RESEARCH ARTICLE

Using Linked Lung Cancer Registry and Hospital Data for Guiding Health Service Improvement

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Abstract

Objective: To use linked NSW Cancer Registry and hospital lung cancer (LC) data for raising discussion points on how to improve outcomes.

Design: Historical cohort – cases diagnosed in 2003-2007.

Setting: New South Wales, Australia

Outcome Measures: Relative odds (OR) of localised disease and resection of non-small cases (NSCLC) using multiple logistic regression. Comparisons of risk of NSCLC death using competing risk regression.

Findings:
(1) Older patients have fewer resections of localised NSCLC [adjusted OR 95% CLs; 80+Vs <60 years; 0.20 (0.14, 0.28)]. Cases with co-morbidity have fewer resections [adjusted OR, 0.74 (0.61, 0.90)] and have more conservative resections. Question: Is there the best balance between resection and avoiding surgery to accommodate frailty and co-morbidity?

(2) Compared with public patients, the health insured: have higher odds of localised LC [adjusted OR, 1.23 (1.12, 1.35] and resection for localised NSCLC [adjusted OR, 2.08 (1.70, 2.54)]; are more likely to have lobectomies than wedge/segmental resections (p<0.001); and have a lower risk of LC death [adjusted SHR, 0.89 (0.85, 0.93)]. Question: Are there opportunities for improving public-patient outcomes?

(3) Patients born in non-English speaking countries have lower odds of localised disease [adjusted OR, 0.88 (0.79, 0.99)]. – Question: Could this difference be decreased by reducing cultural and language barriers?

(4) Cancers of pulmonary lobes rather than the main bronchus pose lower risks of LC death. Question: Could outcomes for main bronchus cancers be improved by up-skilling or referral to higher-volume centres?

(5) Greater extent of disease is strongly predictive of case fatality – Question: Could LC deaths be reduced by earlier treatment?

(6) Use of lobectomies varies – Question: Could survival be increased through greater use of lobectomies for localised NSCLC?

Conclusions: Linked cancer registry and hospital data can increase system-wide understanding of local health-service delivery and prompt discussion points on how to improve outcomes.

Abbreviations: APDC – Australian Patient Data Collection; CHeReL – Centre for Health Record Linkage; EOD – Extent of Disease; LC – Lung Cancer; NSCLC – Non-Small Cell Cancers; NSWCR – New South Wales Cancer Registry; OR – Relative Odds; SEIFA – Socio-Economic Index for Areas; SES – Socio-Economic Status.

Key words: epidemiology; health service delivery; management.

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Introduction

Decisions in health service administration ideally are guided by objective evidence of local needs and service performance. Because an evidence gap often applies, varying reliance is placed on anecdotal reports and intuitive judgement. In this study, we explore the utility of linked cancer registry and hospital data to reduce the evidence gap and prompt questions for decision-making.

Lung cancer (LC) is used as a case study because of its importance as the leading cause of cancer death in NSW, Australia and worldwide. [1-3] While prevention through reducing tobacco smoking is the principal public health response, preventive benefits can take many years to materialise. [3] Although a reduction in age-standardised LC incidence and mortality of about 30% occurred in New South Wales males in the last 25 years, there was a corresponding 133% increase for females, [1] despite concurrent decreases in tobacco smoking in both sexes. [3] This reflects an extensive lag time. Based on the lag time between smoking decreases and lung cancer mortality reductions in males, female lung cancer mortality is expected to peak soon before beginning to decline. [1] While continued emphasis on reducing tobacco smoking is critically important, supplementary initiatives are needed for more immediate gains, potentially including earlier diagnosis and improved treatment.

Although survival has increased, about 86% of Australian LC patients still die from their disease within five years of diagnosis. [4] The United States figure is similar at 82%. [5] Risk of death potentially could be reduced by earlier diagnosis. [5-7] Compared with localised cases, the relative risk of death in the five years following diagnosis is about 1.6 for regional and 2.1 for distant stage. [5,7] Unfortunately there is not an accepted population-based screening test. [3] Early United States trial data comparing annual helical computed tomography screening with conventional chest X-ray found earlier diagnostic stage and reduced lung cancer mortality for high risk individuals, but confirmatory data are required. [6]

Increased resection could also be beneficial. National Health and Medical Research Council guidelines indicate surgical resection to be the preferred treatment for localised non-small cell cancers (NSCLC), as do other guidelines. [8-10] Treatment differences are important when interpreting survival inequalities, but data on extent of disease (EOD) and treatment rarely are available from Australian cancer registries, which complicates interpretation of survival.

New South Wales has the only Australian state registry that routinely records EOD for all solid tumours. Opportunities exist to link NSCLC incidence and death data from the registry to inpatient treatment statistics, using the Centre for Health Record Linkage (CHeReL). The aim of this study is to explore the administrative utility of linked data for investigating associations of system-wide patient and tumour characteristics with: EOD at diagnosis; treatment by resection (localised NSCLC cases); and death from LC. Results are used to raise questions on how to improve health outcomes.

The extent to which characteristics associated with EOD, resection and LC death represent modifiable causes will need consideration. Nonetheless study results are expected to increase system-wide understanding of local health service delivery and provide an evidence base for guiding discussions on improving service outcomes.

Methods

LC incidence data for 2003 (Jan) - 2007 (Dec) from the NSW Cancer Registry (NSWCR) and associated death data to December 31, 2008 were linked to surgical resection data for the period from January 2003 to June 2008, extracted from the NSW Admitted Patient Data Collection (APDC). APDC data from July 2000 to June 2008 were also linked to NSWCR data to obtain source data on co-morbidity. Data linkage occurred through CHeReL using ChoiceMaker probabilistic linkage software. Resections were included if occurring up to six months after diagnosis.

The NSWCR includes population-based registry data, operating under authority of the *NSW Public Health Act* (1991), which mandates notification by hospitals, pathology laboratories, nursing homes and ancillary sources for invasive cancers (apart from non-melanoma skin cancers) diagnosed in the New South Wales population.

The APDC covers admissions to New South Wales public and private hospitals. NSWCR data were extracted from the registry for the International Classification of Diseases for Oncology (Version 3) (ICD-O-3) C34 topography code but excluding neuroendocrine tumours and non-epithelial cancers, such as soft tissue tumours and sarcomas, fibromatous and myomatous neoplasms. Cancers recorded only on the basis of information from death certification and those first diagnosed at post-mortem were also excluded. [3] In all, 15,014 of 15,498 bronchus and lung cancers on the NSWCR file were included. [3]

Cases were classified by:

- Socio-demographic characteristics – age at diagnosis, sex, country of birth, geographic remoteness of residence, socio-economic status (using the ABS SEIFA (Socio-Economic Index for Areas) relative socio-economic disadvantage index [11]) and Local Health District of residence. The process involved using residential census collection districts to classify by remoteness according to the Australian Standard Geographical Classification (major city, inner regional, outer regional, remote and very remote) and to derive the SEIFA Index of Relative Socio-economic Disadvantage by ABS Statistical Local Area using equal-population quintiles. [11]

Table 1: Relative odds (OR) (95% confidence limits) of localised extent of disease for lung cancers diagnosed in New South Wales in 2003-2007*

Multivariable logistic regression

CHARACTERISTIC	NUMBERS (ALL CANCERS/LOCALISED CANCERS)	ADJUSTED OR **
Age at diagnosis. (yrs.):		
<60	2255/565	1.00
60-69	3275/939	1.17 (1.03, 1.33)
70-79	3927/1210	1.34 (1.19, 1.52)
80+	2037/667	1.61 (1.40, 1.86)
Sex:		
Male	7124/2094	1.00
Female	4370/1287	1.07 (0.98, 1.17)
Public/private status:		
Public	7683/2153	1.00
Private (+ Veterans Affairs)	3636/1187	1.23 (1.12, 1.35)
Unknown	175/41	1.23 (0.83, 1.81)
Remoteness (residence):		
Major city	6523/1950	1.00
Inner regional	3328/925	0.96 (0.84, 1.10)
Outer regional	1505/451	1.08 (0.88, 1.32)
Remote/very remote	138/55	1.54 (1.01, 2.35)

Table 1: Relative odds (OR) (95% confidence limits) of localised extent of disease for lung cancers diagnosed in New South Wales in 2003-2007* *continued*

CHARACTERISTIC	NUMBERS (ALL CANCERS/LOCALISED CANCERS)	ADJUSTED OR **
SES quintile (SEIFA) (residence):		
1 (least disadvantaged)	1920/565	1.00
2	1908/547	1.00 (0.84, 1.19)
3	2404/688	1.04 (0.86, 1.26)
4	2807/823	1.08 (0.89, 1.31)
5 (most disadvantaged)	2455/758	1.15 (0.94, 1.40)
Country of birth:		
Australia	7493/2223	1.00
Other-English speaking	1431/396	0.93 (0.81, 1.06)
Other-not English speaking	2395/674	0.88 (0.79, 0.99)
Unknown	175/88	2.56 (1.86, 3.52)
Lung location:		
C340 (main bronchus)	1057/294	1.00
C341 (upper lobe)	4269/1502	1.48 (1.27, 1.72)
C342 (middle lobe)	480/191	1.81 (1.43, 2.28)
C343 (lower lobe)	2368/904	1.63 (1.38, 1.92)
C348 (overlapping)	125/35	1.03 (0.67, 1.56)
C349 (not specified)	3195/455	0.45 (0.38, 0.54)
Histology type:		
Adenocarcinoma	3711/1014	1.00
Squamous cell carcinoma	2020/890	1.93 (1.71, 2.18)
Large cell carcinoma	3740/910	0.89 (0.80, 0.99)
Other/unknown	2023/567	1.16 (1.02, 1.32)
Charlson co-morbidity score:		
0	4639/1430	1.00
1+	5687/1686	0.96 (0.87, 1.05)
Unknown	1168/265	0.71 (0.60, 0.83)

*Data source: NSW Cancer Registry; **Adjusted for other variables in the Table1(and Local Health District of residence).
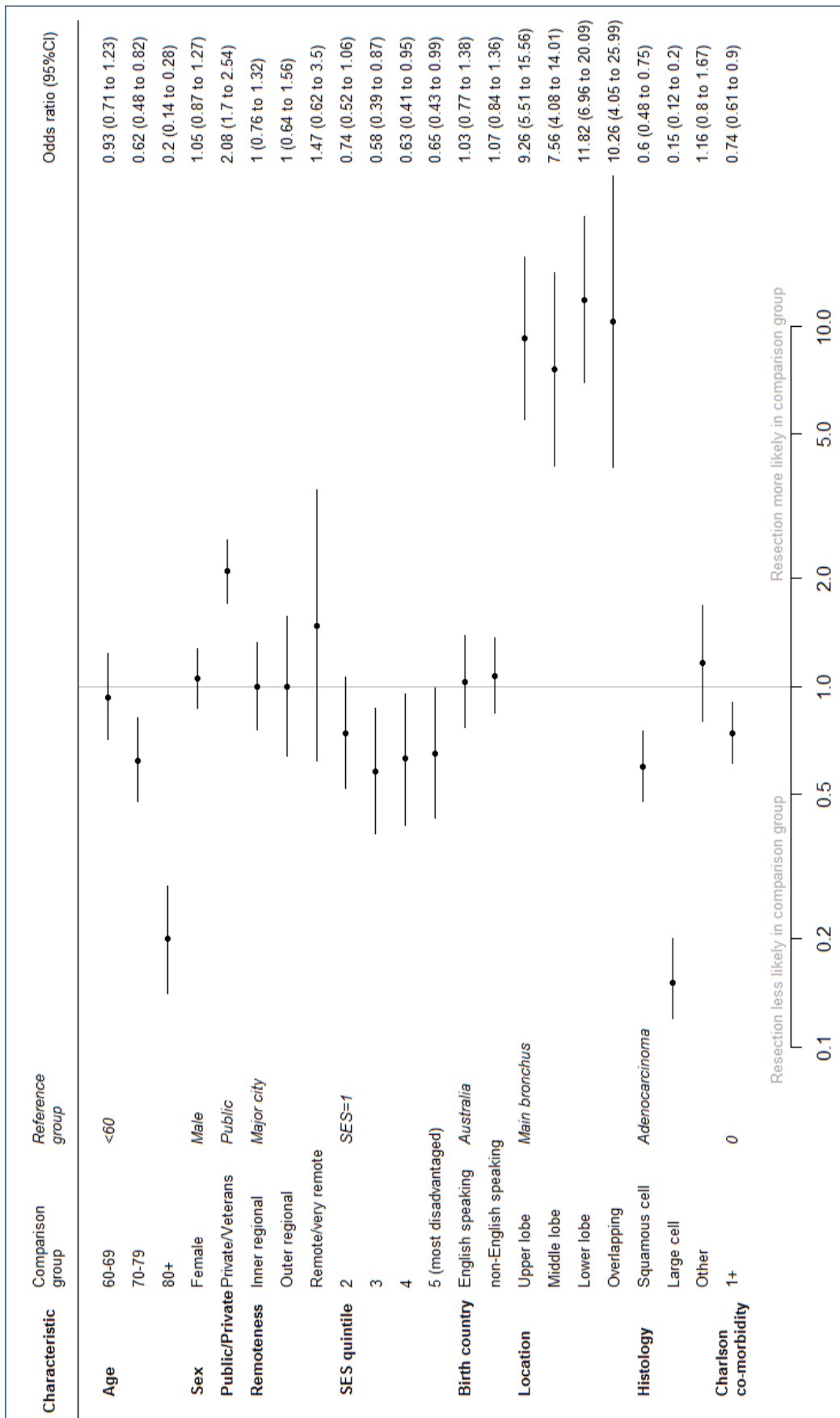Note: Excludes cases with unknown extent of disease.

- Histology type – adenocarcinoma, squamous cell carcinoma, large cell carcinoma, and other types, as classified by ICD-O-3. [12]

- Location of tumour - main bronchus and upper, middle and lower pulmonary lobes. [12]

- EOD - localised, regional and distant. [12]

- Resection type - wedge, segmental, lobectomy and pneumonectomy. [12]

- Co-morbidity - Charlson index derived from APDC data for up to five years before LC diagnosis. [13]

- Payment status - public or private (or Veterans coverage) for the payment status applying at the first hospital episode for the index cancer.

- Emergency attendance – as indicated by the urgency of admission flag for admission where treatment was required within 24 hours.

NSWCR and APDC data were linked by CHeReL using probabilistic linkage and identifiers removed before release for analysis. Research ethics approval was obtained [NSW Population and Health Services Research Ethics Committee Reference No. 2009/04/150].

Multiple logistic regression analysis was used to calculate relative odds (odds ratios) of localised compared with more advanced EOD at diagnosis (Table 1), and treatment of localised cases by resection (Figure 1) and resection type, adjusting for socio-demographic and clinical factors. [14] Multivariable competing risk regression was used to calculate

Figure 1: Relative odds (95% CI) of resection for localized non-small cell lung cancer diagnosed in New South Wales in 2003 – 2007*

Characteristic	Comparison group	Reference group	Odds ratio (95%CI)
Age	60-69	<60	0.93 (0.71 to 1.23)
	70-79		0.62 (0.48 to 0.82)
	80+		0.2 (0.14 to 0.28)
Sex	Female	Male	1.05 (0.87 to 1.27)
Public/Private	Private/Veterans	Public	2.08 (1.7 to 2.54)
Remoteness	Inner regional	Major city	1 (0.76 to 1.32)
	Outer regional		1 (0.64 to 1.56)
	Remote/very remote		1.47 (0.62 to 3.5)
SES quintile	2	SES=1	0.74 (0.52 to 1.06)
	3		0.58 (0.39 to 0.87)
	4		0.63 (0.41 to 0.95)
	5 (most disadvantaged)		0.65 (0.43 to 0.99)
Birth country	English speaking	Australia	1.03 (0.77 to 1.38)
	non-English speaking		1.07 (0.84 to 1.36)
Location	Upper lobe	Main bronchus	9.26 (5.51 to 15.56)
	Middle lobe		7.56 (4.08 to 14.01)
	Lower lobe		11.82 (6.96 to 20.09)
	Overlapping		10.26 (4.05 to 25.99)
Histology	Squamous cell	Adenocarcinoma	0.6 (0.48 to 0.75)
	Large cell		0.15 (0.12 to 0.2)
	Other		1.16 (0.8 to 1.67)
Charlson co-morbidity	1+	0	0.74 (0.61 to 0.9)

sub-hazards ratios for LC death from time of diagnosis to death (in months) or December 31, 2008, whichever came first, with deaths from other causes as the competing event. [14] Co-linearity assumptions were checked and log-normal plots examined to test proportionality.

Cases with unknown extent of disease (24.2% of cases) were excluded from logistic regression models comparing localised with more advanced EOD, but were included as a dummy variable in competing risk regression models when deriving sub-hazards ratios for LC death. Missing values for other independent variables were also included as dummy variables. When results of logistic regression and competing risk regression were checked using complete case analysis that excluded cases with missing values, findings were similar. STATA release 12 was used. [14]

Results

By socio-demographic characteristic

Age at diagnosis
Odds of localised EOD were higher for older ages (Table 1). Older cases with localised NSCLC had fewer resections (Figure 1). Compared with those under 60 years, the adjusted relative odds of resection (95% CLs) were 0.62 (0.48, 0.82) and 0.20 (0.14, 0.28) for 70-79 and 80+ year olds respectively. Surgery also tended to be more conservative (p=0.051), the ratio of lobectomies to wedge resections decreasing from 8.5 to 1 for cases less than 60 years to 4.9 to 1 for those aged 80 years or more. The corresponding ratio of lobectomies to wedge and segmental resections decreased from 2.2 to 1 to 1.8 to 1. The older the age, the higher was the risk of LC death (Table 2).

Sex
Females had more conservative resections, the ratio of lobectomies to wedge resections being 5.7 to 1 for females compared with 8.7 to 1 for males (p=0.050). The corresponding ratio of lobectomies to wedge and segmental resections was 1.7 to 1 and 2.2 to 1 respectively. Female patients had a lower risk of LC death (Table 2).

Payment status
Patients with private health insurance (or Veterans coverage) had higher odds of localised EOD (Table 1) and compared with public patients, adjusted relative odds of resection for localised NSCLC of 2.08 (1.70, 2.54) (Figure 1). They also had higher odds of lobectomy compared with wedge resection of 15.8 to 1 compared with 4.6 to 1 for public patients (p<0.001), and of lobectomy compared with wedge and segmental resections, of 3.2 to 1 and 1.4 to 1 respectively (p<0.001). The risk of LC death was lower in insured patients (Table 2).

Remoteness
An unexpected 54% elevation in odds of localised EOD occurred at presentation for residents from remote/very remote compared with major city areas after adjustment (Table 1). Odds of resection from localised NSCLC did not vary by remoteness (Figure 1), nor did types (p>0.200), as indicated by the ratio of lobectomies to wedge resections (p=0.329) and to wedge and segmental resections (p=0.549). Elevated risk of LC death in inner and outer regional than major city areas did not persist after co-variable adjustment (Table 2). Risk of LC death was not elevated in remote/very remote areas.

Socio-economic status (SES)
Adjusted relative odds of resection for localised NSCLC were lower at 0.58 (0.39, 0.87), 0.63 (0.41, 0.95) and 0.65 (0.43, 0.99) for lower quintiles three, four and five respectively compared with quintile one (highest SES) (Figure 1), but resection types did not vary by quintile (p=0.233). SES was not associated with risk of LC death (Table 2).

Country of birth
Adjusted analysis indicated lower odds of localised disease for patients with non-English speaking than Australian country of birth (Table 1) and lower risk of LC death (Table 2). Resection types did not differ by country of birth (p=0.275).

By co-morbidity status
Cases with co-morbidity (Charlson score 1+ Vs 0) had lower adjusted odds of resection than other patients for localised NSCLC at 0.74 (0.61, 0.90) (Figure 1). The lobectomy to wedge resection ratios was 2.2 to 1 and 4.6 to 1 respectively, and the lobectomy to wedge and segmental resection ratios was 1.7 to 1 and 2.3 to 1 respectively. Higher co-morbidity was associated with higher risk of LC death which persisted, although more marginal, in multivariable models (Table 2).

By clinical characteristics

Location
Cancers of pulmonary lobes had higher odds of localised EOD than cancers of the main bronchus (Table 1). Higher adjusted relative odds of resection applied for localised NSCLC of the pulmonary lobes at 9.26 (5.51, 15.56), 7.56 (4.08, 14.01) and 11.82 (6.96, 20.09) respectively, compared with cancers of the main bronchus (Figure 1), but with little difference in resection types (p=0.820). Risk of LC death was lower for LC in pulmonary lobes than the main bronchus (Table 2).

Histology type
Compared with adenocarcinomas, squamous cell lesions had higher and large cell lesions lower odds of localised EOD

Table 2: Sub-hazard ratios (SHR) (95% confidence limits) for cumulative probability of death from lung cancer among New South Wales cases diagnosed in 2003-2007, according to patient and cancer characteristics, and treatment by resection*

Competing risk regression

CHARACTERISTIC	NUMBERS (CASES/LUNG CANCER DEATHS)	UNADJUSTED SHR	ADJUSTED SHR**	ADJUSTED SHR***	ADJUSTED SHR****
Age at diagnosis (yrs.):					
<60	2710/1874	1.00	1.00	1.00	1.00
60-69	4047/2861	1.07 (1.02, 1.13)	1.07 (1.01, 1.13)	1.12 (1.06, 1.18)	1.11(1.05,1.17)
70-79	5232/3951	1.28 (1.21, 1.35)	1.24 (1.17, 1.30)	1.36 (1.29, 1.44)	1.32 (1.25, 1.39)
80+	3025/2396	1.59 (1.50, 1.68)	1.48 (1.39, 1.57)	1.72 (1.61, 1.83)	1.57 (1.47, 1.67)
Sex:					
Male	9374/7012	1.00	1.00	1.00	1.00
Female	5640/4070	0.91 (0.88, 0.94)	0.91 (0.87, 0.95)	0.91 (0.87, 0.94)	0.92 (0.88, 0.95)
Public/private status:					
Public	9891/7526	1.00	1.00	1.00	1.00
Private (+ Veterans Affairs)	4792/3369	0.84 (0.81, 0.87)	0.81 (0.77, 0.84)	0.84 (0.81, 0.88)	0.89 (0.85, 0.93)
Unknown	331/187	0.64 (0.55, 0.74)	0.75 (0.64, 0.88)	0.82 (0.70, 0.96)	0.75 (0.64, 0.88)
Remoteness (residence):					
Major city	8439/6164	1.00	1.00	1.00	1.00
Inner regional	4425/3315	1.07 (1.03, 1.12)	0.99 (0.93, 1.04)	0.99 (0.93, 1.05)	0.98 (0.93,1.04)
Outer regional	1943/1459	1.09 (1.03, 1.15)	0.96 (0.88, 1.05)	0.98 (0.89, 1.07)	0.95 (0.87, 1.04)
Remote/very remote	207/144	0.94 (0.80, 1.10)	0.84 (0.69, 1.02)	0.89 (0.74, 1.07)	0.89 (0.74, 1.07)
SES quintile (SEIFA) (residence):					
1 (least disadvantaged)	2403/1716	1.00	1.00	1.00	1.00
2	2486/1810	1.05 (0.98, 1.11)	1.04 (0.96, 1.12)	1.04 (0.96, 1.13)	1.04 (0.96, 1.12)
3	3206/2391	1.11 (1.05, 1.18)	1.02 (0.93. 1.11)	1.04 (0.96, 1.14)	1.03 (0.95, 1.13)
4	3698/2768	1.12 (1.06, 1.18)	1.01 (0.92, 1.10)	1.03 (0.94, 1.13)	1.02 (0.93, 1.12)
5 (most disadvantaged)	3221/2397	1.09 (1.03, 1.16)	1.06 (0.97, 1.16)	1.07 (0.97, 1.17)	1.06 (0.97, 1.16)
Country of birth:					
Australia	9796/7369	1.00	1.00	1.00	1.00
Other-English speaking	1853/1408	1.02 (0.96, 1.07)	1.00 (0.94, 1.05)	0.98 (0.92, 1.03)	0.98 (0.92, 1.04)
Other-not English speaking	3029/2203	0.90 (0.86, 0.94)	0.91 (0.87, 0.96)	0.88 (0.84, 0.92)	0.88 (0.84, 0.93)
Unknown	336/102	0.30 (0.24, 0.36)	0.31 (0.25, 0.38)	0.36 (0.29, 0.45)	0.39 (0.31, 0.48)
Lung location:					
C340 (main bronchus)	1315/1112	1.00	1.00	1.00	1.00
C341 (upper lobe)	5446/3718	0.61 (0.58, 0.65)	0.64 (0.60, 0.68)	0.68 (0.64, 0.73)	0.78 (0.73, 0.84)
C342 (middle lobe)	614/408	0.59 (0.53, 0.66)	0.60 (0.54, 0.67)	0.66 (0.59, 0.73)	0.75 (0.67, 0.84)
C343 (lower lobe)	2991/2035	0.61 (0.57, 0.66)	0.64 (0.60, 0.69)	0.70 (0.65, 0.75)	0.83 (0.77, 0.89)
C348 (overlapping)	143/98	0.66 (0.53, 0.81)	0.66 (0.53, 0.83)	0.69 (0.54, 0.87)	1.00 (0.80, 1.26)
C349 (not specified)	4505/3711	1.04 (0.97, 1.10)	1.01 (0.94, 1.08)	0.89 (0.83, 0.95)	0.93 (0.87, 1.00)
Histology type:					
Adenocarcinoma	4394/2954	1.00	1.00	1.00	1.00
Squamous cell carcinoma	2645/1776	0.98 (0.92, 1.03)	0.91 (0.86, 0.96)	1.06 (1.00, 1.13)	1.05 (0.99. 1.11)
Large cell carcinoma	5230/4274	1.59 (1.51, 1.66)	1.39 (1.33, 1.46)	1.43 (1.37, 1.50)	1.27 (1.21, 1.34)
Other/unknown	2745/2078	1.31 (1.24, 1.38)	1.44 (1.08, 1.21)	1.16 (1.09, 1.23)	1.04 (0.98, 1.10)

Table 2: Sub-hazard ratios (SHR) (95% confidence limits) for cumulative probability of death from lung cancer among New South Wales cases diagnosed in 2003-2007 *continued*

CHARACTERISTIC	NUMBERS (CASES/LUNG CANCER DEATHS)	UNADJUSTED SHR	ADJUSTED SHR**	ADJUSTED SHR***	ADJUSTED SHR****
Charlson co-morbidity score:					
0	5740/4149	1.00	1.00	1.00	1.00
1+	7420/5586	1.20 (1.16, 1.25)	1.05 (1.01, 1.10)	1.05 (1.01, 1.09)	1.03 (0.99, 1.08)
Unknown	1854/1347	0.95 (0.90, 1.00)	0.93 (0.88, 0.99)	0.95 (0.90, 1.01)	0.95 (0.90, 1.01)
Extent of disease:					
Localised	3381/1785	1.00		1.00	1.00
Regional	2475/1645	1.45 (1.36, 1.54)		1.48 (1.38, 1.58)	1.44 (1.34, 1.54)
Distant	5638/5122	3.42 (3.24, 3.62)		3.18 (3.00. 3.37)	2.39 (2.25, 2.53)
Unknown	3520/2530	1.62 (1.53, 1.72)		1.39 (1.31, 1.48)	1.05 (0.99, 1.12)
Resection:					
None	12774/10420	5.66 (5.14, 6.22)	3.94 (3.57, 4.35)		
Segmental	462/111	0.87 (0.72, 1.07)	0.86 (0.70, 1.04)		
Wedge	190/68	1.36 (1.08, 1.72)	1.29 (1.03, 1.63)		
Lobectomy	1384/380	1.00	1.00		
Pneumonectomy	204/103	1.95 (1.62,2.35)	1.64 (1.35, 1.98		

*Data source: NSW Cancer Registry; **Adjusted for other variables in Table 2 (+ Local Health District of residence) (except extent of disease and resection); ***Adjusted for other variables in Table 2 (+ Local Health District of residence) (except resection); **** Adjusted for all other variables in Table 2 (+ Local Health District of residence)

(Table 1). Also compared with adenocarcinomas, squamous cell and large cell carcinomas had fewer resections for localised NSCLC, with adjusted relative odds of 0.60 (0.48, 0.75) and 0.15 (0.12, 0.20) respectively (Figure 1), but resection type did not vary (p=0.373). Case fatality was elevated for large cell carcinomas (Table 2).

EOD
Cases with regional and distant spread had higher risk of LC death than localised cases (Table 2).

Resection type
Risks of LC death were highest for non-resected cases (Table 2). Compared with lobectomy cases, risk of LC death was higher for those having a pneumonectomy or wedge resection. Statistically significant differences were not evident between cases having lobectomies and segmental resections (adjusted SHR for segmental resection=0.92 (0.72, 1.19)) (Table 3).

By service characteristics (resection cases/localised and regional EOD only)
Emergency presentation
Cases presenting as an emergency at time of diagnosis had

an elevated risk of LC death but this could have occurred by chance (adjusted SHR=1.09 (0.60, 1.97)) (Table 3).

Time from diagnosis to surgery
Unadjusted analysis indicated higher case fatality with longer time to surgery, but the adjusted model did not indicate a significant difference (Table 3).

Hospital resection volume
While SHRs were lower when numbers of lung resections were in the top two of three volume categories, confidence intervals encompassed 1.00 and differences were attributable to chance (Table 3).

Discussion
NSWCR and administrative data provide similar statistical profiles for LC to international research evidence, lending credibility to findings. They include lower odds of surgical resection of localised NSCLC for older people and use of more conservative resection types, likely reflecting accommodations for reduced physiological capacity. [18] Older people also had a higher case fatality from LC, probably due to higher levels of co-morbidity and frailty and lower resection rates for localised NSCLC. [18]

Table 3: Sub-hazard ratios (SHR) (95% confidence limits) for cumulative probability of death from lung cancer among non-small cell cases diagnosed with localised or regional extent of disease in New South Wales in 2003-2007 and treated by resection within six months of diagnosis*

Competing risk regression

CHARACTERISTIC	NUMBERS (CASES/LUNG CANCER DEATHS)	UNADJUSTED SHR	ADJUSTED SHR**
Extent of disease:			
Localised	1168/213	1.00	1.00
Regional	766/312	2.71 (2.28, 3.22)	2.52 (2.09, 3.03)
Resection type:			
Segmental	395/85	0.84 (0.66, 1.06)	0.92 (0.72, 1.19)
Wedge	146/48	1.44 (1.07, 1.93)	1.60 (1.17, 2.21)
Lobectomy	1222/310	1.00	1.00
Pneumonectomy	171/82	2.08 (1.64, 2.64)	1.57 (1.19, 2.09)
Emergency attendance:			
No	1889/511	1.00	1.00
Yes	45/14	1.09 (0.63,1.86)	1.09 (0.60, 1.97)
Time from diagnosis to resection (months):			
<1	844/200	1.00	1.00
1-2	915/264	1.23 (1.02, 1.47)	1.02 (0.84, 1.24)
3-6	175/61	1.60 (1.20, 2.13)	1.12 (0.81, 1.55)
Hospital resection volume per year:			
<16	626/178	1.00	1.00
16-55	671/179	0.92 (0.75, 1.13)	0.87 (0.70, 1.07)
>55	637/168	0.90 (0.73, 1.11)	0.87 (0.68, 1.12)

*Data source: NSW Cancer Registry
**Adjusted for: other variables in Table 3, age at diagnosis; sex; public/private status; remoteness of residence; SES quintile; Local Health District of residence; country of birth; lung location of cancer; histology type; and Charlson co-morbidity

The lower EOD at diagnosis in older patients is contrary to patterns seen for many cancers, [15] but accords with results of earlier United States lung studies. [16,17] While reasons are unknown, it could reflect earlier detection from regular medical attention for tobacco-related respiratory and other comorbidity in older people. Also, less intensive diagnostic investigation of older cases may have led to under detection of more distant disease.

More conservative resections and risk of LC death applied for females than males for localised NSCLC, as reported in other studies. [19,20] Although this was not explained by differences in modelled variables, the measure of co-morbidity was blunt and residual confounding from higher levels of tobacco-induced and other co-morbidity could have led to an artificial elevation of deaths in males. [3]

Private health insurance was associated with more localised EOD, which may reflect higher SES. Higher SES Danish lung cancer cases have also shown higher odds of more localised EOD. [21] New South Wales patients with private insurance had higher odds of resection for localised NSCLC and were more likely to have a lobectomy than more conservative wedge or segmental resections. Similar results have been reported for NSCLC in North America. [22] The privately insured also had a lower risk of LC death which accords with North American evidence. [23] Statistical modelling indicated that this was not explained in New South Wales by more localised EOD at diagnosis, higher resection rates for localised NSCLC or a higher ratio of lobectomies to conservative procedures among the privately insured.

The presence of more advanced EOD at diagnosis among patients born in non-English speaking countries was a novel finding. BreastScreen data show that women from culturally and linguistically diverse backgrounds have lower screening participation. [24] This may be part of a broader pattern where cultural and language barriers reduce or delay use of diagnostic and related health services.

Despite this difference, patients born in non-English speaking countries had a lower recorded risk of LC death than the Australian born. This may be due to a greater residential proximity to specialist treatment centres in major cities or alternatively a healthy migrant effect. It is also possible that underrecording of deaths could occur if significant numbers returned to birth countries in the terminal stages of their disease, such that their deaths were not recorded in Australia.

Reasons for earlier EOD in remote/very remote areas are not known and run counter to data for other populations. [25] Lower access to specialised diagnostic services in these areas may have reduced detection of more advanced disease. An elevation in case fatality was not suggested in remote/very remote regions, which accords with a study of United States Medicare data. [26]

Resection rates for localised NSCLC were lower for lower than upper SES groups in New South Wales, as observed in other populations, [27] potentially due to more limited service access. While United States research has indicated lower survivals in lower SES groups, [27] poorer survivals were not indicated in lower SES areas of New South Wales in multivariable analyses.

Patients with higher co-morbidity had fewer resections for localised NSCLC and their resections were more conservative, as found in other populations. [21] This may reflect attempts to avoid undue surgical risk. It was anticipated that co-morbidity would be predictive of risk of LC death, [28] but only a weak relationship was observed, potentially due to the bluntness of the co-morbidity measure.

Cancers of pulmonary lobes had higher odds of localised EOD than cancers of the main bronchus, possibly reflecting greater visibility in imaging. Higher odds of resection for localised NSCLC presented for those located in pulmonary lobes than the main bronchus where more extensive and complex surgery may carry greater risks, especially for patients with low cardiopulmonary reserve. [29] Risk of LC death was lower for pulmonary lobe lesions than for those in the main bronchus, as reported elsewhere. [29]

Compared with adenocarcinomas, squamous cell lesions had higher odds and large cell lesions lower odds of localised EOD. Squamous cell and large-cell lesions were less likely to be treated by resection. Squamous cell carcinomas are often located centrally where surgery may be more difficult. [29] Risk of LC death was highest for large cell carcinomas, likely due to more aggressive biology. [29] Predictably, advanced EOD was strongly predictive of risk of LC death. For resection cases with localised or regional disease, a higher risk of LC death with longer time to surgery was evident in the unadjusted analysis, but not after co-variable adjustment.

The highest case fatality applied to non-resected cases. This may reflect a causal association for localised NSCLC, but also residual confounding. Compared with those having a lobectomy, risk of LC death following wedge resection was higher. Lobectomy would often be the surgery type of choice in treatments of localised NSCLC with curative intent, [8-10] which may explain the better outcomes for lobectomy cases. The lack of a significant difference in outcomes between lobectomies and segmental resections is consistent with earlier United States findings for early EOD NSCLC. [30,31]

While risk of LC death was lower when hospital numbers for lung resections were in the top two of three volume categories, differences were in the range attributable to chance. Further investigation is needed into relationships between surgical volume within resection types and by sub-group of patients.

The present data are observational, not experimental, and sometimes of sub-optimal quality, as seen for co-morbidity. Nonetheless findings generally accord with the international evidence, which adds to their credibility in the New South Wales setting. The potential for these relationships to be causal and modifiable needs to be considered by the clinical community, along with relevant interventions.

Example questions arising from the present study include:

(1) Is the best balance being achieved between resection and non-resection to accommodate age-related frailty and co-morbidity?

(2) Are there modifiable causal factors for improving survival outcomes for public patients?

(3) Could more advanced EOD in patients born in non-English speaking countries be decreased by reducing cultural and language barriers to services?

(4) Is the best balance being achieved between optimal therapy and accommodations for co-morbidity?

(5) Could the higher risk of LC death for cancers of the main bronchus be reduced by up-skilling or referral to higher-volume centres?

(6) Do opportunities exist for earlier treatment to increase survival? (7) Could survivals be increased through greater use of lobectomies? (8) Are segmental resections an effective substitute for lobectomies for some patients?

Conclusions

Linked registry and administrative data can increase system-wide understanding of health service delivery and outcomes. They prompt questions that could be workshopped with a view to achieving better outcomes. Linked data can provide useful input for administrative decision-making.

Competing interests

The authors declare that they have no competing interests.

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