The Relationship Between Volume or Surgeon Specialty and Outcome in the Surgical Treatment of Lung Cancer

A Systematic Review and Meta-Analysis

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Background: Whether improvement of quality of surgical cancer care can be achieved by centralizing care in high-volume specialized centers is a subject of ongoing debate. We have conducted a meta-analysis of the literature on the effect of procedural volume or surgeon specialty on outcome of lung resections for cancer.

Methods: A systematic search of articles published between January 1, 1990 and January 20, 2011 on the effects of surgeon specialty and hospital or surgeon volume of lung resections on mortality and survival was conducted. After strict inclusion, meta-analysis assuming a random-effects model was performed. Meta-regression was used to identify volume cutoff values. Heterogeneity and the risk of publication bias were evaluated.

Results: Nineteen relevant studies were found. Studies were heterogeneous, especially in defining volume categories. The pooled estimated effect size was significant in favor of high-volume hospitals regarding postoperative mortality (odds ratio [OR] 0.71; confidence interval 0.62–0.81), but not for survival (OR 0.93; confidence interval 0.84–1.03). Surgeon volume showed no significant effect on outcome. General surgeons had significantly higher mortality risks than general thoracic (OR 0.78; 0.70–0.88) or cardiothoracic surgeons (OR 0.82; 0.69–0.96). A minimal annual volume of resections for lung cancer could not be identified.

Conclusions: Hospital volume and surgeon specialty are important determinants of outcome in lung cancer resections, but evidence-based minimal-volume standards are lacking. Evaluation of individual institutions in a national audit program might help elucidate the influence of individual quality-of-care parameters, including hospital volume, on outcome.

Key Words: Lung cancer, Quality improvement, Thoracic surgery, Procedural volume, Surgeon specialty.

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Improvement of safety, quality, and increased cost-effectiveness of cancer care are a subject of ongoing debate in the professional, public, and political arenas in many countries. The outcome of high-risk, low-volume procedures, such as esophageal and pancreatic resections, is especially thought to improve when centralized in high-volume specialized centers.[1,2] One of the parameters that is frequently suggested in guiding this centralization process is procedural volume. Introduction of minimal volume standards to impose centralization might be appealing to policy makers, because it is a clear and easily enforceable parameter. Because many factors—for example, patient selection, perioperative care protocols, and dedicated nursing staff—influence the outcome of low-volume, high-risk surgical cancer care, the emphasis of governing bodies on hospital-volume criteria seems too limited when the quality of research supporting these criteria is substandard.

Even though the annual case-load is larger than that of pancreatic or esophageal cancer, lung cancer surgery is also deemed to be a low-volume, high-risk surgery. There is, however, limited evidence to support volume standards in lung cancer surgery.

The methodological quality of volume-outcome studies is sometimes disputable and no meta-analysis is yet available. The vast majority of studies is observational and based on administrative data collected for other purposes. Differences in case mix are not always accounted for, and postoperative mortality is often presented as the sole outcome measure. These inadequate reports only feed an endless debate and hamper the introduction of minimal-volume standards in several countries, including The Netherlands.[3]

The aim of this study was to contribute to the ongoing debate by conducting a systematic review and meta-analysis of methodologically high-quality studies on the relationship between hospital volume, surgeon volume, and surgeon specialization on mortality and survival after lung resections.

METHODS AND MATERIALS

Systematic Search Strategy

We performed a systematic search to identify articles published after January 1, 1990, which described the

TABLE 1. Search Terms Used; Last Search January 20, 2011

Medline (PubMed)
((“Pneumonectomy “[majr] OR “ Lung Neoplasms /surgery “[MAJR] OR (“Surgical Procedures, Operative”[MAJR:NoExp] AND “Neoplasms”[MAJR:NoExp])) AND (“hospital volume” OR “surgeon volume” OR “surgeon specialty” OR “provider volume” OR “Outcome Assessment (Health Care)”[MAJR] OR regionalization[ti] OR regionalization[ti] OR “Health Facility Size”[majr] OR “Workload”[majr] OR (outcome*[ti] AND volume*[ti]) OR (outcome*[ti] AND complication*[ti])))

association between surgeon specialty, surgeon volume or hospital volume of lung resections and postoperative mortality and survival. The search was conducted in the Medline database (PubMed) and Cochrane library with a combination of MESH terms and text words (Table 1). Because volume is not well indexed in electronic databases, we formulated the search terms to be as sensitive as possible to ensure no publications were missed. The last search was conducted on January 20, 2011.

Study Selection

Two reviewers (G.G. and E.v.M.) independently screened titles and abstracts of all retrieved articles. Studies were selected using the following inclusion criteria:

- Written in English.
- Primary data.
- Subject: surgical treatment of lung cancer.
- Comparisons between providers (hospitals or surgeons).
- No single-hospital nor single-surgeon studies.
- Postoperative mortality or survival as outcome parameters.
- Distinct cutoff value for procedural volume or clearly defined specialty.

After this first selection on the basis of titles and abstracts, the remaining articles were obtained in full text and were further selected by the same reviewers. Any discrepancies regarding inclusion of a study were solved by consensus after discussion with a third author (M.W. or P.P.). Reference lists of relevant articles and recent reviews were hand-searched to identify additional articles. We also used the “related articles” function in PubMed.

The following information was retrieved from the selected articles and entered in our database: year of publication, country, data source, study period, number of patients, hospitals and surgeons, surgeon specialty, case-mix adjustments, volume categories for hospitals, volume categories for surgeons, outcome parameters (mortality and survival), and results regarding these outcome parameters (statistically significant or nonsignificant).

Assessment of Study Quality

Two authors (E.v.M. and G.G.) critically appraised each study in the review on methodological quality and multiple use of the same database. Data were gathered in a data-extraction form, which was based on the Strengthening the Reporting of Observational studies in Epidemiology criteria (www.strobe-statement.org).

Study inclusion criteria were checked for probability of selection bias. When multiple use of the same database was established, the study with the largest patient cohort was used. Cutoff values for high- and low-volume were noted per volume group. The study results were recorded separately for each unit (surgeon, surgeon specialty, or hospital) and for each outcome parameter (postoperative mortality and long-term survival). Subsequently, we noted the estimated effect size after adjustment comparing the highest volume group with the lowest, expressed as odds ratios (OR), hazard ratios (HR), or risk rates (RR) with confidence intervals (CI). If necessary, we converted the effect sizes so that the lowest-volume group was the reference in all studies. Studies without a multivariate analysis and/or no reporting of OR, HR, or RR were excluded from the meta-analysis.

Synthesis of the Data for Meta-Analysis

A meta-analysis was performed for the relationship between hospital volume, surgeon volume, and surgeon specialty on the one hand and postoperative mortality and long-term survival on the other. The random-effect model, which accounts for the expected heterogeneity in pooling observational studies,

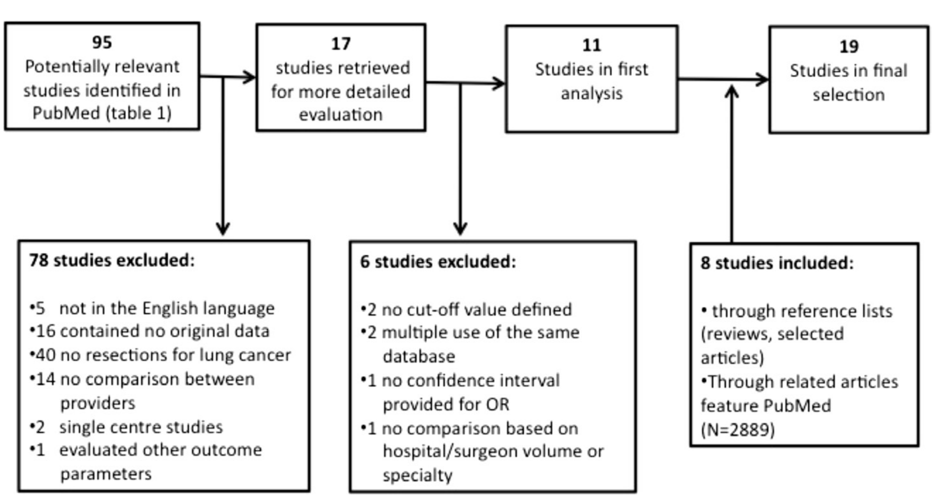


FIGURE 1. Selection process of reviewed studies. OR, odds ratio.

TABLE 2. Studies Included in the Systematic Review of the Literature on the Relationship Between Volume and Outcome of Lung Resections for Cancer

						Case-Mix Adjustment				
Study	Country	Data	Patients	Hospitals	Surgeons	Demographic	Comorbidities	Urgency	Tumor	Treatment
Birkmeyer et al.[1]	USA	Adm	19410	1877	n.r.	•	•	•	—	•
Birkmeyer et al.[2]	USA	Adm	24092	n.r.	4178	•	•	•	—	—
Sioris et al.[13]	Finland	Adm	5339	26	n.r.	•	—	—	•	•
Bilimoria et al.[14]	USA	Adm	40754	1528	n.r.	•	•	—	•	•
Urbach et al.[15]	Can	Adm	5156	54	n.r.	•	•	—	—	—
Freixinet et al.[16]	Spain	Clin	2994	19	n.r.	•	•	—	•	•
Romano and Mark[17]	USA	Adm	12439	389	n.r.	•	•	—	•	•
Simunovic et al.[18]	Canada	Adm	2698	67	n.r.	•	•	—	•	—
Finlayson et al.[19]	USA	Adm	21890	674	n.r.	•	•	•	—	•
Osada and Yamakoshi[20]	Japan	Clin	3233	91	n.r.	•	—	—	•	•
Osada and Yamakoshi[20]	Japan	Clin	18055	540	n.r.	•	—	—	—	•
Hollenbeck et al.[21]	USA	Adm	90088	n.r.	n.r.	•	•	•	—	—
Kim et al.[22]	South Korea	Adm	987	n.r.	n.r.	•	•	•	—	—
Li et al.[23]	Netherlands	Clin	1097	20	n.r.	•	—	—	•	—
Birkmeyer et al.[24]	USA	Adm	12967	517	n.r.	•	•	•	•	•
Cheung et al[25]	USA	Adm	13469	90	n.r.	•	•	—	•	•
Lien et al.[26]	Taiwan	Adm	4841	79	377	•	•	—	•	•
Goodney et al.[27]	USA	Adm	25545	n.r.	n.a.	•	•	—	—	•
Schipper et al.[28]	USA	Adm	86538	n.r.	n.a.	•	•	—	—	•
Farjah et al.[29]	USA	Adm	19745	n.r.	n.a.	•	•	—	•	•

Adm, based on administrative data; Clin, based on clinical data; n.r., not reported; n.a., not applicable; Demographic, adjusted for demographic data (e.g., patient age, sex, race, and income); Comorbidities, adjusted for comorbidities (including American Society of Anesthesiologists classification); Urgency, adjusted for urgency of the operation; Tumor, adjusted for tumor characteristics (e.g., stage, grade, and location); Treatment, adjusted for treatment differences (e.g., surgical approach; [neo]adjuvant treatments); Mortality, s urvival analysis adjusted for postoperative mortality; Hospital, adjusted for other hospital characteristics (e.g., teaching or academic status); Low: <10, low-volume group < 10, High: >20, high-volume > 20 resections a year; S, statistically significant; NS, statistically nonsignificant; L, lesser lung resections; P, pneumonectomies; TS, general thoracic surgeon; CTS, cardio thoracic surgeon; GS, general surgeon.

was used.[4] Heterogeneity was quantified by the I^2 test. An I^2 less than 40 was considered homogeneous; between 40 and 60, moderately heterogeneous; and greater than 60 very heterogeneous.[5] We conducted a sensitivity analysis to assess the impact of subgroups in case of heterogeneity. Publication bias was assessed with an Egger's regression intercept.[6] Meta-regression analysis was done for cutoff values of hospital volume, using a fixed-effects regression test. The meta-analysis was conducted with Comprehensive Meta Analysis, professional version 2.2 (Biostat Inc., Englewood NJ).

RESULTS

Search Results

Our initial search identified 95 potentially relevant articles. After the first screening, 17 articles were retrieved for more detailed evaluation. From these, six articles were excluded.[7–12] The remaining 11 articles were selected. After this first selection, the related-articles feature in PubMed was used, and the reference lists of retrieved articles were hand-searched to identify eight additional articles, which met the

		Hospital Volume				Surgeon Volume				Surgeon Specialty		
		Volume Categories				Volume Categories						
Mortality	Hospital	Low	High	Mortality	Survival	Low	High	Mortality	Survival	Surgeon Categories	Mortality	Survival
—	—	<9	>46	S(L) & (P)	—	—	—	—	—	—	—	—
—	•	—	—	—	—	<7	>17	NS	—	—	—	—
—	—	<5	>20	NS	S	—	—	—	—	—	—	—
—	—	<21	>83	S	S	—	—	—	—	—	—	—
—	—	<18.2	>129,4	NS	—	—	—	—	—	—	—	—
—	—	<44	>54	NS	NS	—	—	—	—	—	—	—
—	•	<9	>24	S (L), NS (P)	—	—	—	—	—	—	—	—
—	•	<10.7	>43,7	NS	S	—	—	—	—	—	—	—
—	—	<19	>37	NS(L) &(P)	—	—	—	—	—	—	—	—
—	—	<20	>79	—	S	—	—	—	—	—	—	—
—	—	<25. quartiles	>99	NS	—	—	—	—	—	—	—	—
—	—	<3.6	>116,3	S	—	—	—	—	—	—	—	—
—	—	<5	>20	NS	—	—	—	—	—	—	—	—
—	•	<40	>60	—	NS	—	—	—	—	CTS vs. GS	—	NS
•	—	<11.4	>25,2	—	S	—	—	—	—	—	—	—
—	•	<60	>60	—	S	—	—	—	—	—	—	—
—	—	—	—	—	—	<11.5	>33	S	—	—	—	—
—	•	—	—	—	—	—	—	—	—	663 TS, 1516 CTS, 2614 GS	S	—
—	•	—	—	—	—	—	—	—	—	331 TS, 3401 CTS, 9194 GS	S (L), NS (P)	—
—	—	—	—	—	—	—	—	—	—	388 TS, 684 CTS, 776 GS	NS	S

predefined inclusion criteria. Nineteen eligible articles were analyzed (Fig. 1).

Study Characteristics

Table 2 shows the characteristics of the 19 studies included in the review. Most studies are from the United States and Canada, and the remaining studies are from Asia and Europe. Study data have been obtained frequently from the databases of insurance companies or national cancer registries (Medicare, National Inpatient Sample). The number of patients, hospitals, and surgeons varied widely among the included studies. In all selected studies, the results were adjusted for differences in case mix, but the parameters used for the adjustments differed largely. For hospital volume, cutoff values of the highest volume strata varied between 20 and 129.4 procedures annually, and the lowest hospital-volume strata cutoff varied between 3.6 and 60. The rationale for the cutoff values used varied and was not always explained in the sections on methodology in the articles.

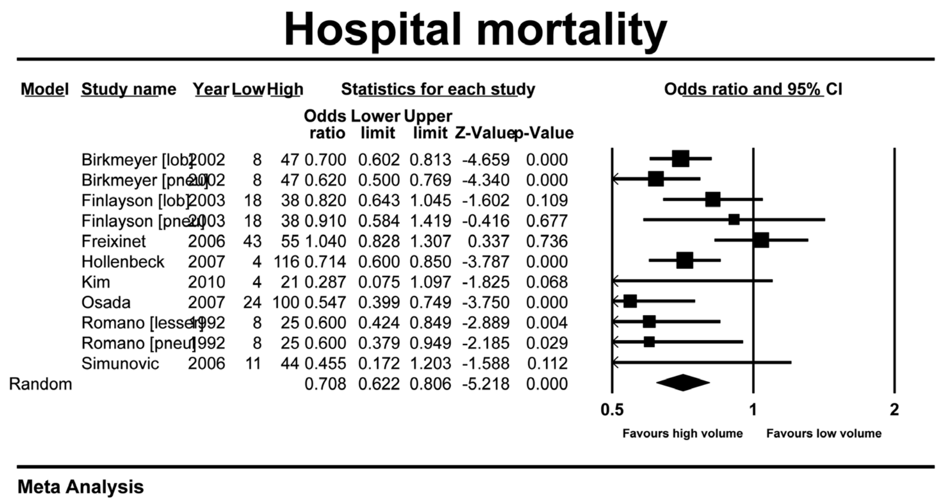


FIGURE 2. Forest plot of the included studies using OR in the meta-analysis on hospital volume and postoperative mortality for lung resections for cancer. Separate analysis of pneumonectomies and lobectomies in case of sufficient data. OR, odds ratio; Study name, name of first author (resection type if specific odds ratios available); Year, year of publication; Low, highest annual volume of low-volume category; High, lowest annual volume of high-volume category; CI, confidence interval.

Hospital Volume

Postoperative mortality was used as an outcome parameter in 11 studies; in five of these studies, a significant inverse relationship between hospital volume and 30-day or in-hospital mortality was found.[1,13–22]

Ten studies were used for the meta-analysis, as one did not provide an OR.[13] All of these studies had an observational design, and only two studies were based on clinical data; the remaining eight were based on administrative data. In all but one, the results were adjusted not only for age and sex, but also for other parameters. (Table 2)

Figure 2 shows the forest plot regarding hospital volume and postoperative mortality using ORs. The effect was significant in favor of high-volume hospitals (OR 0.71; CI 0.62–0.81). One study used HRs and one study used relative risk, both favoring high hospital volume, with an HR of 0.76 (CI 0.66–0.88) and RR of 0.83 (CI 0.59–1.25), respectively.[14,15] There was moderate heterogeneity between the two studies (I^2 = 53). Subgroup analysis of the studies using ORs did not reveal any parameter showing significant influence on the pooled estimate effect size. (Table 3) No publication bias was detected (p = 0.36).

Regression analysis did not identify a cutoff value for volume of resections for lung cancer to differentiate hospitals with high versus low postoperative mortality rates. The p value for the slope is 0.73 (Fig. 3).

Differences in survival between high- and low-volume hospitals were evaluated in eight studies, five of which showed a significant inverse relationship between hospital volume and survival and one of which showed a significant benefit for the lower-volume category.[13,14,16,18,20,23–25]

Seven studies met the criteria for the meta-analysis, as one did not provide an HR.[16] All studies were observational; two studies used clinical instead of administrative data. In all studies, the results were adjusted not only for age and sex, but also for other parameters (Table 2).

Figure 4 shows the forest plot on hospital volume and survival. The effect was in favor of high-volume hospitals but it did not reach statistical significance (HR 0.93; CI 0.84–1.03). This result was very heterogeneous (I^2 = 85). In

TABLE 3. Sensitivity Analysis of the 11 Included Series on Hospital Volume and Postoperative Mortality with Odds Ratios as Effect Size

Factor	Subgroup	N	OR	CI	*p* Value
Datasource					0.367
	Administrative	9	0.69	0.60–0.79	
	Clinical	2	0.79	0.60–1.04	
Comorbidity					0.198
	Not adjusted	1	0.55	0.36–0.83	
	Adjusted	10	0.73	0.64–0.83	
Urgency					0.810
	Not adjusted	5	0.69	0.55–0.86	
	Adjusted	6	0.72	0.60–0.85	
Tumor stage					0.367
	Not adjusted	9	0.69	0.60–0.79	
	Adjusted	2	0.79	0.60–1.04	

This (two-sided) p value is the result of the mixed-effects analysis and tells us whether there is a statistically significant difference in the effect between subgroups.

N, number of studies; OR, odds ratio; CI, confidence interval; I^2, result of I square test on heterogeneity of study results.[8]

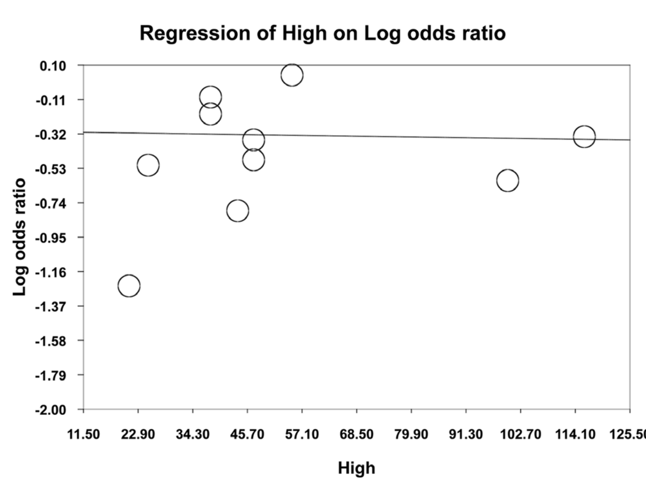


FIGURE 3. Regression analysis of the effect of high procedural hospital volume on hospital mortality.

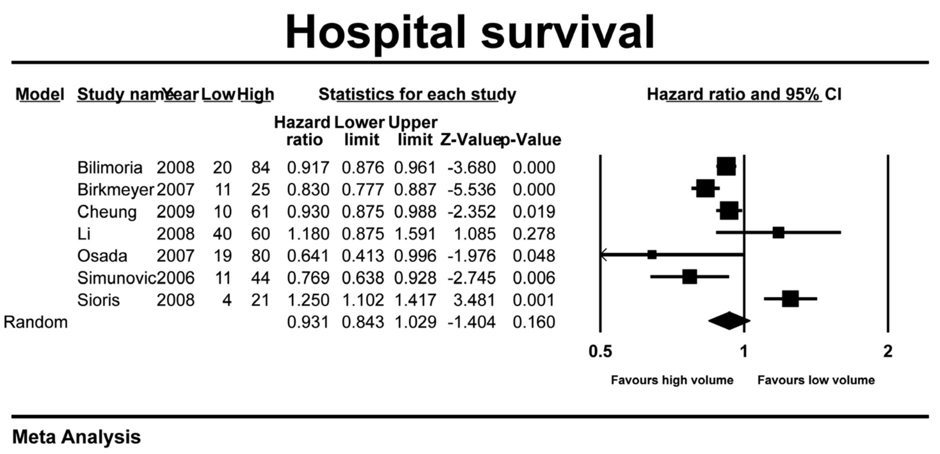


FIGURE 4. Forest plot of the included studies in the meta-analysis on hospital volume and survival of lung resections for cancer. Study name, name first author (resection type if specific odds ratios available); Year, year of publication; Low, highest annual volume of low-volume category; High, lowest annual volume of high-volume category; CI, confidence interval.

TABLE 4. Sensitivity Analysis of the Included Studies on Hospital Volume and Survival with Hazard Ratios as Effect Size

Factor	Subgroup	N	OR	CI	*p* Value
Datasource					0.961
	Administrative	3	0.93	0.79–1.10	
	Clinical	4	0.93	0.79–1.09	
Comorbidity					**0.003**
	Not adjusted	3	1.15	0.98–1.34	
	Adjusted	4	0.88	0.81–0.95	
Urgency					0.472
	Not adjusted	5	0.96	0.83–1.12	
	Adjusted	2	0.88	0.72–1.07	
Tumor stage					0.127
	Not adjusted	1	0.64	0.39–1.05	
	Adjusted	6	0.95	0.86–1.05	

This (two-sided) *p* value is the result of the mixed-effects analysis and tells us whether there is a statistically significant difference in the effect between subgroups.

Bold indicates statistical significance.

N, number of studies; OR, odds ratio; CI, confidence interval; I^2, result of I square test on heterogeneity of study results.[8]

subgroup analysis, a significant effect of hospital volume on survival was observed after adjustment for comorbidities (OR 0.88; CI 0.81–0.95) ($p = 0.003$, Table 4). No publication bias was detected ($p = 0.82$).

Surgeon Volume

In two studies, the relationship between surgeon volume and outcome was investigated.[2,26] Both studies used postoperative mortality as an outcome parameter; one showed a significant result favoring high volume. Both were used for the meta-analysis. Age, sex, and comorbidities were included in the multivariate analysis in both studies. One adjusted for tumor characteristics and treatment differences in its outcome analyses, the other for urgency of operation and other hospital characteristics.

Figure 5 shows the forest plot of the two studies. In the meta-analysis, a pooled estimated effect size was detected in favor of high-volume surgeons, but this effect did not reach statistical significance (OR 0.68; CI 0.42–1.08) and was very heterogeneous ($I^2 = 66$). The number of studies is too small to properly assess publication bias or perform subgroup analysis.

Surgeon Specialty

In three studies, the relationship between surgeon specialty and postoperative mortality was investigated.[27–29] These studies compared three provider groups: general surgeons (GS), cardiothoracic surgeons (CTS), and general thoracic surgeons (TS). One study showed a significant difference; in another, the difference was significant in lobectomies, not in pneumonectomies. The third study did not show a significant difference. All three studies met the inclusion criteria for the meta-analysis. In all, age, sex, comorbidities, and treatment differences were included in the multivariate analysis. Two adjusted for other hospital characteristics and one adjusted for tumor characteristics in their survival analyses. Figures 6*A* and *B* show the forest plots of the included studies. There was a significant pooled estimated effect size in favor of TS over GS (OR 0.78; 0.70–0.88), and of CTS over GS (OR 0.82; CI 0.69–0.96). As a result of the lack of ORs comparing TS with CTS, no pooled estimate could be calculated. The number of studies, again, is too small to properly assess publication bias or perform subgroup analysis.

Differences in survival between different specialties were evaluated in two studies, one of which showed a significant difference both when comparing GS with CTS and when comparing GS with TS.[23,29] Both studies met the inclusion criteria for the meta-analysis. Both adjusted for age, sex, and tumor characteristics; one also adjusted for comorbidity and treatment differences, the other, for other hospital characteristics.

Figure 7 shows the forest plot of the included studies. In the meta-analysis, a pooled estimated effect size was detected in favor of TS over GS, but this effect did not reach statistical significance (HR 0.86; CI 0.74–1.00). This result was very homogeneous ($I^2 = 28$). The number of studies is too small to properly assess publication bias or perform subgroup analysis.

DISCUSSION

This study is the first meta-analysis on the effect of surgeon specialty and of procedural volume on postoperative

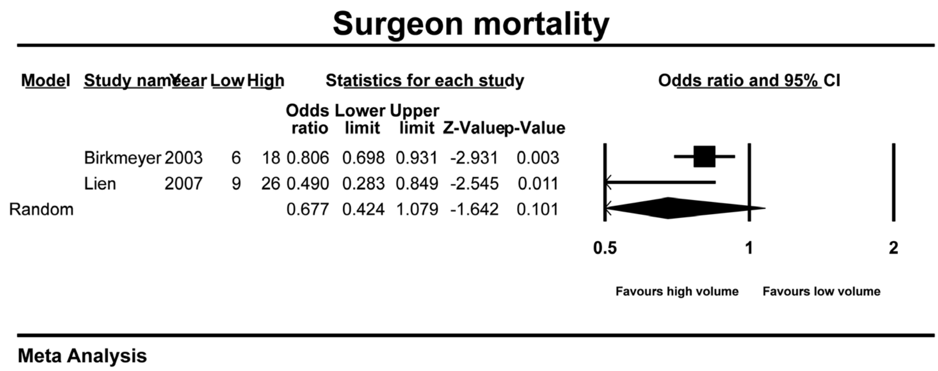


FIGURE 5. Forest plot of the included studies in the meta-analysis on surgeon volume and postoperative mortality of lung resections for cancer. Year, year of publication; Low, highest annual volume of low-volume category; High, lowest annual volume of high-volume category; CI, confidence interval.

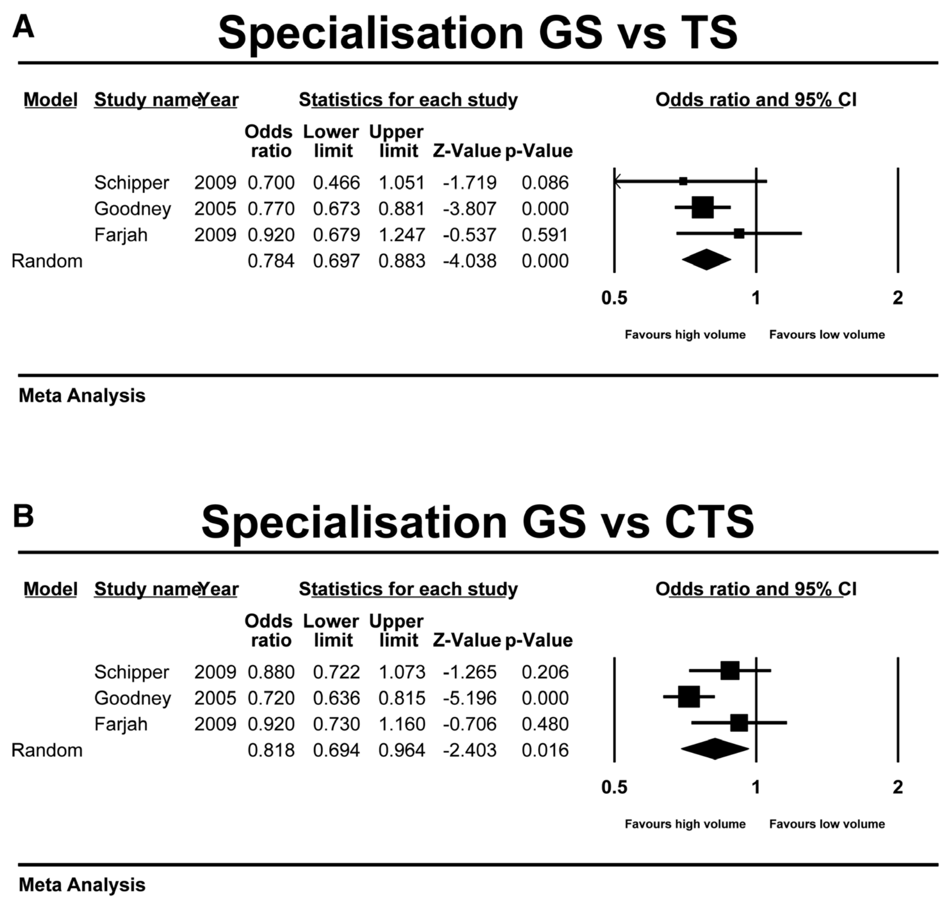


FIGURE 6. *A* and *B*, Forest plot of the included studies in the meta-analysis on surgeon specialty and postoperative mortality of lung resections for cancer. *A*, General surgeon versus general thoracic surgeon. *B*, General surgeon versus cardiothoracic surgeon. GS, general surgeon; TS, general thoracic surgeon; CTS, cardiothoracic surgeon; Year, year of publication; Low, highest volume of low-volume category; High, lowest annual volume of high -volume category; CI, confidence interval.

mortality and long-term survival after lung resections for cancer. Only a minority of the increasing number of published studies met our strict inclusion criteria for methodological quality. We found that hospital volume has a significant inverse relationship with postoperative mortality, although moderate heterogeneity among studies exists. A cutoff value for hospital volume could not be identified.

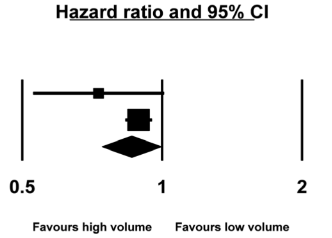
The effect of hospital volume on survival only reached significance in the subgroup of these very heterogeneous studies, which adjusted for comorbidity (Table 4). This suggests that high-volume hospitals tend to treat more patients with multiple comorbidities, which influences the overall survival in these hospitals.

The pooled-effect estimate of surgeon volume on mortality did not reach significance (very heterogeneous), suggesting that outcome depends more on hospital setting and team performance than on volume of individual surgeons. Specific thoracic training, however, is of significant importance. Postoperative mortality and survival rates are significantly in favor of CTS and TS when compared with GS (very homogeneous).

The available evidence has limitations that cannot be ignored. Our review confirms that most studies are observational, retrospective, and based on administrative data collected for other purposes, instead of carefully designed comparative studies (Table 2). However, we did not observe

Specialisation GS vs TS survival

Model	Study name	Year	Hazard ratio	Lower limit	Upper limit	Z-Value	p-Value
	Li	2008	0.730	0.529	1.008	-1.913	0.056
	Farjah	2009	0.890	0.835	0.949	-3.574	0.000
Random			0.861	0.744	0.996	-2.020	0.043



Meta Analysis

FIGURE 7. Forest plot of the included studies in the meta-analysis on surgeon specialty and survival of lung resections for cancer. General surgeon versus general thoracic surgeon. GS, general surgeon; TS, general thoracic surgeon; Year, year of publication; Low, highest annual volume of low-volume category; High, lowest annual volume of high-volume category; CI, confidence interval.

significantly different effect sizes among studies using clinical data and those using administrative data. Large variation was observed in demographical, geographical, and epidemiological factors and in standards of care and definitions of surgeon specialties. Awareness of these differences in training and certification of "specialized" surgeons is important in interpreting these results. In the Dutch situation, for instance, a growing number of GSs have had specialist training in lung resections, which should qualify them as general TSs.[23]

Substantial heterogeneity was identified in evaluating studies' methodological quality. The choice of volume categories was extremely diverse but seldom explained. The variety in cutoff values made it impossible to identify a minimal hospital volume with regression analysis, despite looking for the biggest difference by comparing the highest- and lowest-volume category from each article.

Apart from the methodological shortcomings mentioned above, volume-outcome studies have other important limitations. In only few studies, data have been corrected for (other) provider characteristics, such as the available infrastructure, teaching or academic status, experience with other high-risk operations, expertise in multimodality cancer treatments, a hospital's budget, focus and/or referral bias.[17,18] Also, in almost all studies, only the resected patients were analyzed. Essential data on patient selection and resection rates are missing; therefore, the effect of procedural volume or surgeon specialty on the ability to provide appropriate surgical care for more challenging patients remains unclear. Low-volume centers might predominantly select a more favorable patient group (lower stage and less comorbidity), thus influencing their outcome. The question of whether this clinically more favorable patient group would also benefit from referral to high-volume centers could not be assessed in this meta-analysis. These factors are often related to, but not identical with, procedural volume.

In the Netherlands the Quality of Cancer Care task force of the Dutch Cancer Society has recently proposed to concentrate specific cancer treatments in hospitals that meet a set of criteria.[30] The Dutch Surgical Society set the criteria for lung cancer surgery.[31] These criteria focus not only on procedural volume, but also on the available infrastructure, specialization, and outcome measures, which should be reported by individual institutions.[32] Careful analysis of audit data retrieved from different hospitals that vary in patterns of care and outcomes might identify ways to improve lung cancer treatment more than merely enforcing volume criteria.[33–35] In our opinion, policy makers should bear this in mind when efforts are made to centralize complex high-risk surgical procedures.

In conclusion, this meta-analysis has shown that higher procedural volume is associated with better outcomes in lung cancer surgery. Annual hospital volume seems more important than the volume of individual surgeons. Surgeon specialty is also of significant importance. Concentration of lung cancer surgery could lead to a decrease in postoperative mortality and a better overall survival, although there is no evidence for a specific annual volume cutoff. Evaluation of individual institutions in a national audit program might help elucidate the influence of individual quality-of-care parameters, including hospital volume, on outcome, and provide better parameters to help improve surgical cancer care.

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