ORIGINAL ARTICLE

Survival of Australian lung cancer patients and the impact of distance from and attendance at a thoracic specialist centre: a data linkage study

Elizabeth Tracey,[1] Brian McCaughan,[2] Tim Badgery-Parker,[1] Jane Young,[1] Bruce Armstrong[1]

▶ Additional material is published online only. To view please visit the journal online (http://dx.doi.org/10.1136/thoraxjnl-2014-205554).

[1]University of Sydney, Sydney, New South Wales, Australia
[2]Royal Prince Alfred Hospital, Sydney, New South Wales, Australia

Correspondence to
Elizabeth Tracey, The University of Sydney, Level 6 Chris O'Brien Lifehouse (C39Z), 119–143 Missenden Road, Camperdown, NSW 2050, Australia;
elizabeth.tracey@sydney.edu.au

Received 11 April 2014
Revised 20 June 2014
Accepted 3 July 2014
Published Online First 29 July 2014

ABSTRACT

Background Lung cancer patients have better survival when treated in thoracic surgical (specialist) centres.

Aims To determine whether outcome of non-small cell lung cancer (NSCLC) patients is poorer with increasing distance to the nearest accessible specialist hospital (NASH).

Methods We linked cancer registry, hospital and death records of 23 871 NSCLC patients; 3240 localised, 2435 regional and 3540 distant stage patients hospitalised within 12 months of diagnosis were analysed. Distance from patients' residences to the NASH was measured using geographical coordinates. Cox proportional hazards models examined predictors of NSCLC death.

Results Having a resection of the cancer, which admission to a specialist hospital made more likely, substantially reduced hazard of NSCLC death. Distance influenced hazard of death through both these variables; a patient was less likely to be admitted to a specialist hospital than a general hospital and less likely to have a resection the further they lived from the NASH. However, patients who lived distant from the NASH and were admitted to a specialist hospital were more likely to have a resection and less likely to die from NSCLC than patients admitted to a specialist hospital and living closer to the NASH. These patterns varied little with lung cancer stage.

Conclusions NSCLC outcome is best when patients are treated in a specialist hospital. Greater distance to the NASH can affect its outcome by reducing the likelihood of being treated in a specialist hospital. Research is needed into patient and health service barriers to referral of NSCLC patients for specialist care.

Key messages

What is the key question?

- Does increasing distance to the nearest accessible specialist hospital (NASH), one with a thoracic surgery service, lead to poorer survival from lung cancer?

What is the bottom line?

- With increasing distance from the NASH, patients were more likely to attend a general hospital for their care, less likely to have surgery for their cancer and more likely to die from it.

Why read on?

- The findings make a strong case that all patients should be referred to a hospital with a thoracic surgical service to maximise their chance of surgery regardless of how far they live from specialised services.

Linked

▶ http://dx.doi.org/10.1136/thoraxjnl-2014-205517
▶ http://dx.doi.org/10.1136/thoraxjnl-2014-205692
▶ http://dx.doi.org/10.1136/thoraxjnl-2014-205841
▶ http://dx.doi.org/10.1136/thoraxjnl-2014-206153

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To cite: Tracey E, McCaughan B, Badgery-Parker T, *et al*. *Thorax* 2015;**70**:152–160.

INTRODUCTION

Surgical resection is recommended for early stage non-small lung cancer patients with lobectomy the preferred type of surgery.[1] Depending on the location of the tumour, surgery may also be appropriate for patients with up to stage IIIa tumours.[2] Postoperative mortality is lower and survival longer when patients are treated by thoracic surgeons in high volume centres probably because these surgeons are most likely to adhere to established practice standards.[3 4]

Distance to specialist centres is hypothesised to be a barrier to access to specialised medical care.[5 6] Most studies of the effects of distance to specialist care on treatment of non-small cell lung cancer (NSCLC) have been done in the UK. The majority of these studies have shown that patients' access to surgical treatment is influenced by distance and also by clinician specialty and hospital of treatment.[5–8] These studies generally could not take account effects of lung cancer stage on their conclusions.

New South Wales (NSW) Central Cancer Registry (CCR) based patterns of care studies have shown that probability of no surgical treatment varies by a patient's area of residence.[9–11] The 5 year relative excess risk of death for NSW lung cancer patients was found to be significantly higher for patients living in accessible and moderately accessible areas regardless of stage.[12] A NSW general practitioner (GP) or specialist can refer a patient to hospital as a planned admission, or patients can themselves present to the emergency department and be admitted directly to hospital. The commonest non-emergency pathway is probably referral by a GP to a specialist and referral by the specialist to a hospital for treatment under his or her care. Chemotherapy and radiotherapy are usually provided in outpatient settings.

In this study, we investigate whether increasing distance to the nearest accessible specialist hospital (NASH, the nearest public hospital with a thoracic

surgical service) is associated with poorer survival for patients with localised, regional and distant stage primary lung cancer after adjusting for potentially confounding variables.

METHODS

The NSW CCR was the primary data source.[13] The study population included all patients with NSCLC (International Classification of Disease topography codes C33–C34 excluding morphology codes M80413–M80453, M82463) diagnosed in NSW between 2000 and 2008 and followed up to the end of 2008. Stage at diagnosis is determined by cancer registry coders on the basis of pathology reports, doctor's letters and other notifications. It is grouped into four categories: localised (confined to the organ of origin), regional (invasion of adjacent organs and proximal lymph nodes), distant (invasion distant lymph nodes or distant organs) and unknown (not recorded because pathology information was not available). Previous studies have shown these extent-of-disease categories to provide broadly comparable information with other methods of staging.[14 15] A total of 23 871 patients were potentially eligible for this study. Of these, 22 997 patients whose CCR[13] record linked to one or more records in the NSW Admitted Patients Data Collection (APDC), which details diagnosis and surgical treatment for all separations from NSW public and private gospitals,[16] were considered for the analysis. The combined automated and manual record linkage process had an estimated false positive rate of 0.4%.[17] Patients were excluded if they were diagnosed by death certificate only (707), were not admitted to hospital after diagnosis (10 684) or were admitted more than 12 months after diagnosis (459), which left 11 147 patients. Inpatient staging procedures could not have occurred and hospital risk factor and treatment information was not available for the patients not admitted to hospital after diagnosis. We also excluded (1932) unknown stage patients except in a sensitivity analysis. This left 9215 in the main analysis. Of these patients, 3240 patients had localised stage, 2435 had regional stage and 3540 had distant stage cancer.

Distance

Distance to the NASH was obtained for each patient by using the geographical coordinates of the patient's address and the NASH and the 'Great Circle Distance Calculator' (a SAS program). This algorithm calculates the shortest distance between two points on Earth, treating it as a sphere.[18] We considered this distance to be a measure of access to best care because it encompasses both distance to and affordability of care; all Australians are entitled to treatment free-of-charge in public hospitals. Distance to a patient's actual hospital of treatment as an alternative measure of access may be biased because more mobile patients may be referred to more distant hospitals. In addition, it can only apply to those who received treatment.[6] UK studies using travel time and straight line distance[19] have found them to be highly correlated (R=0.856).

Patients were grouped into three categories of distance: 0–39, 40–99 and ≥100 km. The >100 km category was made the most distant category because patients living this distance from required care in NSW can obtain financial support for travel and accommodation through the Isolated Patient Travel, Accommodation and Assistance Scheme.[20] Patients' place of residence was also classified broadly as metropolitan, outer metropolitan and rural, based on the 2010 boundaries of NSW Local Health Districts.

Hospitals

Eleven public specialist hospitals were identified using Canrefer,[21] a Cancer Institute NSW web directory of cancer services. We grouped hospitals in which patients were treated as specialist (public and private hospitals with a thoracic surgery service) or general hospitals (public and private hospitals without a thoracic surgery service). We selected the hospital of treatment as the hospital where patients received their most invasive procedure; in the absence of any procedure, we selected the first hospital to which the patient was admitted after diagnosis.

Because there was structural correlation between distance to the NASH and the type of hospital in which a patient was treated (the specialist hospitals were in Sydney or a large city while the general hospitals were distributed more widely throughout the State), we created a six-category variable of hospital type in two categories, specialist and general, by distance from the NASH in three categories, 0–39, 40–99, and ≥100 km. Other covariates are described in online supplementary appendix 1 tables 1 and 2.

Surgery

Whether or not patients had their primary cancer treated surgically by lobectomy, segmental resection or pneumonectomy (referred to hereafter as a resection) was determined from hospital procedure codes in APDC records covering the period a month before diagnosis to 12 months after diagnosis. Other characteristics of patients are found in online supplementary appendix 1.

STATISTICAL ANALYSIS

Stata V.12.1 was used for the statistical analysis. We described cause-specific survival from NSCLC and its predictors using Kaplan–Meier curves. Univariable Cox proportional hazards regression models were fitted for each covariate. Proportionality was examined and time varying components were retained if proportionality assumptions failed. Interactions were included on an a priori basis. Independent determinants of cause-specific survival were identified by backward elimination from a full Cox proportional hazards model. A p value less than 0.05 in the likelihood ratio test was used to determine whether a variable was retained in the final model. Sex, age, comorbidity and history of COPD were retained in the final model, regardless of their statistical significance, because of their clinical importance. The combination of type of hospital and distance from the NASH were similarly retained because investigation of the effects of distance was the main objective of this study. For all other variables, nested maximum likelihood ratio tests compared two models with and without the covariate. We checked model fit by comparing unadjusted Kaplan–Meier survival curves with adjusted curves for each covariate after redoing the model using the Royston and Palmer stmp2[22] command and the Predict command in STATA 12.1 (see online supplementary appendix 1 figure 1). This model was the source of the adjusted survival curves in figures 1 D, E and F and figures 2 D, E and F. A sensitivity analysis was done by repeating the Cox modelling after imputing values for unknown stage (data available on request).

RESULTS

Most NSCLC patients were men and Australian born. The mean age was 70 years in men and 69 years in women. There was a lower proportion in the highest socioeconomic status group

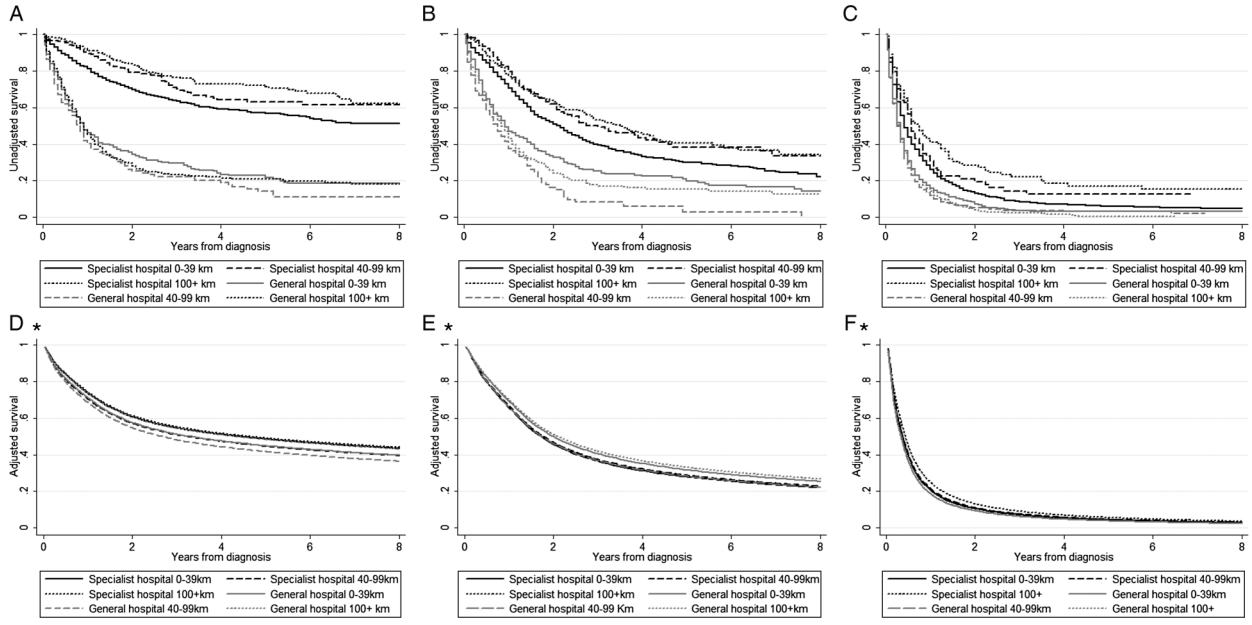

Figure 1 Kaplan–Meier survival curves by hospital of treatment and distance from the nearest accessible surgical hospital (NASH) for patients with primary non-small cell lung cancer by stage unadjusted and adjusted for confounding variables, New South Wales, 2000–2008. (A) Localised stage patients (n=3240). (B) Regional stage patients (n=2435). (C) Distant stage patients (n=3540). (D) Localised stage patients (n=3240). (E) Regional stage patients (n=2435). (F) Distant stage patients (n=3540). *Adjusted for sex, age at diagnosis, country of birth, comorbidity, COPD, smoking, method of diagnosis, histology, type of admission, major surgery and time to diagnosis; the effects of age and time to diagnosis were time varying.

than is found in the general Australian population. In all, 72% were recorded as being current or previous smokers, 31% had COPD and 35% one or more comorbid conditions (see online supplementary appendix 1 table 1).

Of the 3240 patients with localised cancer, 59.2% (95% CI 57.5 to 60.9) had resections. A lower proportion of patients who lived 100 km or more from the NASH had a resection (49.4%, 95% CI 45.8 to 53.1) compared with patients living 0–39 km (62.5%, 95% CI 60.3 to 64.4) or 40–99 km from it. Conversely, for patients who attended a specialist hospital there was a greater likelihood of resection with increasing distance to the NASH (69.7% at 0–39 km, 91.6 at 40–99 km and 94.6 at ≥100 km) (table 1). For patients with regional stage cancer, the proportion attending a general hospital also increased with distance from the NASH: 14.8% at 0–39 km to 51.2% at ≥100 km for localised stage, and 15.3% at 0–39 km to 54.4% at ≥100 km. Much higher proportions of patients with distant stage than localised or regional stage attended general hospitals

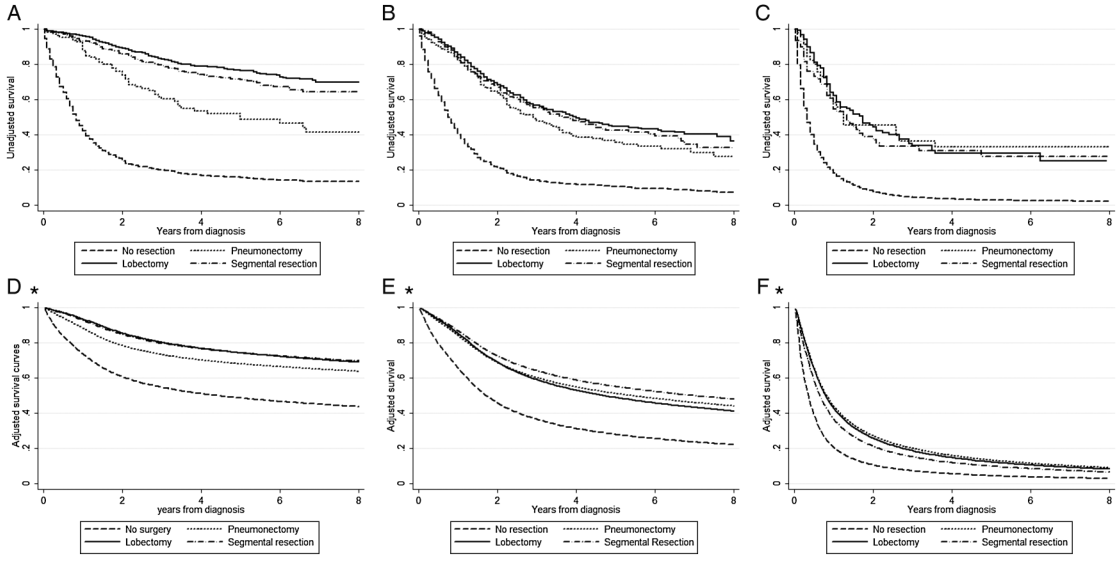

Figure 2 Kaplan–Meier survival curves by surgery for patients with primary non-small cell lung cancer (NSCLC) by stage unadjusted and adjusted for confounding variables, New South Wales, 2000–2008. (A) Localised stage (NSCLC) patients (n=3240). (B) Regional stage (NSCLC) patients (n=2435). (C) Distant stage (NSCLC) patients (n=3540). (D) Localised stage (NSCLC) patients (n=3240). (E) Regional stage (NSCLC) patients (n=2435). (F) Distant stage (NSCLC) patients (n=3540). *Adjusted for hospital of treatment and distance from the NASH, sex, age at diagnosis, country of birth, comorbidity, COPD, smoking, method of diagnosis, histology, type of admission and time to diagnosis.

Table 1 The proportional breakdown of non-small cell lung cancer patients hospitalised within 12 months of diagnosis by distance from the NASH by their hospital of treatment and whether they had major surgery by stage category, New South Wales, 2000–2008

Distance from the NASH by stage at diagnosis	Hospital of treatment					Had surgical resection				
	Specialist		General		Total	Specialist		General		Total
	n	%	n	%	n	n	%	n	%	n
Localised stage										
0–39 km	1757	85.2	306	14.8	2063	1225	69.7	63	20.6	1288
40–99 km	263	63.2	153	36.8	416	241	91.6	13	8.5	254
100+	371	48.8	390	51.2	761	351	94.6	25	6.4	376
Regional stage										
0–39 km	1244	84.7	224	15.3	1468	836	67.2	46	20.5	882
40–99 km	208	64.0	117	36.0	325	191	91.8	5	4.3	196
100+	293	45.6	349	54.4	642	267	91.1	10	2.9	277
Distant stage										
0–39 km	1539	70.5	644	29.5	2183	166	10.8	7	1.1	173
40–99 km	85	19.5	351	80.5	436	24	28.2	0	0	24
100+	131	14.2	790	85.8	921	46	35.1	1	0.1	47
	5891	63.9	3324	36.1	9215	3347	95.2	170	5.1	3517

(table 1). Overall, there were 3517 surgical resections, or 16% of total NSCLC patients; 95% occurred in specialist hospitals, while only 5% occurred in general hospitals (table 1).

There was substantial variation in unadjusted survival of NSCLC patients depending on type of hospital of treatment and distance from the NASH (figure 1A–C). Patients attending specialist hospitals had better survival while patients attending general hospitals had poorer survival for each stage category. Most of these differences, however, diminished greatly on adjustment of the survival curves for the covariates that were retained in the backward elimination Cox models of hazard of death from NSCLC (figure 1B).

Consistently with figure 1D–F, the fully adjusted, stage-specific HRs for death from lung cancer did not vary greatly by distance and hospital type particularly in patients with regional and distant stage cancer (table 2). To the extent that individual HRs were materially above unity, these increases appeared more consistent with an independent effect of hospital type than an independent effect of distance from the NASH, with the poorer outcome in patients treated in general hospitals. However, since there are strong relationships between distance and hospital type, and hospital type and having a lung resection (table 1), it is likely that resection, which reduced the hazard of death from NSCLC (figure 2, table 2), mediates most of the effects that distance and hospital have on the hazard of death, because only 170 of the 3517 resections were undertaken in general hospitals (table 1). To explore this possibility, we examined the impact of removing resection from the fully adjusted model on the associations of distance and hospital type with death from NSCLC (table 3). With resection excluded from the model, there was a strong association with distance from the NASH and a reduced hazard of death for patients treated in a specialist hospital regardless of cancer stage because with increasing distance from the NASH, patients underwent a resection when they attended a specialist hospital (for localised patients 91.6% at 40–99, and 94.6% at 100+, table 1). Conversely, patients who attended a general hospital were more likely to die from their cancer; this increased risk varied little, by the distance patients lived, from the NASH. This poorer relative outcome in general hospitals was similar for all stage categories (table 3).

Resection was strongly associated with a lower risk of lung cancer death in all three stage categories, and this was true for each type of resection: pneumonectomy, lobectomy and segmental resection (figure 2, table 2). For localised and regional cancer, this impact appeared greater at 1 year after diagnosis than at 5 years.

Women had a lower risk of death than men for all stage categories (table 2). As expected, increasing age, one or more comorbid conditions, having squamous cell carcinoma and having only a clinical diagnosis of lung cancer were strong predictors of a poor outcome. Except for comorbidity, these associations appeared weaker with regional and distant disease. Previous smokers had a lower risk of death than non-smokers or current smokers regardless of stage; this might be a consequence of smoking cessation preparatory to resection. Similarly, patients with a history of COPD had a better outcome, particularly if they had localised disease, perhaps because of better recording of medical history in patients considered for resection. Patients with localised disease who had an emergency admission had a higher hazard of death at 1 year (HR 1) than patients who had planned admissions (HR 0.75). Patients admitted for resection 2–12 months after diagnosis had a hazard of death at 5 years that was more than double than that in patients admitted within a month of diagnosis, and an even greater relative hazard if they had distant disease (table 2). Most patients who had resection were admitted to hospital within a month of diagnosis (80.2%).

The stage-specific results in table 2 were similar when stage was imputed for patients with unknown stage (data available on request).

DISCUSSION

Two factors most influenced the hazard of death: attendance at a specialist hospital and having a resection of the lung cancer. Both were associated with a lower hazard of death. With increasing distance from the NASH, a patient was less likely to be admitted to a specialist hospital and therefore less likely to have a resection. To add to the complexity, when patients who lived further from the NASH were admitted to a specialist hospital, they were more likely to have a resection, probably because patients referred over long distances were more carefully selected for operability. Either way, distance and hospital

Table 2 Hospital of treatment, distance from the NASH and other variables independently associated with hazard of death from localised, regional and distant primary non-small cell lung cancer in New South Wales, 2000–2008

	Localised					Regional					Distant				
	One year*		Five years*			One year*		Five years*			One year*		Five years*		
	HR	95% CI	HR	95% CI	p Value	HR	95% CI	HR	95% CI	p Value	HR	95% CI	HR	95% CI	p Value
Hospital of treatment and distance from the NASH															
Specialist hospital 0–39.9	1		1			1		1			1		1		
Specialist hospital 40–99.9	1.32	(0.96 to 1.82)	1.32	(0.96 to 1.82)		0.99	(0.79 to 1.23)	0.99	(0.79 to 1.23)		0.92	(0.71 to 1.18)	0.92	(0.71 to 1.18)	
Specialist hospital 100+	0.96	(0.72 to 1.28)	0.96	(0.72 to 1.28)		0.93	(0.76 to 1.13)	0.93	(0.76 to 1.13)		0.77	(0.62 to 0.95)	0.77	(0.62 to 0.95)	
General hospital 0–39.9	1.28	(1.00 to 1.65)	1.28	(1.00 to 1.65)		0.92	(0.77 to 1.10)	0.92	(0.77 to 1.10)		1.12	(1.01 to 1.24)	1.12	(1.01 to 1.24)	
General hospital 40–99.9	1.57	(1.14 to 2.18)	1.57	(1.14 to 2.18)		1.03	(0.82 to 1.30)	1.03	(0.82 to 1.30)		1.09	(0.96 to 1.24)	1.09	(0.96 to 1.24)	
General hospital 100+	1.02	(0.80 to 1.29)	1.02	(0.80 to 1.29)	p<0.022	0.84	(0.71 to 0.99)	0.84	(0.71 to 0.99)	p=0.2494	1.10	(0.99 to 1.22)	1.10	(0.99 to 1.22)	p=0.0097
Sex															
Males	1		1			1		1			1		1		
Females	0.84	(0.75 to 0.94)	0.84	(0.75 to 0.94)	p<0.0019	0.90	(0.80 to 1.00)	0.90	(0.80 to 1.00)	p<0.0187	0.80	(0.75 to 0.87)	0.80	(0.75 to 0.87)	p<0.0001
Age at diagnosis															
50–59 years	1		1			1		1			1		1		
60–69 years	1.31	(1.10 to 1.55)	1.31	(1.10 to 1.55)		1.12	(0.97 to 1.29)	1.12	(0.97 to 1.29)		1.13	(1.03 to 1.24)	1.13	(1.03 to 1.24)	
70–79 years	1.51	(1.29 to 1.77)	1.51	(1.29 to 1.77)		1.44	(1.24 to 1.66)	1.44	(1.24 to 1.66)		1.32	(1.20 to 1.45)	1.32	(1.20 to 1.45)	
80+ years	1.91	(1.58 to 2.30)	1.91	(1.58 to 2.30)	p<0.0064	1.62	(1.32 to 1.99)	1.62	(1.32 to 1.99)	p<0.0001	1.51	(1.32 to 1.73)	1.51	(1.32 to 1.73)	p<0.0001
Country of birth															
Australian born	1		1			1		1			1		1		
English speaking	0.99	(0.81 to 1.20)	0.99	(0.81 to 1.20)		1.00	(0.82 to 1.22)	1.00	(0.82 to 1.22)		1.10	(0.96 to 1.27)	1.10	(0.96 to 1.27)	
Non-English speaking	0.87	(0.76 to 0.99)	0.87	(0.76 to 0.99)		0.85	(0.75 to 0.96)	0.85	(0.75 to 0.96)		0.81	(0.74 to 0.88)	0.81	(0.74 to 0.88)	
Unknown	0.58	(0.40 to 0.83)	0.58	(0.40 to 0.83)	p<0.0001	0.51	(0.36 to 0.73)	0.51	(0.36 to 0.73)	p<0.0002	0.76	(0.60 to 0.96)	0.76	(0.60 to 0.96)	p<0.0001
Comorbidity															
No comorbidity	1		1								1		1		
Comorbidity	1.15	(1.01 to 1.29)	1.15	(1.01 to 1.29)	p<0.0258	1.13	(1.00 to 1.28)	1.13	(1.00 to 1.28)	p=0.0443	1.16	(1.07 to 1.26)	1.16	(1.07 to 1.26)	p=0.0005
Chronic obstructive pulmonary disease†															
No COPD	1		1								1		1		
COPD	0.85	(0.75 to 0.96)	0.85	(0.75 to 0.96)	p=0.0110	0.99	(0.87 to 1.12)	0.99	(0.87 to 1.12)	p=0.8356	0.91	(0.83 to 1.01)	0.91	(0.83 to 1.01)	p=0.0874
Smoking‡															
No smoking	1		1			1		1			1		1		
Previous smoking	0.86	(0.75 to 0.99)	0.86	(0.75 to 0.99)		0.84	(0.73 to 0.97)	0.84	(0.73 to 0.97)		0.89	(0.81 to 0.97)	0.89	(0.81 to 0.97)	
Current smokers	0.97	(0.83 to 1.13)	0.97	(0.83 to 1.13)	p=0.0596	0.91	(0.78 to 1.05)	0.91	(0.78 to 1.05)	p=0.0607	0.93	(0.85 to 1.02)	0.93	(0.85 to 1.02)	p=0.0367
Method of diagnosis															
Cytology	1		1			1		1			1		1		
Clinical	1.65	(1.25 to 2.19)	1.65	(1.25 to 2.19)		1.21	(0.88 to 1.66)	1.21	(0.88 to 1.66)		1.17	(1.01 to 1.35)	1.17	(1.01 to 1.35)	
Histologically verified	0.97	(0.79 to 1.10)	0.97	(0.79 to 1.10)	p<0.0001	0.78	(0.64 to 0.96)	0.78	(0.64 to 0.96)	p< 0.0013	0.79	(0.72 to 0.88)	0.79	(0.72 to 0.88)	p<0.0001
Histology§															
Squamous	1		1			1		1			1		1		
Adenocarcinoma	0.89	(0.77 to 1.03)	0.89	(0.77 to 1.03)		1.20	(1.05 to 1.38)	1.31	(1.02 to 1.68)		0.94	(0.80 to 1.11)	1.02	(0.75 to 1.39)	
Large cell	1.04	(0.89 to 1.20)	1.04	(0.89 to 1.20)		1.31	(1.12 to 1.54)	1.02	(0.76 to 1.37)		1.03	(0.86 to 1.22)	0.85	(0.62 to 1.18)	

Continued

Table 2 Continued

	Localised					Regional					Distant				
	One year*		Five years*			One year*		Five years*			One year*		Five years*		
	HR	95% CI	HR	95% CI	p Value	HR	95% CI	HR	95% CI	p Value	HR	95% CI	HR	95% CI	p Value
Other	0.47	(0.37 to 0.61)	0.47	(0.37 to 0.61)	p<0.0001	0.93	(0.72 to 1.19)	0.63	(0.41 to 0.98)	p<0.0001	1.00	(0.80 to 1.25)	0.86	(0.57 to 1.31)	p<0.0001
Type of admission															
Emergency	1		1			1		1			1		1		
Planned	0.75	(0.64 to 0.87)	0.75	(0.64 to 0.87)		0.85	(0.72 to 1.00)	1.34	(0.99 to 1.80)		1.00	(0.89 to 1.13)	1.66	(1.32 to 2.09)	
Other	0.93	(0.67 to 1.30)	0.93	(0.67 to 1.30)	p<0.0001	0.97	(0.68 to 1.38)	0.99	(0.52 to 1.88)	p<0.0001	1.16	(0.89 to 1.51)	1.34	(0.83 to 2.17)	p<0.0001
Major surgery¶															
No resection	1		1			1		1			1		1		
Pneumonectomy	0.35	(0.25 to 0.50)	0.74	(0.44 to 1.25)		0.42	(0.34 to 0.53)	0.60	(0.40 to 0.90)		0.28	(0.18 to 0.42)	0.16	(0.07 to 0.35)	
Lobectomy	0.14	(0.11 to 0.17)	0.32	(0.23 to 0.44)		0.31	(0.26 to 0.37)	0.54	(0.40 to 0.73)		0.34	(0.27 to 0.45)	0.32	(0.19 to 0.54)	
Segmental resection	0.18	(0.15 to 0.23)	0.37	(0.25 to 0.54)	p<0.0001	0.32	(0.26 to 0.40)	0.60	(0.41 to 0.87)	p<0.0001	0.36	(0.25 to 0.51)	0.24	(0.13 to 0.48)	p<0.0001
Time to surgery															
At diagnosis	1		1			1		1			1		1		
2–3 months	0.96	(0.77 to 1.19)	1.67	(1.12 to 2.47)		0.97	(0.82 to 1.14)	1.51	(1.11 to 2.04)		1.71	(1.43 to 2.04)	4.63	(3.23 to 6.64)	
3–6 months	0.67	(0.50 to 0.90)	1.74	(1.02 to 2.96)		1.14	(0.93 to 1.39)	2.99	(2.01 to 4.44)		1.44	(1.19 to 1.76)	7.58	(4.82 to 11.92)	
7–12 months	1.15	(0.97 to 1.38)	1.74	(1.27 to 2.37)	p<0.0001	0.65	(0.50 to 0.85)	2.00	(1.25 to 3.20)	p<0.0001	0.89	(0.70 to 1.13)	12.44	(7.01 to 22.07)	p<0.0001

*HRs at one and five years after diagnosis are presented because the effects of some variables in the model were time varying.
†COPD (diagnosis codes J41.0, J41.1, J41.8, J42.0, J42, J43, J43.1, J43.2, J43.8, J43.9, J44.0, J44.1, J44.8, J44.9).
‡Smoking codes (diagnosis codes Z86.43, Z72.0, Z71.6, F17).
§Cancer codes (ICD 0–3 morphology codes: squamous 80503–80783, large cell 80353, 83103, 80103–80123, 80143–80313, adenocarcinoma 82303–82313, 82503–82603, 81403, 82113, 83233, 85763, 82463 Other 80003–80053, 88003, 88013, 88023, 8053 88113, 88303, 88903, 89203, 90403, 90413, 91203, 91333, 91503, 95403, 88403–89213, 89903–89913, 91203–91333, 95403–95813, 88303, 91503).
¶Procedure codes (lobectomy (38438–01, 38441–00), resection (38438–00, 38440–00, 38440–01, 90169–00,90181–00), pneumonectomy (38441–01, 38438–02)).

Table 3 Effect of presence or absence of surgery on associations of hospital of treatment and distance from a NASH with hazard of death from NSCLC in patients with localised, regional and distant stage disease

Hospital of treatment and distance from a NASH	HR	95% CI	p Value	HR	95% CI	p Value
	Multivariable model including surgery*			Multivariable model excluding surgery*		
Localised NSCLC patients (n=3240)						
Specialist hospital 0–39.9	1			1		
Specialist hospital 40–99.9	0.82	(0.64 to 1.05)		1.32	(0.96 to 1.82)	
Specialist hospital 100+	0.64	(0.51 to 0.81)		0.96	(0.72 to 1.28)	
General hospital 0–39.9	1.69	(1.43 to 2.00)		1.28	(1.00 to 1.65)	
General hospital 40–99.9	2.01	(1.63 to 2.48)		1.57	(1.14 to 2.18)	
General hospital 100+	1.82	(1.55 to 2.13)	p<0.0001	1.02	(0.80 to 1.29)	p<0.022
Regional NSCLC patients(n=2435)						
Specialist hospital 0–39.9	1			1		
Specialist hospital 40–99.9	0.82	(0.66 to 1.01)		0.99	(0.79 to 1.23)	
Specialist hospital 100+	0.77	(0.63 to 0.93)		0.93	(0.76 to 1.13)	
General hospital 0–39.9	1.24	(1.04 to 1.47)		0.92	(0.77 to 1.10)	
General hospital 40–99.9	1.58	(1.26 to 1.98)		1.03	(0.82 to 1.30)	
General hospital 100+	1.23	(1.04 to 1.45)	p<0.0001	0.84	(0.71 to 0.99)	p=0.2494
Distant NSCLC patients (n=3540)						
Specialist hospital 0–39.9	1			1		
Specialist hospital 40–99.9	0.82	(0.64 to 1.06)		0.92	(0.71 to 1.18)	
Specialist hospital 100+	0.65	(0.52 to 0.80)		0.77	(0.62 to 0.95)	
General hospital 0–39.9	1.18	(1.06 to 1.30)		1.12	(1.01 to 1.24)	
General hospital 40–99.9	1.21	(1.07 to 1.38)		1.09	(0.96 to 1.24)	
General hospital 100+	1.23	(1.11 to 1.36)	p<0.0001	1.10	(0.99 to 1.22)	p=0.0097

*Adjusted for hospital of treatment and distance from a NASH, sex, age at diagnosis, country of birth, comorbidity, COPD, smoking, method of diagnosis, histology, type of admission and time to diagnosis.
NSCLC, non-small cell lung cancer.

type appeared as important determinants of having a resection and, therefore, of outcome of NSCLC.

We found as have others[23 24] in a number of UK[5–7 25] and US studies[26 27] that patients living in proximity to a specialist hospital attended one. In addition, we found this pattern of attendance was similar regardless of the stage at diagnosis with 85% of localised and regional and 70% of distant stage patients attending specialist hospitals if they lived within 0–39 km of one. There is evidence, too, that the proximity to hospital and specialty of the referring doctor is important. In a study of US SEER registered lung cancer patients with linked Medicare records, patients were more likely to attend a National Cancer Institute centre if they lived within 30 min of one and had care from a specialist doctor in the preceding 6 months.[24]

We found that if patients attended a general hospital, their survival was poorer, because they were less likely to have a resection of their cancer. Crawford and coworkers[7] in a UK registry study also found that lung cancer patients whose closest hospital was district hospital were significantly less likely to have thoracic surgery than those whose closest hospital was a cancer centre. Other studies of lung cancer patients in the north of England found that both distance from a cancer centre and deprivation reduced the likelihood of surgery, and treatment in a cancer centre reduced the likelihood of death.[5–7] More recently, the UK lung cancer audit found that NSCLC patients first seen at thoracic surgical centres were 51% more likely to have resection than those seen in other centres (adjusted OR 1.51, 95% CI 1.16 to 1.97).[8] A recent UK study also found better survival in hospitals with higher resection volumes even for patients who were older, had lower socioeconomic status or had comorbidities.[28] We found as have others that regardless of stage at diagnosis and after adjustment for other factors, having any resection (pneumonectomy, lobectomy or segmental resection) was the single most important factor in reducing the hazard of death.[8 24]

Most studies of the efficacy of surgical resection of early stage NSCLC have been observational, based on routinely collected data or audits.[29] However, both US[30] and Australian[1] guidelines recommend that stage I to stage IIIa NSCLC patients with potentially resectable disease have a lung resection, subject to staging that includes systematic lymph node sampling or mediastinal lymph node dissection. We could not determine if formal staging was undertaken. However, NSW lung cancer patterns of care studies[9–11] report that 89% of lung cancer patients saw a specialist at some time in their care, with 54% initially referred to a respiratory physician. Of these, 90% were referred to either an oncologist or cardiothoracic surgeon. Vinod *et al*[11] found that 49% of stage I patients, 24% of stage II and 4% of stage III NSCLC patients would have expected to have their lung cancer resected.

The outcomes for surgically treated patients we observed are similar to those of Rich *et al*,[8] who examined the outcomes for 34 513 NSCLC patients in a lung cancer audit. They found that potentially curative surgery was the most powerful overall determinant of survival. Relative to patients who did not have surgery, patients who had surgery had an HR of 0.41 (95%CI 0.39 to 0.44) after adjusting for age, sex, performance status, stage and comorbidity.

Apart from the increased likelihood of having a resection, patients referred to specialist centres would have access to lung cancer specialists for all their care, positive emission tomography (PET) for operative prestaging, guideline based lung

cancer treatment[23] and a reduced likelihood of developing complications.[3] A recent lung cancer audit in Victoria, Australia, found that multidisciplinary team management of lung cancer patients, which is most likely to be available in specialist centres, was an independent predictor of receiving guideline based treatment and of a lower hazard of death.[31] Specialised facilities and practices are less likely to be available in general hospitals, which tend to be outer urban or rural and to serve smaller, less dense populations.[32]

We found, as have others, consistently lower hazard of death in women[5 8] and a higher hazard of death with increasing age.[5 7 8] Unlike others[5 6] but consistent with some NSW studies,[10 33] though not all,[34] we did not find that socioeconomic status affected the hazard of dying from lung cancer. We also found, as have other Australian[9–11 31] and UK studies,[7] that there were higher hazards of death in patients with any comorbidity,[8] those without histological confirmation[35] and patients who were admitted through the emergency department.[36]

LIMITATIONS AND STRENGTHS

This study was limited to surgical treatment. Other studies have shown that, as for surgery, there is lower use of radiotherapy,[6 37] chemotherapy[7 37] and combined treatment[37] with increasing distance to a specialist centre. Our study used a cancer registry based definition of localised, regional and distant stage; while tumour, nodes and metastases (TNM) definitions would have been preferable, they were not available. Cancer registry summary staging categories, however, are routinely used for international comparisons of survival.[14] A recent comparison of lung cancer summary staging and TNM staging showed that whereas all metastases are grouped into T4 category with summary staging, extension to adjacent organs (mediastinum, great vessels, trachea, oesophagus or carina) is categorised as regional stage.[14] However, we do not believe that staging error will have an effect on our main findings because results for hospital of treatment and distance to the NASH were similar in each stage category.

The major strengths of our study are its coverage of the whole population and our ability to link cancer registry and hospital separation records, both public and private, include routinely recorded measures of cancer stage (albeit imperfect) and use geocoded data to provide precise measures of distance between patients' residences and distance to the NASH.

If patients were being referred to specialist hospitals on the basis of appropriateness for resection, then the proportion of patients so referred would not vary by distance from the NASH. A better understanding of physician referral patterns is needed. A greater understanding of patient factors influencing travel to specialist care is also required.

Acknowledgements The authors thank Professor Patrick Royston from the MRC Clinical Trials Unit at the University College London for his advice about directly adjusted survival curves, as well as for providing the method and STATA syntax to determine model fit by comparing Kaplan-Meier unadjusted survival curves with the covariate-adjusted survival curves. The authors would also like to thank the NSW Central Cancer Registry for processing the data and for their dedication and commitment to data quality, and the Centre for Health Record Linkage for linking the Cancer Registry and Hospital data.

Contributors ET: conceived the design of the manuscript and discussed this with BA and JY, undertook the literature review, data analysis and drafting and revision of the manuscript. BM: reviewed the surgical procedure codes and provided clinical advice on the manuscript. TBP: provided biostatistical advice and commented on the results and interpretation. JY: provided suggestions on the design commented on the results and health service implications. BA: provided suggestions on the design, advice in interpreting the results and presenting the tables, suggested further analyses and revised drafts of the manuscript. All authors provided commentary on revisions of the manuscript. All authors have read and approved the final draft of the manuscript.

Funding This work has been partially funded by a University Postgraduate Scholarship funded by the University of Sydney.

Competing interests None.

Ethics approval NSW Population and Health Services Research Ethics Committee.

Provenance and peer review Not commissioned; externally peer reviewed.

Data sharing statement Sensitivity analyses are available on request as mentioned in the text.

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Appendix 1 online text - methods

Other characteristics of patients

The following variables were obtained from cancer registry records: sex; age at diagnosis (grouped into four categories: 15–59, 60–69, 70–79 and ≥80 years); country of birth (grouped as Australian born, born in an English speaking country, born in a non English speaking country and unknown country of birth); socioeconomic status (allocated in five categories using the Australian Bureau Statistics' Index of Relative Socioeconomic Disadvantage based on the 2001 or 2006 Census depending on the period of diagnosis[1]) and year of diagnosis (grouped as 2000–2004 and 2005–2008).

Additional variables obtained from Admitted Patient Data Collection (APDC) records were: smoking status (non smoker, past smoker, current smoker based on ICD-10 codes Z86.43, Z72.0, Z71.6, F17 in any hospital admission record); any or no comorbidity (any condition in the Charlson index[2], except secondary cancer coded as a primary or other diagnosis in any record, or no condition); and any or no history of chronic obstructive airways disease (based on relevant four-digit ICD-10 codes in the range J41.0–J44.9 in any separation record).

Because of its relevance to which hospitals a person might have access to, patients' financial status at admission, as recorded in the APDC, was also included in the analysis, grouped into three categories: public patient in a public hospital, private patient in a private hospital and private patient in a public hospital.

Stage, pathology and treatment

Summary stage at diagnosis was classified, on the basis of the extent of disease notified to, or inferred by, the Central Cancer Registry (CCR), as localised, regional, distant or unknown[3]. Histological sub-type of cancer was coded by the CCR from pathology reports using the ICD-O version 3 morphology codes[4], which were grouped in accord with Cancer Incidence in Five Continents Vol IX[5]. Method of diagnosis, clinical, cytology or histopathology, which is recorded by the CCR, was also included because a number of studies have reported it to be a reliable indicator of lack of investigation.[6] Time to surgery was recorded in months from diagnosis to the procedure.

Statistical methods: sensitivity analyses

Sensitivity analyses were conducted by modelling factors associated with the hazard of death for patients with unknown stage and those not admitted to hospital after diagnosis. A complete analysis was undertaken of all non-small cell lung cancer (NSCLC) patients and we applied multiple imputation using the "ice" (imputation by chained equations) command in Stata 12.1[7] to impute unknown stage, creating 10 imputed datasets.(Available on request).

Determining model fit

To determine model fit we plotted the unadjusted Kaplan Meier survival curves and the adjusted survival curves predicted from our `stpm2`model after using the Predict command. We found very little difference between the survival curves within each of the covariates indicating good model fit.

Appendix 1 Table 1 New South Wales, NSCLC patients diagnosed between 2000-2008 distributed by patient, tumour and treatment factors

Characteristics	N	%
Total	23,871	100
Hospital of treatment distance from the NASH[1]		
Specialist hospital 0-39.9	8,247	34.5
Specialist hospital 40-99.9	769	3.2
Specialist hospital 100 plus	1,029	4.3
General hospital 0-39.9	4,837	20.3
General hospital 40-99.9	2,364	9.9
General hospital 100 plus	5,573	23.3
No hospital[2]	1,022	4.3
Index of remoteness		
Accessible	23,051	96.6
Not accessible	802	3.4
Area of residence		
Urban	8,572	35.9
Outer metropolitan	6,493	27.2
Rural	8,788	36.8
Sex		
Males	15,053	63.1
Females	8,800	36.9
Age at diagnosis		
15-59 years	4,244	17.8
60-69 years	6,143	25.77
70 -79 years	8,418	35.31
80 plus years	5,036	21.12
Country of birth		
Australian born	15,675	65.7
Born in an English Speaking country	1,760	7.4
Born in a Non English speaking country	5,393	22.6
Unknown country of birth	1,025	4.3
Socioeconomic status		
Lowest SES	4,917	20.6
Second lowest SES	4,383	18.4
Middle SES	5,404	22.6
Second highest SES	4,904	20.5
Highest SES	4,233	17.7
Period of diagnosis		
2000-2004	9,849	41.3
2005-2008	14,004	58.7
Comorbidity		
No comorbidity	15,611	65.4
Comorbidity	8,242	34.6
Smoking status[3]		
Non smoker	6,547	27.4
Previous smoker	8,755	36.7
Current smoker	8,551	35.8
Chronic obstructive airways disease[4]		
no COAD	16,495	69.2
COAD	7,358	30.8
Method of diagnosis[5]		
Cytology	3,355	14.1
Clinical	3,587	15.0
Histology coded by hospital	6,730	28.2
Histology coded by cancer registry	9,474	39.7
Discovered at Autopsy	51	0.2
Death certificate only	656	2.8
Order of lung cancer		
First cancer	22,336	93.6
Second or subsequent cancer	1,517	6.4
Histology[6]		
Squamous	4,808	20.2

Adenocarcinoma	7,596	31.9
Large Cell	7,760	32.6
Other	3,677	15.4
Stage		
Localised	5474	22.9
Regional	4156	17.4
Distant	8105	34.0
Unknown	6136	25.7
Emergency presentation		
Emergency	10,495	44.0
Planned admission	12,626	52.9
Other	750	3.1
Major surgery for the primary cancer[7]		
No admission to hospital[2]	1,022[2]	4.3
Admitted to hospital for diagnostic purposes only	5,912	24.8
No cancer procedure	13,185	55.3
Lobectomy	2,224	9.3
Segmental resections	1,122	4.7
Pneumonectomies	388	1.6
Time from diagnosis to surgery or admission		
At diagnosis	8,607	36.1
2-3 months	1,287	5.4
3-6 months	782	3.3
7 to 12 months	525	2.2
More than 12 months	459	1.8
Admission to hospital before diagnosis	11,189	46.9
No admission[2]	1,022	4.3
Financial status		
Public financial status treated in public hospitals	14,231	59.69
Private financial status treated in private hospitals	5,811	24.37
Private financial status treated in public hospitals	2,777	11.65
No admission to hospital	1,022	4.29

[1]Nearest accessible specialist hospital.

[2]These patients were a combination of New South Wales patients that did not have any hospitalisations because they did not link or were patients who were death certificate or autopsy notifications

[3]Smoking codes (diagnosis codes Z86.43, Z72.0, Z71.6,F17)

[4]Chronic obstructive Airways Disease (diagnosis codes J41.0,J41.1,J41.8,J42.0,J42,J43,J43.1,J43.2,J43.8,J43.9,J44.0,J44.1,J44.8,J44.9

[5]Histology by cancer registry staff means the record is coded using a pathology report notified to the registry. Histology hospital means that hospital staff have coded records from a pathology report. When the cancer registry sights the histology report, coding of diagnosis is likely to be more accurate than when it does not.

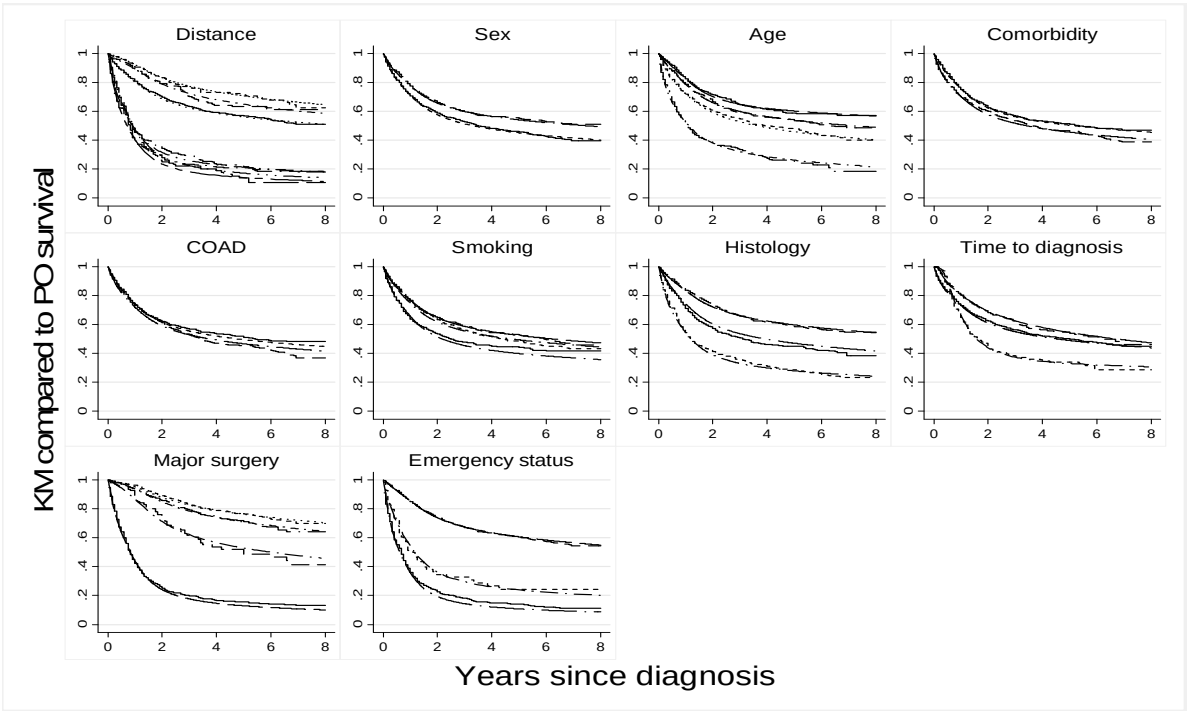
[6]Cancer codes: ICD0-3 morphology codes: Squamous 80503-80783, Large cell 80353, 83103,80103-80123,80143-80313, Adenocarcinoma 82303-82313, 82503-82603, 81403, 82113, 83233, 85763, 82463 Other 80003-80053, 88003, 88013, 88023, 8053 88113, 88303, 88903, 89203, 90403, 90413, 91203, 91333, 91503, 95403, 88403-89213, 89903-89913, 91203-91333, 95403-95813, 88303, 91503. There are two main morphology codes responsible for 81% of the 15.4% of "other" these are morphology code 80003 Neoplasm not otherwise specified (1,375 or 37% of "other") and 80463 non-small cell carcinoma not otherwise specified (1,609 or 44% of "other").

[7]Procedure codes Lobectomy (38438-01, 38441-00), Resection (38438-00, 38440-00, 38440-01, 90169-00,90181-00, Pneumonectomy (38441-01,38438-02).

Appendix 1 Table 2 New South Wales, NSCLC patients diagnosed between 2000-2008 and admitted to hospital within 12 months of diagnosis by patient, tumour and treatment factors and localised, regional and distant stage

	Localised stage patients				Regional stage patients				Distant stage patients			
		%	Died	%		%	Died	%		%	Died	%
Hospital of treatment and distance from the NASH	3,240	100	1,384	100	2,435	100	1,461	100	3,540	100	3087	100
Specialist hospital 0-39.9	1,757	54.2	628	19.4	1,244	51.1	703	48.1	1,539	43.5	1,313	42.5
Specialist hospital 40-99.9	263	8.1	71	2.2	208	8.5	100	6.8	85	2.4	67	2.2
Specialist hospital 100 plus	371	11.5	86	2.7	293	12.0	134	9.2	131	3.7	97	3.1
General hospital 0-39.9	306	9.4	210	6.5	224	9.2	171	11.7	644	18.2	574	18.6
General hospital 40-99.9	153	4.7	116	3.6	117	4.8	98	6.7	351	9.9	323	10.5
General hospital 100 plus	390	12.0	273	8.4	349	14.3	255	17.5	790	22.3	713	23.1
Sex												
Males	2,005	61.9	927	28.6	1,527	62.7	965	66.1	2,221	62.7	1,953	63.3
Females	1,235	38.1	457	14.1	908	37.3	496	33.9	1,319	37.3	1,134	36.7
Age at diagnosis												
50-69 years	662	20.4	225	6.9	606	24.9	342	23.4	1,053	29.7	895	29.0
60-69 years	970	29.9	368	11.4	825	33.9	463	31.7	1,123	31.7	979	31.7
70 -79 years	1,176	36.3	528	16.3	792	32.5	505	34.6	990	28.0	877	28.4
80 plus years	432	13.3	263	8.1	212	8.7	151	10.3	374	10.6	336	10.9
Country of birth												
Australian born	2,094	64.6	924	66.8	1,557	63.9	946	64.8	2,223	62.8	1,965	63.7
English speaking	232	7.2	113	8.2	164	6.7	114	7.8	254	7.2	223	7.2
Non English speaking	772	23.8	315	22.8	626	25.7	369	25.3	970	27.4	826	26.8
Unknown	142	4.4	32	2.3	88	3.6	32	2.2	93	2.6	73	2.4
Comorbidity												
No comorbidity	2,035	62.8	831	60.0	1,633	67.1	974	66.7	2,498	70.6	2,169	70.3
Comorbidity	1,205	37.2	553	40.0	802	32.9	487	33.3	1,042	29.4	918	29.7
Smoking												
Non smoker	720	22.22	349	25.22	529	21.7	353	24.2	1,065	30.1	934	30.3
Previous smoker	1,371	42.31	557	40.25	986	40.5	580	39.7	1,209	34.2	1,040	33.7
Current smoker	1,149	35.46	478	34.54	920	37.8	528	36.1	1,266	35.8	1,113	36.1
Chronic obstructive airways disease												
no COAD	2,147	66.3	864	62.4	1,712	70.3	1,013	69.3	2,953	83.4	2,562	83.0
COAD	1,093	33.7	520	37.6	723	29.7	448	30.7	587	16.6	525	17.0
Method of diagnosis												
Cytology	164	5.1	107	3.3	150	6.2	122	8.4	498	14.1	452	14.6
Clinical	144	4.4	100	3.1	78	3.2	63	4.3	412	11.6	378	12.2
Histologically verified	2,932	90.5	1,124	93.7	2207	90.6	1276	87.3	1,241	35.1	1,121	36.3
Histology[3]												
Squamous	962	29.7	459	14.2	658	27.0	380	26.0	446	12.6	390	12.6
Adenocarcinoma	1,214	37.5	394	12.2	1,051	43.2	588	40.2	1,393	39.4	1,169	37.9
Large cell	692	21.4	431	13.3	522	21.4	383	26.2	1,288	36.4	1,162	37.6
Other	372	11.5	100	3.1	204	8.4	110	7.5	413	11.7	366	11.9
Type of admission												
Emergency	730	22.5	558	17.2	566	23.2	455	31.1	2,215	62.6	1,983	64.2
Planned	2,440	75.3	778	24.0	1,804	74.1	961	65.8	1,157	32.7	958	31.0
Other	70	2.2	48	1.5	65	2.7	45	3.1	168	4.7	146	4.7
Major surgery												
No surgery	1,322	40.8	994	30.7	1,080	44.4	885	60.6	3,296	93.1	2,940	95.2
Pneumonectomy	113	3.5	50	1.5	219	9.0	113	7.7	46	1.3	27	0.9
Lobectomy	1,185	36.6	211	6.5	812	33.3	318	21.8	119	3.4	74	2.4
Segmental resection	620	19.1	129	4.0	324	13.3	145	9.9	79	2.2	46	1.5
Time to diagnosis												
At diagnosis	2,600	80.2	1,090	78.8	1,831	75.2	1,107	75.8	2,899	81.9	2,546	82.5
2-3 months	409	12.6	152	11.0	344	14.1	177	12.1	373	10.5	314	10.2
3-6 months	154	4.8	92	6.6	168	6.9	110	7.5	179	5.1	150	4.9
7 to 12 months	77	2.4	50	3.6	92	3.8	67	4.6	89	2.5	77	2.5

Appendix 1 Figure 1 Testing model fit: a comparison of unadjusted Kaplan Meier survival curves with adjusted survival curves for primary localised NSCLC treated within 12 months of diagnosis, New South Wales, 2000-2008*



*When the unadjusted Kaplan Meier curve and the adjusted survival curve obtained from the model show little difference to one another then this variable is considered to have good fit

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