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Hospital lung surgery volume and patient outcomes

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ABSTRACT

Objectives: There has been evidence of an association between patient outcomes and the number of surgeries performed at a hospital. To our knowledge, there are no Australian data on hospital cancer surgery volumes and patient outcomes. We evaluated the relationship between hospital non-small cell lung cancer (NSCLC) surgery volume and patient outcomes in Victoria.

Materials and methods: Patients with a primary diagnosis of NSCLC between 2008 and 2014 were identified in the Victorian Cancer Registry (n = 15,369), 3,420 (22%) of whom had lung cancer surgery. Primary outcome was death within 90 days of surgery and secondary outcomes included overall survival, use of postoperative ventilation and ≥24hours spent in ICU. Hospital volume was measured as the average number of lung surgeries performed per year, with quartiles Q1: 1–17, Q2: 18–34, Q3: 35–58 and Q4: 59 + .

Results: 57% (1,941/3,420) lung cancer patients underwent lobectomy, 38% (1,299/3,420) sub-lobar resection and 5% (180/3,420) pneumonectomy. The overall 90-day mortality after lung surgery was 3.5%, and was 2.6% and 4.5% for patients undergoing lobectomy and sub-lobar resection respectively. There was no difference in 90-day mortality and overall survival between low- and high-volume centres regardless of procedure. Patients operated on in lower volume centres had more admissions to ICU ≥24hours (Q1. 55% vs. Q4. 11%, p-trend < 0.001). A higher proportion of patients attending private hospitals (19%) had an ASA score of 4 compared with patients attending a public hospital (9%).

Conclusion: We observed no evidence of survival differences between lung cancer patients attending low- and high-volume hospitals for cancer surgery. A higher proportion of patients had an ICU admission ≥24hours in lower volume centres and there are a higher proportion of patients with an ASA score of 4 in private hospitals compared to public hospitals.

1. Introduction

Lung cancer is the fifth most common cancer diagnosed in Australia and the leading cause of cancer death. It is estimated that 9000 patients will have died from lung cancer in Australia in 2017 [1]. Australia has some of the best patient outcomes compared to international data, but 5-year survival for localised disease is still only approximately 40% [2,3].

Surgical resection remains the primary curative option for early stage non-small cell lung cancer (NSCLC) with lobectomies considered the gold standard due to a reduction in local recurrence and improved overall survival [4–6]. Interest in hospital surgical volumes and patient outcomes has grown since the 1979 seminal paper by Luft et al that demonstrated 25–41% lower mortality for patients undergoing operations in hospitals performing 200 or more of the operations annually [7]. Since then, there is growing evidence of an association between patient outcomes and the number of cancer surgeries performed at a hospital. Luchtenborg et al found that hospitals with high lung cancer surgical volumes had reduced length of stay, lower risk of readmission and lower 30-day and 90-day mortality [8]. To our knowledge, there are no Australian data on hospital cancer surgery volumes and patient outcomes by procedure, and few data worldwide on specific lung surgery procedures and outcomes.

We evaluated the relationship between hospital lung cancer surgery volume and patient outcomes in 30 centres across Victoria, Australia over a 7-year period.

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2. Materials and methods

2.1. Patients

Victorian residents, aged 18 years and over, with a primary diagnosis of lung cancer (International Classification of Diseases [version 10] codes C33 and C34) between 2008 and 2014 were identified in the Victorian Cancer Registry (VCR) (n = 18,036). Patients with histologically confirmed small cell lung cancer were excluded (n = 1904). The remaining cohort comprised of histologically confirmed NSCLC (12,920/16,132) and unknown morphology patients (3,212/16,132) who were assumed to be NSCLC. The first tumour diagnosis was selected for patients with more than one diagnosis of NSCLC, affecting 48 patients. Patients diagnosed on death certificate only (n = 763) were excluded. The final data set included 15,369 eligible NSCLC patients.

2.2. Patient characteristics

The VCR dataset was linked to hospital admission records between 2007 and 2014 from the Victorian Admitted Episodes Dataset (VAED). The linked dataset provides patient demographics, comorbidities, hospitalization details, specific lung surgery procedure performed and date of admission for surgery. Data on surgery were included for procedures that occurred between 30 days prior to and 6 months after NSCLC diagnosis date. There were 3,420 NSCLC patients who underwent a surgical resection.

Patients were grouped by surgical procedure performed, defined as pneumonectomies, lobectomies and sub-lobar resections including wedge/segmental resections. If patients had more than one surgery admission, the earliest admission was selected, with the exception of patients who underwent a sub-lobar resection followed by a lobectomy within 30 days. If a patient underwent more than one lung procedure type within the same admission, the patient was assigned to the most severe surgical group (pneumonectomy followed by lobectomy and sub-lobar resection).

Comorbidities were extracted from the diagnosis codes of admitted episodes in the year prior to the patient's surgery date (inclusive) and classified using the Charlson comorbidity index (excluding cancer and metastases) with updated weights described by Quan et al 2011 [9]. Scores were grouped into three categories of increasing severity (0, 1–2 and 3+). The American Society of Anesthesiologists (ASA) score was categorized into four groups: 1–2 (most fit), 3, 4 (least fit) and 9 (unknown). Patients were categorised as non-emergency or emergency as defined by the admission type prior to surgery. This included patients who were admitted through an emergency department, or "other emergency admission" including "GP referral for an acute issue; transfer from an outpatient department or another campus" or designated as an emergency on the anesthesia procedure code.

2.3. Hospital volume

Mean annual lung surgery volume was calculated for each of the 30 campuses over the time period of 2008–2014 based on all surgical admissions of NSCLC patients, including patients who are not in our study cohort. Mean annual volume was assigned to each patient by the campus of their surgery. Patients were grouped into hospital volume quartiles.

2.4. Outcomes

The distribution of patients and surgical characteristics were calculated according to hospital volume quartile. Associations between patient, surgical characteristics and volume quartile were assessed using proportional odds model for independent categorical variables and the Kendall Tau rank correlation for independent ordinal variables, excluding missing value categories.

The primary endpoint was death within 90 days of surgery date. Secondary endpoints were overall survival, use of mechanical ventilation during the surgery admission, 24 h or more spent in an intensive care unit (ICU) following the surgery and prolonged length of stay (LOS) of 16 days or greater (90th percentile). Multivariable logistic regression analyses were performed to examine the association between mean annual hospital volume quartile and binary outcomes. Cox proportional hazard models were used to estimate hazard ratios (HR) for the association between mean annual hospital volume quartile and risk of death. All included patients had at least 90-days follow-up. Overall survival analysis was calculated from the date of surgery to date of death from all causes or censor date of 31 December 2014. All models were adjusted for age (categorical; < 60, 60–69, 70–79, 80+), sex (male/female), comorbidity score (0, 1, 2 or 3+) and emergency admission type (no/yes). A limited post-hoc analysis regarding differences in surgical procedures and ASA score between private and public centres was also performed.

Linear trends of hospital volume on outcomes were estimated by fitting mean annual hospital volume quartile as a continuous variable. P-values were determined using a likelihood ratio test. All analyses were performed using R Statistical Software (version 3.3.2).

3. Results

There were 15,369 eligible patients diagnosed with NSCLC between 2008 and 2014 in Victoria. Overall, 3420 (22%) of patients underwent surgery with 1941 (57%) lobectomies, 1299 (38%) sub-lobar resections and 180 (5%) pneumonectomies. Seventy-eight percent of surgery patients had no prior comorbidities. Only 37 of the 3420 surgical patients included had unknown morphology at the time of notification of cancer diagnosis to the VCR.

Mean annual hospital volume quartiles were defined as Q1: < 18, Q2: 18–34, Q3: 35–58 and Q4: > 58. Table 1 summarizes patient and surgery characteristics in each mean annual hospital volume quartile. The distribution of the mean annual lung surgery volume by hospital and the mean annual hospital volume range per quartile are shown in Supplementary Fig. 1 and Supplementary Table 1 respectively. The mean and median for NSCLC surgical admissions were similar for the majority of centres; 15 centres, 12 centres and 3 centres had < 1 surgical admission difference, 1–4 surgical admission difference and 5–7 surgical admission difference between the median and mean respectively. The number of surgical admissions is very similar to the number of procedures performed. Of the 30 hospitals included, 8 hospitals had at least one year where no NSCLC surgical admissions were documented, however, in the majority of other years, their volume is within the range of quartile 1 (Fig. 1). Patient populations within the surgical volume quartiles in terms of age, sex and comorbidity score did not vary. Emergency admissions and surgery group varied between volume quartiles, with a greater proportion of emergency admission type and fewer pneumonectomies performed in lower volume hospitals.

The overall 90-day mortality after lung surgery was 3.5%. The 90-day mortality at 2.6% was lower for patients undergoing lobectomy compared with 4.5% for those undergoing a sub-lobar resection. Unadjusted data for the sub-lobar resection patients showed 90-day mortality of 5.4% for hospitals in the lowest volume quartile compared with 3.1% for hospitals in the highest volume quartile. However, when adjusted there was no statistically significant difference between 90-day mortality and hospital volume for patients who underwent a sub-lobar resection (Table 2).

The proportion of patients requiring admission to ICU for ≥24hours was significantly lower in patients undergoing lung surgery in higher volume hospitals compared to the lowest (p-trend < 0.001) (Table 3). There was less use of mechanical ventilation in the highest volume quartile, but this was not statistically significant (Supplementary Table 2).

The HR estimate was consistent with better overall survival for

Table 1
Characteristics of Victorian patients with NSCLC who underwent a lung resection by mean hospital volume quartile.2008–2014.

Variable	Surgical volume (Mean no. of surgeries/year)	Q1: < 18 (N = 866)	Q2: 18-34 (N = 1026)	Q3: 35-58 (N = 753)	Q4: > 58 (N = 775)	P-trend	Total
Surgical group	Lobectomy	473 (55%)	649 (63%)	397 (53%)	422 (54%)	< 0.001[a]	1941 (57%)
	Pneumonectomy	23 (3%)	50 (5%)	41 (5%)	66 (9%)		180 (5%)
	Sub-lobar resection	370 (43%)	327 (32%)	315 (42%)	287 (37%)		1299 (38%)
Age	< 60	149 (17%)	209 (20%)	165 (22%)	151 (19%)	0.803^	674 (20%)
	60-69	304 (35%)	359 (35%)	247 (33%)	250 (32%)		1160 (34%)
	70-79	316 (36%)	347 (34%)	285 (38%)	267 (34%)		1215 (36%)
	80+	97 (11%)	111 (11%)	56 (7%)	107 (14%)		371 (11%)
Sex	Female	399 (46%)	485 (47%)	321 (43%)	337 (43%)	0.105[a]	1542 (45%)
	Male	467 (54%)	541 (53%)	432 (57%)	438 (57%)		1878 (55%)
Comorbidity score	0	688 (79%)	802 (78%)	569 (76%)	608 (78%)	0.351^	2667 (78%)
	1-2	161 (19%)	201 (20%)	165 (22%)	153 (20%)		680 (20%)
	3+	17 (2%)	23 (2%)	19 (3%)	14 (2%)		73 (2%)
Emergency admission	No	826 (95%)	976 (95%)	728 (97%)	757 (98%)	0.007[a]	3287 (96%)
	Yes	40 (5%)	50 (5%)	25 (3%)	18 (2%)		133 (4%)

[a] Proportional odds model ; ^Kendall Tau rank correlation.

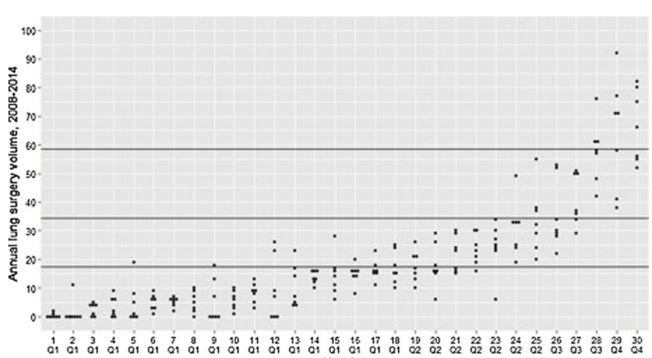

Fig. 1. Within and between variation in annual lung surgery volume by hospital, 2008–2014. Each dot represents a year. The lines represent the cutoffs for the 4 vol groups.

patients having surgery in the hospitals with higher volume but was not statistically significant in multivariable models (Supplementary Table 3). Survival curves by surgery type are shown in Fig. 2, with median survival following surgery being 6.2 years for lobectomy patients, 5.4 years for sub-lobar resection patients and 5.8 years for pneumonectomy patients.

Patients categorised based on emergency admission type had poorer outcomes. The odds of dying within 90d of surgery were 3.44 [95%CI 1.15–10.23] (lobectomy) and 7.99 [95%CI 4.18–15.26] (sub-lobar resection) times higher for emergency vs. non-emergency patients. In the overall survival analysis, emergency lobectomy patients had a more than double (2.11 [95%CI 1.36–3.28]) and emergency sub-lobar patients a more than triple (3.29 [95%CI 2.38–4.56]) increased risk of death compared to non-emergency patients. The rate of emergency admissions associated with a surgical episode was low (4%), but still greater than expected. A chart audit was consequently carried out in one institution, which identified that for the majority of patients, these

Table 2
90-day mortality for NSCLC patients post-lung resection by surgery type.2008–2014.

Surgery	Surgical volume (Mean no. of surgeries/ year)	n/N	OR [95% CI]	P-trend
Lobectomy	1-17	13/473	1	0.820
	18-34	18/649	1.01 [0.48 - 2.10]	
	34-58	8/397	0.74 [0.30 - 1.84]	
	59+	12/422	0.98 [0.43 - 2.19]	
Sub-lobar resections	1-17	20/370	1	0.263
	18-34	16/327	0.76 [0.38 - 1.56]	
	34-58	13/315	0.80 [0.38 - 1.67]	
	59+	9/287	0.62 [0.27 - 1.40]	
Any (pneumonectomy/ sub-lobar/ lobectomy)	1-17	34/866	1	0.408
	18-34	38/1026	0.93 [0.57 - 1.51]	
	34-58	24/753	0.83 [0.48 - 1.42]	
	59+	24/775	0.82 [0.47 - 1.40]	

CI, confidence interval; n: number of deaths; N: number of cases; NSCLC, Non-small cell lung cancer; OR, odds ratio. Adjusted for age, sex, comorbidity score and emergency status.

Table 3
Odds ratio and 95% CI for the risk of spending ≥24 h in ICU post lung resection for NSCLC patients.2008–2014.

Surgery	Surgical volume (Mean no. of surgeries/ year)	n/N	OR [95% CI]	P-trend
Lobectomy	1-17	284/473	1	< 0.001
	18-34	139/649	0.17 [0.13 - 0.22]	
	34-58	122/397	0.28 [0.21 - 0.38]	
	59+	40/422	0.06 [0.04 - 0.09]	
Sub-lobar resections	1-17	183/370	1	< 0.001
	18-34	63/327	0.21 [0.15 - 0.30]	
	34-58	66/315	0.25 [0.18 - 0.36]	
	59+	26/287	0.09 [0.06 - 0.15]	
Any (pneumonectomy/ sub-lobar/ lobectomy)	1-17	480/866	1	< 0.001
	18-34	231/1026	0.22 [0.18 - 0.27]	
	34-58	212/753	0.30 [0.24 - 0.37]	
	59+	85/775	0.09 [0.07 - 0.12]	

CI, confidence interval; ICU, Intensive Care Unit; n: number of patients spending > 24 h in ICU; N: number of cases; NSCLC, Non-small cell lung cancer; OR, odds ratio. Adjusted for age, sex, comorbidity score and emergency status.

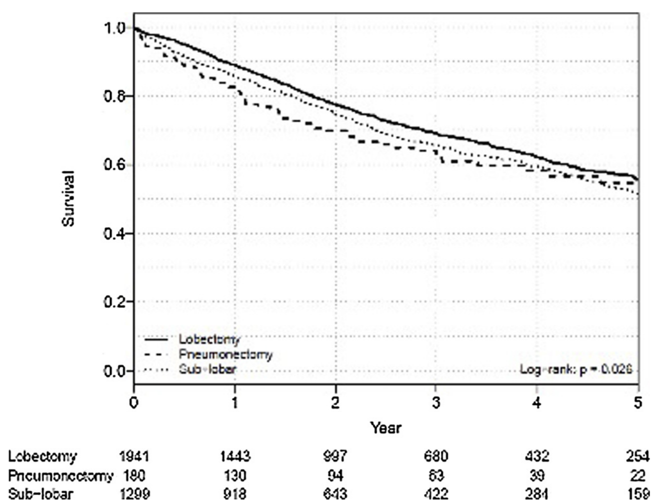

Fig. 2. Kaplan-Meier survival curves for NSCLC patients who underwent a lobectomy, pneumonectomy or sub-lobar resection, 2008 - 2014.

were not emergency admissions, despite being flagged as such. Regardless, this group of patients had very poor outcomes and what is driving outcomes for this category of patients requires further investigation.

Median LOS was 8 days (inter-quartile range, IQR, 6–11) for patients who underwent a lobectomy or pneumonectomy and 7 days (IQR, 5–10) for sub-lobar resection. The proportion of patients requiring a prolonged length of stay in hospital did not differ significantly between hospital volume quartiles regardless of surgical procedure (Supplementary Table 4).

The distribution of ASA scores differed between patients attending public hospitals and private hospitals, and consequently, calculations were not risk adjusted for ASA. A higher proportion of patients attending private hospitals had an ASA score of 4 compared to patients attending public hospital (Table 4). Interestingly, this was not reflected in comorbidity score, a more objective measure of comorbidities (Supplementary Table 5). The proportion of patients undergoing lobectomies, sub-lobar resections and pneumonectomies were similar in private and public hospitals (Supplementary Table 6).

4. Discussion

Our study provides an in-depth exploration of the association between hospital lung cancer surgery volumes, specific surgical procedure and patient outcomes that, to our knowledge, has not been published previously for Australia.

We observed that 22% of patients underwent resection for NSCLC, similar to data from an earlier Victorian study as well as data from New South Wales (NSW) and Queensland where surgical rates are between 17–20% [2,10–12]. We are comparable to overseas centres in the United Kingdom (UK) and Europe although our data describe a more recent cohort [13–15]. Our data demonstrated that 57%, 38% and 5% of patients with NSCLC underwent a lobectomy, sub-lobar resection and pneumonectomy respectively, compared to 63%, 32% and 5% in NSW. American series have reported higher rates of lobectomies compared to sub-lobar resections [16–19]. The reasons for the international difference are unknown.

Despite similar use of resection, we have better survival compared to other Australian states, the UK, and USA. One and five-year overall survival for patients undergoing resection were 87.4%, and 54.1% respectively. Prior data from Victoria and Western Australia reported 46% and 38% five-year survival rates respectively for all patients undergoing lung cancer resection [3,20]. Five-year survival in the USA is between 33–46% [21]. In the UK, one year and five-year survival have been reported as 63% and 31% respectively [14]. There are likely a number of contributing factors such as differences in the stage of disease at diagnosis [22], histology [22], proportion microscopically verified diagnoses [23,24], uptake of adjuvant chemotherapy [25,26] and centralization of specialist services [23] to explain the differences in survival between developed countries.

There was no difference in 90-day mortality between high volume and low volume centres in patients undergoing lobectomies or sub-lobar resections. However, patients undergoing lobectomies in both high and low volume centres had a lower 90-day mortality compared to patients undergoing sub-lobar resections, likely reflecting the comparable health status of the patient group. Lobectomy is the preferred approach to curative resection but is limited to patients who are good surgical candidates that can tolerate the removal of a lung lobe.

Table 4
Distribution of ASA scores between public and private hospitals in NSCLC patients.2008–2014.

ASA	1	2	3	4	9	Total
Public hospital	17 (1%)	417 (20%)	1050 (50%)	179 (8%)	445 (21%)	**2,108**
Private hospital	15 (1%)	167 (13%)	644 (49%)	244 (19%)	242 (18%)	**1,312**

We have chosen 90-day mortality over 30-day mortality as it allows for better representation of post-operative complications. Several studies in the USA and UK have reported that 90-day mortality after cancer surgery captures post-operative deaths from multiple causes and is often nearly double the rate of 30-day mortality [27–32]. Our study is the first to explore 90-day mortality by specific surgical procedure for Australian patients and provides information on this heterogeneous group.

Patients with emergency admissions had poorer 90-day and overall survival. Interestingly, lower volume hospitals have a higher proportion of emergency cases. (Table 1) They are clearly a group of patients with poorer outcomes and warrant investigation in future studies.

Intriguingly, a difference in the distribution of ASA scores was found between patients attending private and public hospitals. More patients attending a private hospital had an ASA score of 4. (4) The same difference should theoretically be noted in the distribution of the comorbidity scores, but in fact, we observed a higher proportion of patients with a high comorbidity score in the public health system. The ASA score is calculated by the treating anaesthetist, and could be subject to bias. In contrast, the comorbidity score is calculated by using the diagnosis codes from the last 12 months. Increased payments are made for higher ASA scores in the private health system which is largely not the case in public hospitals [33]. Our findings, with the caveats associated with post hoc analyses, warrant further exploration, as there are clear financial implications for our health system.

The use of health care resources also differed between low and high volume centres with regards to the proportion of all surgical patients spending ≥24hours in an ICU with a higher proportion of patients requiring an ICU admission ≥24hours in lower volume centres. Higher volume centres may have multidisciplinary specialty teams and wards, higher nurse to patient ratios, and more experienced intensive care physicians contributing to shorter ICU admissions [34–36]. Regardless of contributing factors, prolonged ICU admissions consume significant health resources and should be an area of further investigation.

Variable cut-offs have been used to define categories hospital volumes. Luchtenborg et al used quintiles with the highest volume quintile defined as 187–297 surgeries performed annually [8]. Overall, patients from hospitals in the highest quintile had half the odds of death at 30-days compared to patients from the lowest quintile [8]. Luft et al found a benefit in patients undergoing operations where 200 or more of the operations were done annually [7]. Clearly, these surgical volumes are high compared to those of Victorian centres, but the cutoff of 70 cases per year observed by Luchtenburg et al [8]. above which outcomes were improved was not identified in our data for Victoria.

There are several limitations to our study. There is debate regarding the best way to assess the relationship between hospital volumes and outcomes [37]. Arbitrarily defining volume categories into tertiles or quantiles allows easy interpretation of results but it can inflate the effect of volume on mortality [38]. We conducted a trend analysis to minimize that effect. We also repeated our analysis of 90-day mortality for procedure type and for all lung surgeries combined with volume as a continuous variable and found no significant difference in outcomes. The use of administrative datasets to assess clinical outcomes might be subject to bias [39,40]. However, several studies demonstrate good to very good concordance between administrative databases and chart reviews in evaluating diagnoses and comorbidity data [41,42]. The longevity of the VAED and linkage to the VCR strengthens its use in health outcome analyses. We have used outcome measures that should be least affected by reporting errors or biases and believe our results have implications when assessed in the clinical setting. Finally, we have been unable to replicate this analysis based on patient volumes for individual surgeons, as these data are not available in Australia.

To our knowledge, we have presented the first Australian data on NSCLC surgery and hospital volumes by surgical procedure and characterized patient outcomes such as 90-day mortality and duration of ICU admission. Our results demonstrate no significant difference in mortality between high and low volume centres for patients undergoing lung resections although more patients required an ICU admission ≥24hours in lower volume centres. Encouragingly, the overall survival of Victorian NSCLC surgical patients is excellent. The difference in ASA scores between public and private hospitals is an important issue given the implications for health costs, and should be explored further to see if our findings are representative across other surgical specialties and jurisdictions.

Conflict of interest declaration

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.lungcan.2019.01.002.

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