66, respectively). • Pooled adjusted estimates for both high volume centres and surgeons confirmed these survival benefits (adjusted OR, 0.56; 95% CI: 0.45-0.70, respectively). • Patients treated in centres that introduced a specific multidisciplinary aortic program and a dedicated on-call aortic team also showed a significant reduction in mortality (OR 0.31; 95% CI: 0.19-0.5, and OR 0.37; 95% CI: 0.15-0.87, respectively).
A Systematic Review and Meta-Analysis of the Relationship Between Hospital Volume and the Outcomes of Percutaneous Coronary Intervention Lin, et al. 2016 (36)	• Fourteen relevant articles were included in the analysis. • A meta-analysis of postoperative mortality was performed using a random effects model, and the pooled effect estimate was significantly in favour of high volume providers (OR: 0.79; 95% CI: 0.72-0.86; P<0.001). • A systematic review of long-term survival was performed, and a trend toward better long-term survival in high volume hospitals was observed. • This meta-analysis only included studies published after 2006 and revealed that postoperative mortality following percutaneous coronary intervention correlates significantly and inversely with hospital volume. However, the magnitude of the effect of volume on long-term survival is difficult to assess.
Bladder cancer	
The Importance of Hospital and Surgeon Volume as Major Determinants of Morbidity and Mortality After Radical Cystectomy	• Thirty-nine studies recruiting 549,542 patients were included. • All studies were retrospective observation cohort studies

Source	Summary
Peer reviewed sources	
for Bladder Cancer: A Systematic Review and Recommendations by the European Association of Urology Muscle-invasive and Metastatic Bladder Cancer Guideline Panel Bruins, et al. 2020 (12)	• Higher hospital volume, specifically a hospital volume of >10, was associated with improved primary and secondary outcomes in most studies. In addition, there was some evidence that a hospital volume of >20 improves outcomes. • For surgeon volume, limited and conflicting data were reported. Most studies had moderate to high risk of bias.
Systematic Review of Factors Associated With the Utilization of Radical Cystectomy for Bladder Cancer Williams, et al. 2019 (41)	• Radical cystectomy is reportedly underutilised. There are no published randomised control trials on radical cystectomy (RC) utilisation. Variations in study quality and design precluded a formal statistical meta-analysis. • Age, race, marital status, socioeconomic factors, cancer severity, comorbidity burden, surgeon volume, and facility type and location significantly determined RC receipt. • Finally, hospital factors associated with lower RC use included low hospital volume, non-academic affiliation, and hospital location in the Midwest.
Liver cancer surgery	
Morbidity and Mortality After Major Liver Resection in Patients With Perihilar Cholangiocarcinoma: A Systematic Review and Meta-Analysis Franken, et al. 2019 (33)	• A total of 51 studies were included, representing 4,634 patients. • Univariate meta-regression analysis showed no influence of hospital volume on mortality or morbidity, but when corrected for geographic location, higher hospital volume was associated with higher severe morbidity (P=0.039). • Western studies compared with Asian studies had a significantly higher 30-day mortality, 90-day mortality, and overall morbidity: 8% versus 2% (P <0.001), 12% versus 3% (P < .001), and 63% versus 54% (P = .048), respectively. Pooled overall morbidity and severe morbidity were 57% (95% CI: 50-64%) and 40% (95% CI: 34-47%), respectively. This effect on mortality remained significant after correcting for hospital volume.
Gynaecological cancer surgery	
Surgical Outcomes for Low-Volume vs High-Volume Surgeons in	• Fourteen peer-reviewed studies with 741,760 patients were included in the systematic review.

Source	Summary
Peer reviewed sources	
Gynecology Surgery: A Systematic Review and Meta-Analysis Mowat, et al. 2016 (13)	• For gynaecology the low volume surgeon group had an increased rate of total complications (OR, 1.3, 95% CI: 1.2-1.5), intraoperative complications (OR, 1.6, 95% CI: 1.2-2.1), and postoperative complications (OR, 1.4 95% CI: 1.3-1.4). • In gynaecological oncology, the low volume surgeon group had higher mortality (OR, 1.9, 95% CI: 1.3-2.6). In the urogynaecology group, a single study reported that the LVS group had a higher rate of any complication (risk ratio [RR], 1.4, 95% CI: -1.2-1.6). • Another single study found that LVS had higher rates of reoperation for mesh complications after mid-urethral sling procedures (RR, 1.4, 95% CI: 1.2-1.5). The evidence is of moderate to very low quality. • Gynaecologists performing procedures approximately once a month or less were found to have higher rates of adverse outcomes in gynaecology, gynaecological oncology, and urogynecology, with higher mortality in gynaecological oncology.
Impact of Hospital Care Volume on Clinical Outcomes of Laparoscopic Radical Hysterectomy for Cervical Cancer: A Systematic Review and Meta-Analysis Lee, et al. 2018 (27)	• Fifty-nine studies including 4,367 cases were selected. In high volume hospitals, a higher number of lymph nodes (24.5 vs 21.1; P = .037) were retrieved by laparoscopic radical hysterectomy in older women (48.4 vs 44.5 years; P = .010) with tendencies of shorter operation time (224.4 vs 256.4 minutes; P = .096) and less blood loss (253.1 vs 322.2 ml; P = .080). Compared with low volume hospitals, high volume hospitals had fewer patients with stage IA disease (13.8 vs 24.4%; P = .003) and more patients with stage IIA disease (15.3 vs 7.1%; P = .052) with comparable 5-year overall survival (93.1 vs 88.6%; P = .112). • A higher number of retrieved lymph nodes, shorter operation time, less blood loss, and comparable perioperative complications and survival outcomes were observed in high volume hospitals group consisting of fewer stage IA and more stage IIA cases.
Colon/rectal cancer surgery	
Association Between Hospital and Surgeon Volume and Rectal Cancer Surgery Outcomes in Patients With Rectal Cancer Treated Since 2000: Systematic Literature Review and Meta-analysis	• Twenty-one studies were included. • There was a significant protective association between higher hospital volume and surgical morbidity (OR = 0.80, 95% CI: 0.70-0.93; I = 35%), permanent colostomy (OR = 0.51, 95% CI: 0.29-0.92; I = 34%), and postoperative mortality (OR = 0.62, 95% CI: 0.43-0.88; I = 34%), and overall survival (OR = 0.99, 95% CI: 0.98-1.00; I = 3%). • Surgeon volume was not significantly associated with overall survival. • The articles included in this analysis were high quality according to the Newcastle-Ottawa scale. Funnel plots suggested that the potential for publication bias was low.

Source	Summary
Peer reviewed sources	
Chioreso, et al. 2018 (14)	
Systematic Review and a Meta-Analysis of Hospital and Surgeon volume/outcome Relationships in Colorectal Cancer Surgery Huo, et al. 2017 (15)	• Forty-seven articles were included (1,122,303 patients, 9,877 hospitals and 9,649 surgeons). • The meta-analysis demonstrated that there is a volume-outcome relationship that favours high volume facilities and high volume surgeons. • Higher hospital and surgeon volume resulted in reduced 30-day mortality (HR: 0.83; 95% CI: 0.78-0.87, P<0.001 & HR: 0.84; 95% CI: 0.80-0.89, P<0.001 respectively) and intra-operative mortality (HR: 0.82; 95% CI: 0.76-0.86, P<0.001 and HR: 0.50; 95% CI: 0.40-0.62, P<0.001 respectively). • Post-operative complication rates depended on hospital volume (HR: 0.89; 95% CI: 0.81-0.98, P<0.05), but not surgeon volume except with respect to anastomotic leak (HR: 0.59; 95% CI: 0.37-0.94, P<0.01). • High volume surgeons are associated with greater 5-year survival and greater lymph node retrieval, while reducing recurrence rates, operative time, length of stay and cost. • The best outcomes occur in high volume hospitals with high volume surgeons, followed by low volume hospitals with high volume surgeons.
Shoulder or hip Arthroplasty	
Shoulder Arthroplasty Volume Standards: The More the Better? Kooistra, et al. 2019 (25)	• Eight retrospective studies were included. • Studies did not consistently show any associations of volume with in-hospital complications, revision, discharge to home or cost. • Higher volume hospitals were consistently associated with shorter length of stay and fewer in-hospital complications. • Volume was not consistently associated with mortality. Functional outcomes were not reported.
The Volume-Outcome Relationship for Hip Fractures: A Systematic Review and Meta-Analysis of 2,023,469 Patients Wiegers, et al. 2019 (21)	• Twenty-four studies comprising 2,023,469 patients were included. • Overall, the quality of the studies was reasonable. • 11 studies reported better health outcomes in high volume centres and 2 studies reported better health outcomes in low volume centres. • In the meta-analysis of 11 studies there was a statistically non-significant association between higher hospital volume and both lower in-hospital mortality (adjusted odds ratio (aOR) 0.87, 95% CI: 0.73-1.04) and fewer postoperative complications (aOR 0.87, CI: 0.75-1.02).

Source	Summary
Peer reviewed sources	
	• Four studies on surgeon volume were included in the meta-analysis and showed a minor association between higher surgeon volume and in-hospital mortality (aOR 0.92, CI: 0.76-1.12). • This systematic review and meta-analysis did not find an evident effect of hospital or surgeon volume on health outcomes.
The Impact of Surgeon Volume and Hospital Volume on Postoperative Mortality and Morbidity After Hip Fractures: A Systematic Review Malik, et al. 2018 (22)	• A total of 12 studies were included comprising 891,934 patients. • Studies were variable in defining surgeon and hospital volume thresholds. • Low surgeon volume was associated with a longer length of stay and a higher risk of mortality, but results were in contrast to postoperative complications. High volume hospitals fared better than low volume with respect to length of stay, postoperative complications and time to surgery. • Increasing hospital volume was a stronger predictor of postoperative outcomes compared to surgeon volume.
Effect of Hospital Volume on Outcomes of Total Hip Arthroplasty: A Systematic Review and Meta-Analysis Mufarrih, et al. 2019 (23)	• A total of 44 studies were included in the review. Except for two prospective studies, all were retrospective observational studies. • Results of the meta-analyses show that low volume hospitals were associated with a higher rate of surgical site infections (1.25 [1.01, 1.55]), longer length of stay (RR, 0.83, [0.48-1.18]), increased cost of surgery (3.44, [2.57, 4.30]), 90-day complications (RR, 1.80[1.50-2.17]) and 30-day (RR, 2.33[1.27-4.28]), 90-day (RR, 1.26[1.05-1.51]), and 1-year mortality rates (RR, 2.26[1.32-3.88]) when compared to high volume hospitals following total hip arthroplasty. • Findings suggest superior outcomes following total hip arthroplasty in high volume hospitals. Together with the reduced cost of the surgical procedure, fewer complications may contribute to saving considerable opportunity costs annually. However, a need to define objective volume thresholds with stronger evidence is required.
Does Surgeon Volume Affect Outcomes Following Primary Total Hip Arthroplasty? A Systematic Review Malik, et al. 2018 (24)	• Twenty-eight studies were included in the review. • Increasing surgeon volume was associated with a shorter length of stay, lower costs, and lower dislocation rates. • Studies showed a significant association between an increasing surgeon volume and higher odds of early-term and midterm survivorship, but not long-term survivorships.

Source	Summary
Peer reviewed sources	
	• Although complications were reported and recorded differently in studies, there was a general trend toward a lower postoperative morbidity with regard to complications following surgeries by a high volume surgeon.
The Interaction of Caseload and Usage in Determining Outcomes of Unicompartmental Knee Arthroplasty: A Meta-Analysis Hamilton, et al. 2017 (42)	• Forty-six studies (12,520 knees) were included in the review. An annual revision-rate ranged from 0% to 4.35%, mean 1.21% pa (95% CI: 0.97-1.47). The lowest revision-rates were achieved with caseload >24 unicompartmental knee arthroplasty/y (0.88% pa; 95% CI: 0.63-1.61) and usage >30% (0.69% pa; 95% CI: 0.50-0.90). Aseptic loosening, lateral arthritis, bearing dislocation, and unexplained pain were the predominant failure mechanisms with revision for patellofemoral problems and polyethylene wear exceedingly rare. • Usage was more important than caseload; with high usage (≥20%), the revision-rate was low, whether the caseload was high (>12 unicompartmental knee arthroplasty/y) or low (≤12 unicompartmental knee arthroplasty/y; (0.94% pa; 95% CI: 0.69-1.23 and 0.85% pa; 95% CI, 0.65-1.08), respectively); with low usage (<20%), the revision-rate was high, whether the caseload was high or low (1.58% pa; 95% CI: 0.57-3.05 and 1.76% pa; 95% CI: 1.21-2.41, respectively). • To achieve optimum results, surgeons, whether high or low caseload, should adhere to the recommended indications, such that ≥20% or ideally >30% of their knee arthroplasties are unicompartmental knee arthroplasty.
Patient Outcomes as a Function of Shoulder Surgeon Volume: A Systematic Review Weinheimer, et al. 2017 (26)	• A total of 10 studies were included. Seven studies evaluated arthroplasty with 88,740 shoulders, and 3 studies evaluated rotator cuff repair with 63,535 shoulders. • Variation was seen in how studies defined low versus high volume surgeon. • For arthroplasty, <5 cases per year met the criteria for a low volume surgeon and were associated with increased length of stay, longer operating room time, increased in-hospital complications, and increased cost. Mortality was not significantly increased. • In rotator cuff surgery, <12 surgeries per year met the criteria for low volume and were associated with increased length of stay, increased operating room time, and increase in reoperation rate. • Systematic review demonstrates increased surgical complications, length of stay, surgical time, and surgical cost in shoulder arthroplasty and rotator cuff repair when performed by a low volume shoulder surgeon, which is defined by those performing <5 arthroplasties and/or <12 rotator cuff repairs per year.
Adrenocortical carcinoma	

Source	Summary
Peer reviewed sources	
Surgical Management of Adrenocortical Carcinoma: Impact of Laparoscopic Approach, Lymphadenectomy, and Surgical Volume on Outcomes—A Systematic Review and Meta-analysis of the Current Literature Langenhuijsen, et al. 2016 (35)	• Twenty-six studies were included, however not all were on volume outcomes. • In high volume centres, more aggressive and open surgery was performed. • In low volume centres, higher local recurrence and distant metastases rates, and a shorter time to recurrence were seen. • Findings are limited due to the low level of evidence of selected studies, patient and disease heterogeneity, and heterogeneous surgeon populations.
Carotid revascularisation	
Quality Appraisal of Systematic Reviews, and Meta-Analysis of the hospital/surgeon-linked Volume-Outcome Relationship of Carotid Revascularization Procedures Kallmayer, et al. 2019 (29)	• In total, five systematic reviews published between 2000 and 2018 were identified, each comprising 11-25 primary studies. • Methodological quality appraisal of these reviews revealed high quality the most recent review only, low quality for three reviews, and critically low quality in one review. A high heterogeneity regarding the definitions of volume categories, and of time points assessing outcomes was apparent. • Aggregation of the systematic reviews revealed a significant inverse relationship between hospital/operator volume and the periprocedural risk of death or stroke following carotid endarterectomy. • For carotid artery stenting, high operator volume was associated with lower outcome rates. • Regarding hospital volume, an inverse but non-significant relationship between carotid artery stenting hospital volume and outcome rate was found. • In synthesis of primary studies from these systematic reviews, an inverse carotid endarterectomy hospital and operator volume relationship was present for stroke or death and for carotid artery stenting for hospital volume, respectively.
High Operator and Hospital Volume Are Associated With a Decreased Risk of Death and Stroke After Carotid Revascularization: A Systematic Review and Meta-analysis	• Eighty-seven studies were included. A decreased risk of death or stroke following carotid endarterectomy (CEA) was found for high compared to low operator volume, with a pooled adjusted odds ratio (OR) of 0.50 (95% CI: 0.28-0.87; 3 cohorts), and a pooled unadjusted relative risk (RR) of 0.59 (95% CI: 0.42-0.83; 9 cohorts). For high hospital volume compared to low hospital volume, with a pooled adjusted odds ratio of 0.62 (95% CI: 0.42-0.90; 5 cohorts), and a pooled unadjusted RR of 0.68 (95% CI: 0.51-0.92; 9 cohorts).

Source	Summary
Peer reviewed sources	
Poorthuis, et al. 2019 (30)	• A decreased risk of death or stroke after carotid artery stenting (CAS) was found for operators with high volume compared to those with low volume, with an adjusted odds ratio of 0.43 (95% CI: 0.20-0.95; 1 cohort), and an unadjusted relative risk of 0.50 (95% CI 0.32-0.79; 1 cohort). For high hospital volume compared to low hospital volume, with an adjusted odds ratio of 0.46 (95% CI: 0.26-0.80; 1 cohort), and no significant decreased risk in a pooled unadjusted relative risk of 0.72 (95% CI 0.49-1.06; 2 cohorts). • The review found a decreased risk of procedural death and stroke after CEA or CAS for high operator and high hospital volume, indicating that aiming for a high volume may help to reduce procedural complications.
Systematic Review of Carotid Artery Procedures and the Volume-Outcome Relationship in Europe Phillips, et al. 2017 (31)	• Eleven eligible observational studies comprising 233,411 participants were included. • Two large studies (179,736 patients) suggested an inverse relationship between hospital volume and mortality (number needed to treat (NNT) as low as 165), and combined mortality and stroke (NNT as low as 93), following carotid endarterectomy. The evidence was less clear for carotid artery stenting; multiple analyses in three studies did not identify convincing evidence of an association. Limited data are available on the relationship between clinician volume and outcome in carotid artery stenting; in carotid endarterectomy, an inverse relationship was identified by two of three small studies. • The evidence from the largest and highest-quality studies included in this review support the centralisation of carotid endarterectomy.
Percutaneous transluminal angioplasty and stenting	
Center Volume and the Outcomes of Percutaneous Transluminal Angioplasty and Stenting in Patients With Symptomatic Intracranial Vertebrobasilar Stenoses: A Meta-Analysis Mao, et al. 2018 (37)	• Fifteen cohort studies comprising 554 symptomatic intracranial vertebrobasilar stenoses (IVBS) patients were included in the review. Percutaneous transluminal angioplasty and stenting (PTAS) was associated with an 8% incidence of stroke recurrence or death (95% CI: 5% to 12%) in patients with severe intracranial vertebrobasilar stenoses (IVBS) within 30 days, and 8 per 100 person-years (95% CI: 5 to 11 per 100 person-years) of cumulative stroke recurrence or death during follow-up. Meta-regression indicated that the centre volume, as defined by the numbers of cases per year, was negatively correlated with 30-day (regression coefficient = -0.09, p =0.02) and follow-up (regression coefficient = -0.60, p =0.01) stroke recurrence or death. Age, gender, or comorbidities have no significant effect on the outcomes. • Centres of higher procedural volume may be associated with better clinical outcomes for symptomatic patients with IVBS receiving percutaneous transluminal angioplasty and stenting.

Source	Summary
Peer reviewed sources	
Severely injured patients	
The Volume-Outcome Relationship in Severely Injured Patients: A Systematic Review and Meta-Analysis Sewalt, et al. 2018 (43)	• Eighteen observational cohort studies were included. Eight studies were included in the meta-analysis with a total of 222,418 patients. Overall, the quality of the included studies was reasonable, with insufficient adjustment as one of the most common limitations. • The majority (13 [72%] of 18) studies reported an association between higher hospital or surgeon volume and lower mortality rate. • High hospital volume (>240 admitted severely injured patients per year) was associated with a lower risk of mortality (adjusted odds ratio, 0.85; 95% CI: 0.76-0.94). Four studies were included in the regression model, providing a beta of 0.17 per 10 patients (95% CI: -0.27 to -0.07). • There was no clear association between surgeon volume and mortality rates based on three available studies. • Systematic overview of the literature reveals a modest association between high volume centres and lower mortality in severely injured patients, suggesting that designation of high volume centres might improve outcomes among severely injured patients.
Nephrectomy	
Influence of Hospital Volume on Nephrectomy Mortality and Complications: A Systematic Review and Meta-Analysis Stratified by Surgical Type Hsu, et al. 2017 (20)	• 226,372 patients from 16 publications were included in the review and meta-analysis. • Considerable between-study heterogeneity was noted and only a few reported volume-outcome relationships specifically in partial nephrectomy or nephrectomy with venous thrombectomy. • High volume hospitals were correlated with a 26% and 52% reduction in mortality for radical nephrectomy (OR 0.74, 95% CI: 0.61 to 0.90, p<0.01) and nephrectomy with venous thrombectomy (OR 0.48, 95% CI: 0.29 to 0.81, p<0.01), respectively. Radical nephrectomy in high volume hospitals was associated with an 18% reduction in complications (OR 0.82, 95% CI: 0.73 to 0.92, p<0.01). No significant volume-outcome relationship in mortality (OR 0.84, 95% CI: 0.31 to 2.26, p=0.73) or complications (OR 0.85, 95% CI: 0.55 to 1.30, p=0.44) was observed for partial nephrectomy. • Review findings suggest that patients undergoing radical nephrectomy have improved outcomes when treated by high volume hospitals. Evidence of this in partial nephrectomy and nephrectomy with venous thrombectomy is however not yet clear and could be secondary to the low number of studies included and the small patient number in our analyses.
Aneurysm	

Source	Summary
Peer reviewed sources	
Meta-Analysis and Meta-Regression Analysis of Outcomes of Endovascular and Open Repair for Ruptured Abdominal Aortic Aneurysm Kontopodis, et al. 2020 (19)	• One hundred and thirty-six studies were included in quantitative synthesis reporting a total of 267,259 patients. • The pooled perioperative mortality of endovascular aneurysm repair and open surgical repair was 0.245 (95% CI: 0.234-0.257) and 0.378 (95% CI: 0.364-0.392), respectively. Endovascular aneurysm repair was associated with reduced peri-operative mortality (OR 0.54, 95% CI: 0.51-0.57, p<0.001). Meta-regression analysis found decreasing perioperative mortality over the years following endovascular aneurysm repair (p < .001) and open repair (p <0.001), and a decreasing OR of peri-operative mortality in favour of endovascular aneurysm repair (p =0.053). Meta-regression found a significant positive association between peri-operative mortality and institutional case load for open repair (p=0.004). • There is a significant association between perioperative mortality and institutional case load for open repair of ruptured abdominal aortic aneurysm.
Impact of Hospital Volume on Outcomes Following Treatment of Thoracic Aortic Aneurysms and type-B Dissections Saratzis, et al. 2016 (34)	• Eighty-four series of non-dissecting descending thoracic aortic aneurysms or type-B thoracic aortic dissections were included in data synthesis (4,219 patients). Data were heterogeneous and long-term results were scarcely reported. • Results were not superior in high volume centres (8 vs 6 vs 11% for high, medium and low volume, respectively). • Sub-analyses for emergency and elective repairs showed no significant differences. For type-B thoracic aortic dissections repairs, in the combined population (emergency and elective), results reached borderline significance (p = 0.0475), favouring high volume centres (6 vs 11 vs 14%), but this association disappeared when emergency and elective repairs were analysed separately. Nine series reported outcomes at 1 year and 5 series followed descending thoracic aortic aneurysms and 18 type-B thoracic aortic dissections treatment. • No meaningful long-term comparisons were possible due to lack of data. No significant associations were detected between hospital volume and subsequent mortality following descending thoracic aortic aneurysms or type-B thoracic aortic dissections treatment.
Procedure Volume and the Association With Short-term Mortality Following Abdominal Aortic Aneurysm Repair in	• Sixteen studies (n = 237,074 participants) from the UK were included. • The study quality was limited by the use of observational study designs. • Overall, the evidence favoured the existence of an inverse volume outcome relationship between hospital volume and short-term mortality.

Source	Summary
Peer reviewed sources	
European Populations: A Systematic Review Phillips, et al. 2017 (18)	• Insufficient evidence was available to reach conclusions on the relationship between clinician volume and outcome and between hospital or clinician volume and secondary outcomes, including complications and length of hospital stay.
Prostatectomy	
Systematic Review of the Volume-Outcome Relationship for Radical Prostatectomy Leow, et al. 2018 (17)	• Overall, 49 publications fulfilled the inclusion criteria. • Most of the studies demonstrated that higher-volume surgeries are associated with better outcomes, including reduced mortality, morbidity, postoperative complications, length of stay, readmission, and cost-associated factors. • The volume-outcome relationship is maintained in robotic surgery. • Eleven studies assessed hospital and surgeon volume simultaneously, and findings reflect that neither is an independent predictor variable affecting outcomes. The studies varied in how volume cut offs were categorised as well as how the volume-outcome relationship was methodologically evaluated. • Contemporary evidence continues to support the relationship between high volume surgeries with improved radical prostatectomy (RP) outcomes. Recent studies demonstrate that the volume-outcome relationship applies to robot-assisted RP and may be applied for potential cost savings in healthcare. An increase in the number of international studies suggests reproducibility of the association. Although regionalisation of surgical care remains a contentious issue, there is an increasing body of evidence that short-term outcomes are improved at high volume centres for radical prostatectomy.
Thyroid surgery	
Associations of Volume and Thyroidectomy Outcomes: A Nationwide Study With Systematic Review and Meta-Analysis Liang, et al. 2016 (16)	• This study retrospectively analysed a cohort of 125,037 thyroidectomy patients treated at Taiwan hospitals from 1996 to 2010. • Both high volume hospitals and high volume surgeons were associated with significantly shorter length of stay and lower costs compared with their low volume counterparts ($p<0.001$). • Different volume groups had similar in-hospital mortality rates. • The meta-analysis results consistently showed that the benefits of high volume hospitals and surgeons are reduced length of stay and costs. However, low in-hospital mortality rates were associated with high volume surgeons but not with high volume hospitals.

Appendix

PubMed search terms

(("Hospital volume" OR "surgeon volume" OR "physician volume" OR "surgical volume" OR caseload OR "procedure volume" OR "procedural volume" OR "provider volume" OR "volume outcome" OR "minimum volume" OR ((centre[title/abstract] OR center[title/abstract]) AND excellence[title/abstract])) AND (surgery[MeSH Subheading] OR surgical procedures, operative[MeSH Terms] OR general surgery[MeSH Terms] OR surg*[Title/Abstract])) AND ((meta-analysis[Filter] OR systematicreview[Filter] OR "systematic review*"[title] OR "meta analysis"[title]) AND (2016:2020[pdat]))

Google search terms

Volume outcome systematic review

Surgery volume systematic review

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