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Perioperative immune function and pain control may underlie early hospital readmission and 90 day mortality following lung cancer resection: A prospective cohort study of 932 patients

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ABSTRACT

Background: Mortality following lung cancer resection has been shown to double between 30 and 90 days and readmission following surgery is associated with an increased risk of mortality. The aim of this study was to describe the causes of readmission and mortality and enable the identification of potentially modifiable factors associated with these events.
Methods: Prospective cohort study at a United Kingdom tertiary referral centre conducted over 55 months. Binary logistic regression was used to identify factors associated with death within 90 days of surgery.
Results: The 30 day and 90 day mortality rates were 1.4% and 3.3% respectively. The most common causes of death were pneumonia, lung cancer and Acute Respiratory Distress Syndrome/Multi Organ Failure. Potentially modifiable risk factors for death identified were: Postoperative pulmonary complications (Odds ratio 6.1), preoperative lymphocyte count (OR 0.25), readmission within 30 days (OR 4.2) and type of postoperative analgesia (OR for intrathecal morphine 4.8). The most common causes of readmission were pneumonia, shortness of breath and pain.
Conclusions: Postoperative mortality is not simply due to fixed factors; the impacts of age, gender and surgical procedure on postoperative survival are reduced when the postoperative course of recovery is examined. Perioperative immune function, as portrayed by the occurrence of infection and lower lymphocyte count in the immediate perioperative period, and pain control method are strongly associated with 90 day mortality; further studies in these fields are indicated as are studies of psychological factors in recovery.
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Introduction

Surgical resection is the gold standard treatment for patients with early stage lung cancer; careful counselling regarding perioperative risks are paramount before proceeding with surgery. There is a significant risk of morbidity and mortality following thoracic resection with up to one third of patients suffering at least one complication and mortality rates up to 8% for pneumonectomy [1,2]. Surgical morbidity and mortality is traditionally defined as events within 30 days of the surgical procedure, however it has been shown that the mortality after thoracic surgery assessed at 90 days after surgery is twice that assessed at 30 days and readmission following surgery is associated with an increased risk of mortality [3–5]. The reasons underlying this phenomenon are as yet unclear. It has been suggested that the risk of death after surgery is due to the frailty of the patient population, thus counselling of patients and recommending alternative treatments would be the only measures to instigate in managing the risk of death [4]. The aim of this study was to describe the causes of readmission within 30 days and mortality within 90 days of lung cancer surgery; this may enable the identification of potentially modifiable factors

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associated with these events. We hypothesised that modifiable factors would be present that contribute to 90 day mortality.

Material and methods

A prospective observational study of patients undergoing thoracic surgery at a tertiary referral centre was undertaken. Patients were recruited at the preoperative assessment clinic between March 2010 and October 2015. Patients gave written informed consent for participation. All adult patients undergoing surgery with curative intent for a suspected or proven lung cancer surgery were eligible; exclusion criteria included paediatric patients, and patients who lacked capacity. Institutional approval was obtained for this work from Heart of England NHS Foundation Trust. This has recently been incorporated into University Hospitals Birmingham.

Patients were selected for surgery based on British Thoracic Society Guidelines for Radical Treatment of Lung Cancer. Chemotherapy or radiotherapy was not routinely administered preoperatively. Operations were performed using single lung ventilation under general anaesthesia with extubation performed in operating theatres following the procedure. Postoperative care was delivered on a dedicated thoracic surgical ward and associated level 2 High Dependency Unit (HDU). Postoperative analgesia was planned by the anaesthetist after discussing options with the patient. Routine postoperative regime for all patients included breathing exercises, supported coughing mobilisation, and incentive spirometry as required. Patients were discharged home once considered medically fit by physicians and they no longer required treatment by physiotherapists.

Data were collected prospectively and collated into an electronic database. Baseline data were collected on patient demographics, medical history, smoking status, preoperative lung function and preoperative blood test results. Patients were followed up postoperatively and data collected on tumour stage, unplanned readmission, postoperative pulmonary complications (PPC) and mortality. Patient paper and electronic records were inspected and where patients were not resident locally the closest hospital to the patient was contacted for data on readmission to hospital within 30 days of discharge. If there was no data forthcoming from local hospitals the patient was contacted via telephone. Elective admissions were not recorded. PPC details were recorded on each day of the inpatient postoperative stay by physiotherapists caring for patients; diagnostic criterion for a PPC was a according to the Melbourne Group Scale [6,7]. This scoring system identifies a PPC by a score of four or more based on a system of one point for each dichotomous feature affecting the patient: atelectasis or consolidation on chest radiograph, white blood cell count 11.2×10^9/L or more, temperature of 38 °C or more, positive sputum culture, new purulent appearance of sputum, oxygen saturation 90% or less in room air, clinician diagnosis of pneumonia, prolonged high dependency unit admission for respiratory complications and readmission to high dependency unit or admission to intensive care unit for respiratory complications. Cause of death was recorded as the disease or condition directly leading to death on the death certificate. If records were not available in the hospital notes the patients General Practitioner and the regional Coroner's Office were contacted.

Statistical analysis was performed using binary logistic regression with the backward stepwise method based on likelihood ratios used to remove non-significant variables ($p > 0.1$). Analysis was performed for mortality at 90 days and readmission at 30 days. Variables entered into the models were: age, gender, body mass index (BMI), pathological lung cancer stage, American Society of Anaesthesiologists (ASA) grade, preoperative blood test results, type of operation, predicted postoperative forced expiratory volume in one second (FEV1), type of postoperative analgesia, smoking status, presence of Chronic Obstructive Pulmonary Disease (COPD), ischaemic heart disease (IHD), diabetes mellitus and PPC. The analysis of 90 day mortality also included the occurrence of readmission within 30 days as a variable entered into the model. All statistical analyses were performed using IBM SPSS version 22 (IBM Corp. Armonk, NY) with p values of 0.05 or less considered statistically significant. Univariable comparison of patient characteristics included the following: Mann Whitney *U* test on skewed continuous data, independent samples T test on normally distributed continuous data and Chi squared test on categorical data. Data distributions were assessed using Shapiro-Wilk tests.

Results

Patient characteristics

In total 1078 patients had surgery during this period and 932 patients had a complete data set during follow up (recruitment rate 85.4%). The patient characteristics are shown in Table 1. In the first 30 days following surgery 15 (1.4%) patients died and 11 of these deaths were prior to discharge from the index operation. Between 30 and 90 days following surgery 21 patients died and 3 of these deaths were prior to discharge from the index operation (90 day mortality rate 3.3%). The 30 day and 90 day mortality rate according to the type of surgery is detailed in Table 2.

Eight patients (0.74%) suffered Acute Respiratory Distress Syndrome (ARDS) and required intensive therapy unit (ITU) admission; all patients had undergone a lobectomy. The 30 day mortality rate for patients suffering ARDS was 62.5% and 90 day mortality rate was 75.0%. All of these deaths were in hospital prior to discharge from the index operation.

Factors associated with 90 day mortality

Binary logistic regression analysis was performed on patients with a complete data set ($n = 932$) and found a significant model associated with 90 day mortality, correctly classifying 96.4% of cases (X^2 104.244, $p < 0.001$, Nagelkerke R^2 0.379). Six factors were significantly associated with an increased risk of death within 90 days of surgery: PPC, IHD, increased age, lower preoperative lymphocyte count, readmission within 30 days and type of analgesia used. See Table 3. A total of 271 data points (1.9%) were missing in 146 of the patients, data on 90 day mortality was complete in all cases. To assess the impact of missing data on the model analysis was repeated following multiple imputation (Fully Conditional Specification) of missing values using 5 imputations. The results of the pooled analysis are shown in Table 4. All significant associations remained similar except the effect of Patient Controlled Analgesia. The type of resection was not associated with 90 day mortality.

The development of a PPC had the largest effect size on 90 day mortality and is a potentially modifiable factor along with readmissions and analgesia method. The use of paravertebral, epidural or morphine infusion showed no difference between the mortality rate at 90 days for each method; however the use of intrathecal morphine was associated with an increased risk of mortality.

Factors associated with readmissions

There were 102 (9.5%) patients who had an unplanned admission to hospital in the first 30 days after surgery; the causes of readmission are summarised in Table 5. Readmissions according to type of operation are provided in Table 2. Binary logistic regression analysis found a significant model correctly classifying 89.9% of

Table 1
Patient characteristics, n = 932.

		Alive at 90 days	Dead at 90 days	P value
Age	Median (IQR)	66.3 (61–74)	74 (69–78)	**<0.001**
Gender	Male	55.0% (493)	55.6% (20)	0.989
Operative procedure	Sublobar resection	20.6% (185)	13.9% (5)	0.534
	Lobectomy	73.7% (660)	77.8% (28)	
	Pneumonectomy	5.7% (51)	8.3% (3)	
Incision	VATS	15.2% (136)	11.1% (4)	0.607
Pathological TNM stage	I	21.1% (189)	16.7% (6)	**0.008**
	II	40.5% (363)	55.6% (20)	
	IIIa or higher	12.8% (115)	19.5% (6)	
	Other	25.6% (229)	8.3% (3)	
BMI	Mean (SD)	26.5 (5.1)	27.2 (5.57)	0.368
Analgesia type	Epidural	41.2% (369)	22.2% (8)	**0.006**
	Paravertebral	26.5% (237)	19.4% (7)	
	Intrathecal morphine	18.4% (165)	41.7% (15)	
	Intravenous morphine infusion	7.4% (66)	11.1% (4)	
	PCA	6.6% (59)	5.6% (2)	
ASA grade	1	6.1% (55)	2.8% (1)	0.241
	2	42.9% (384)	33.3 (12)	
	3	48.2% (432)	63.9% (23)	
	4	2.8% (25)	0	
FEV1% predicted	Median (IQR)	82.0% (67.0–96.0)	83.0% (70.3–102.8)	0.429
Smoking status	Never	17.9% (160)	25.0% (9)	0.752
	Ex > 6 weeks	50.7% (454)	50% (18)	
	Ex < 6 weeks	10.4% (93)	5.6% (2)	
	Current	21.1% (189)	19.4% (7)	
IHD	Yes	11.3% (101)	33.3% (12)	**0.001**
Diabetes	Yes	13.1% (117)	25.0% (9)	**0.049**
COPD	Yes	52.6% (471)	61.1% (22)	0.396

Bold = significant at the p<0.05 level.

Table 2
Readmission, PPC and mortality data according to operative procedure, n = 1078.

	PPC	30 day readmission	30 day mortality	90 day mortality
Sublobar resection	11.2% (24)	7.9% (17)	0.9% (2)	2.3% (5)
Lobectomy	13.0% (104)	9.5% (76)	1.5% (12)	3.5% (28)
Pneumonectomy	3.3% (2)	20.0% (12)	1.7% (1)	5.0% (3)

Table 3
Factors associated with 90 day mortality (incomplete data excluded, n = 932).

	Odds ratio	95% Confidence Interval	P value
PPC	6.1	2.6–14.6	**<0.001**
30 day readmission	4.2	1.6–10.7	**0.003**
Analgesia type			
Epidural	1.0	Reference technique	
Paravertebral	1.1	0.34–3.7	0.840
Morphine infusion	2.3	0.52–10.5	0.265
Intrathecal morphine	4.8	1.7–13.6	**0.003**
Patient controlled analgesia	6.6	1.1–38.7	**0.036**
Preoperative lymphocyte count	0.25	0.07–0.91	**0.035**
IHD	2.9	1.2–7.0	**0.022**
Age	1.08	1.03–1.1	**0.003**

Bold = significant at the p<0.05 level.

cases (X^2 41.85, p = 0.019, Nagelkerke R^2 0.091). PPC was associated with increased risk of readmission (OR 2.08, 95% CI 1.17–3.71, p = 0.013); this finding was consistent after repeat analysis using multiple imputation for missing data (OR 2.28, 95% CI 1.33–3.89, p = 0.003). However, overall the model for readmission was sensitive to missing data. Three factors were considered statistically significant in one or other model but not both; this limits drawing further conclusions from the model.

Causes of death and readmissions

Respiratory problems were the most common cause of readmissions up to 30 days and death up to 90 days postoperatively with pneumonia being the most common cause of death, see Table 6. Surgical problems caused almost as many readmissions; within this group pain was the most frequent problem. The individual causes of death along with major preoperative comorbidities

Table 4
Factors associated with 90 day mortality (multiple imputation for missing data, n = 1078).

	Odds ratio	95% Confidence Interval	P value
PPC	5.8	2.6–13.1	**<0.001**
30 day readmission	3.4	1.4–8.1	**0.007**
Analgesia type			
Epidural	1.0	Reference technique	
Paravertebral	1.3	0.44–4.1	0.609
Morphine infusion	3.1	0.85–11.5	0.086
Intrathecal morphine	4.0	1.5–10.6	**0.005**
Patient controlled analgesia	4.8	0.86–26.3	0.074
Preoperative lymphocyte count	0.43	0.22–0.85	**0.016**
IHD	3.1	1.3–7.2	**0.010**
Age	1.08	1.03–1.1	**0.003**

Bold = significant at the p<0.05 level.

Table 5
Causes of readmission (n = 102).

Readmission category		Examples	Number[a]
Respiratory	39.7%	Pneumonia	31
		Shortness of breath	13
		Respiratory failure	2
Surgical	36.2%	Pain	12
		Wound infection, haematoma, discharge	10
		Surgical emphysema	8
		Hydro/pneumothorax	7
		Bronchopleural fistula, empyema	3
		Drain problem	2
Gastrointestinal	8.6%	Constipation	6
		Nausea, abdominal pain, vomiting	4
Cardiovascular	6.9%	Atrial fibrillation	5
		Pulmonary embolism	2
		Stroke	1
Other	6.9%	Leg pain, bleeding duodenal ulcer, mouth ulcers, low haemoglobin, high blood pressure, high calcium	6
		Urinary tract infection	2
Unknown	1.7%		2

[a] Some patients had more than one reason for admission.

and postoperative course are also presented; data from individual cases illustrates the potential chain of causation through the patient journey. The description 'high risk' denotes that in the opinion of the treating surgeon they were concerned that the patient was at high risk of death. The description of 'cardiovascular' comorbidity includes peripheral vascular disease, cerebrovascular disease and diabetes mellitus with one or more additional cardiovascular risk factors. 'Psychological' factors include bereavement, being a carer for a relative or spouse and formal diagnoses of psychiatric illness. Of the 31 patients with a known cause of death, 24 (77.4%) had either a comorbidity or perioperative problem that could be linked to the cause of death.

Discussion

This study aimed to describe the causes of death up to 90 days and the causes of readmission up to 30 days following lung cancer resection with curative intent. Pneumonectomy mortality at 30 days was lower than national rates for the same period; sublobar resection and lobectomy mortality rates were similar to national rates [3]. The results demonstrate PPCs to be the most influential factor associated with 90 day mortality and respiratory problems to be the most common cause of readmission within 30 days of surgery. Age and a diagnosis of IHD cannot be altered but four factors that are associated with 90 day mortality are potentially modifiable.

Table 6
Causes of death.

Category	Total (n = 36)	Example	Total	<30 days (n = 15)	30–90 days (n = 21)
Respiratory	30.6%	Pneumonia, empyema	7	2	5
		Respiratory failure	4	2	2
Oncological	16.7%	Lung cancer progression	6	0	6
Acute postoperative deterioration	13.9%	ARDS/MOF	5	4	1
Cardiovascular	13.9%	Myocardial infarction	3	1	2
		Cerebral infarction	1	0	1
		Pulmonary embolism	1	0	1
Gastrointestinal	11.1%	Ischaemic bowel	2	2	0
		Perforation of viscus	2	2	0
Unknown	13.9%		5	2	3

Postoperative pulmonary complications

The risk of death was found to be six times higher in those affected by a PPC compared to those who were not. Established techniques to reduce PPC include smoking cessation, optimal medical management of existing respiratory disease, a well-structured physiotherapy plan for the patient, and prophylactic mini tracheostomy insertion in patients perceived to be at risk of sputum retention [8–10]. A number of studies have identified additional modifiable risk factors for PPC including low preoperative activity level and high body mass index [11–13]. There is evidence that pulmonary rehabilitation reduces the incidence of postoperative pulmonary morbidity and a combined approach to reduce risk factors and instigate protective measures against PPC may improve patient outcomes [14].

Readmission

Readmission was shown to be associated with a fourfold increased risk of mortality and our data is consistent with published data that this is a major risk factor for death [15]. Respiratory and surgical causes accounted for three quarters of readmissions in this study and respiratory causes were also found to be the most common reason for admission in existing literature [15–17]. Correspondingly PPC measured during the hospital stay was a factor that increased the risk of readmission in this study. Readmission rates for sublobar resection and lobectomy were as expected; readmission for pneumonectomy was greater than expected at 20.0%. The causes of admission among pneumonectomy patients were either respiratory or surgical, but two were unknown; pneumonia was the most common reason accounting for 25% of the admissions. The only death to occur after readmission among the pneumonectomy patients occurred after admission for an unknown reason; the excess of readmissions in pneumonectomy patients did not account for the association between readmission and 90 day mortality.

Issues such as pain, wound infections, constipation or venous thromboembolism (VTE) are all at least partly preventable; these represent factors that could also be modified with the aim of improving patient outcomes.

Analgesia technique

Analgesic technique in the first 24 h after surgery has not been reported before in association with mortality outcomes at 90 days after surgery. It was an unexpected finding that 90 day mortality was increased with intrathecal morphine independent from the occurrence of PPC and readmission. The exact mechanisms behind this association are not certain, confounding factors may be present and responsible for the result including the process of selecting analgesia techniques by the anaesthetist. Postoperative analgesia was planned by the anaesthetist after discussing options with the patient. A false positive finding is always possible within statistical analyses and could underlie this association. This finding was discussed locally at a departmental meeting between thoracic surgeons and thoracic anaesthetists; the opinion of the thoracic anaesthetists regarding intrathecal morphine analgesia was that patients have excellent pain relief for the first 24 h after surgery but may have pain which is more difficult to control after the dose wears off. The protective effect of regional anaesthesia over systemic opioids upon pulmonary morbidity, myocardial infarction and blood oxygenation in the postoperative period has been reported but intrathecal morphine alone has not been studied in this way [18]. Intrathecal morphine may confer the same detrimental effects of systemic opioids and lead to episodes of undetected desaturation, with or without myocardial ischemia, which could then impair functional recovery. Such a cascade of events would potentially explain the adverse association of intrathecal morphine with mortality. The fact that all of the cases of fatal myocardial infarction or ischaemic bowel occurred in patients who received intrathecal morphine analgesia supports a potential mechanism related to aberrations of oxygenation or perfusion.

Our finding of increased mortality at 90 days with intrathecal morphine should be interpreted with caution and certainly effective pain control to facilitate physiotherapy regimes is paramount. If effective alternatives to systemic or intrathecal opioids can be employed it is reasonable to aim to reduce the administration of opioids with the intention of reducing the incidence of their well-established side effects.

Lymphocytes

Low preoperative lymphocyte count was associated with lower survival at 90 days. The interaction between the immune system and tumour microenvironment is fundamental in the cancer process and low lymphocyte counts have been associated with worse survival in resected non-small cell lung cancer in univariable analysis [19,20]. Immunocompromise may underlie the incidence and severity of PPC and pneumonia, though no patients in this study suffered from a clinically manifest immunodeficiency syndrome and there was no multicollinearity between inpatient PPC and lymphocyte count in this study. Tumour induced bronchus associated lymphoid tissue has been associated with a favourable outcome in early stage non-small cell lung cancer; further studies to assess a correlation between peripheral lymphocyte count and density of these lymphoid structures might explain the findings of this study and may be of prognostic value clinically [21].

Causes of death and readmission

This is the first report of patient level data to illustrate the perioperative course prior to death. Over three quarters of patients had a cause of death related to a postoperative problem or an existing comorbidity.

Inspecting the comorbidities and perioperative factors of patients who died reveals 18 of 31 (58.16%) patients suffered a postoperative problem that could be linked to the cause of death and 16 of 31 (51.6%) had a preoperative condition that could be linked to cause of death, some had both. See Table 7. For example, Case 27, the patient was fit preoperatively but suffered a PPC after lung resection and subsequently died from respiratory failure.

PPC or readmission for pneumonia affected five of the six patients with preoperative psychological stressors who died. Two patients were noted to be so non-compliant with perioperative care regimes that this almost certainly lead ultimately to mortality, however existing risk scoring systems do not mention any aspects of psychological morbidity or patient behaviour [22]. Psychological distress is associated with an increased risk of mortality; recovery from thoracic surgery requires active participation in physiotherapy treatment plans and continuing these learned activities after discharge [23]. Self efficacy, defined very briefly as belief in one's self to perform activities in order to achieve a goal, has a significant role in recovery and outcomes after surgery; promisingly this has been shown to improve with pulmonary rehabilitation in patients affected by COPD [24,25]. Further study into interventions to improve the self-efficacy and outcomes of patients undergoing thoracic surgery are needed.

Table 7
Presence of comorbidities and postoperative course according to cause of death.

Mortality case	Major preoperative comorbidity	Postoperative problem	Cause of death
1	Pulmonary[a]	PPC[b]	ARDS
2	Pulmonary, current smoking[a]	PPC[b]	ARDS
3	Pulmonary, psychological, current smoking[a]	PPC[b]	ARDS
4	–	Non-compliant, readmitted with aspiration pneumonia[b]	Aspiration pneumonia
5	Psychological, current smoking[a]	PPC[b]	Empyema thoracis
6	Cardiovascular, gastrointestinal[a]	PPC[b]	Ischaemic bowel
7	Pulmonary	–	Ischaemic bowel
8	Cardiovascular	Readmitted for wound infection	Lung cancer
9	Pulmonary, current smoking	–	Lung cancer
10	Pulmonary, psychological	–	Lung cancer
11	Pulmonary	–	Lung cancer
12	Cardiovascular	–	Lung cancer
13	Neoadjuvant chemotherapy[a]	Surgical margins involved by tumour[b]	Lung cancer
14	High risk, pulmonary[a]	PPC, small cell lung cancer on histology[b]	MOF
15	High risk, cardiovascular, gastrointestinal[a]	–	MOF
16	Cardiovascular[a]	–	Myocardial infarction
17	Psychological	PPC, readmitted for pneumonia[b]	Myocardial infarction
18	Cardiovascular, renal[a]	PPC[b]	Myocardial infarction
19	Cardiovascular	PPC	Perforation
20	Cardiovascular, gastrointestinal[a]	Readmitted for constipation[b]	Perforation
21	Pulmonary[a]	PPC[b]	Pneumonia
22	Cardiovascular, current smoking[a]	–	Pneumonia
23	Pulmonary[a]	Readmitted for pneumonia[b]	Pneumonia
24	Pulmonary, cardiovascular[a]	–	Pneumonia
25	Cardiovascular	PPC, readmitted with shortness of breath[b]	Pneumonia
26	Pulmonary, cardiovascular	Readmitted for pneumonia	Pulmonary embolism
27	–	PPC[b]	Respiratory failure
28	Cardiovascular	PPC[b]	Respiratory failure
29	Cardiovascular, pulmonary, current smoking[a]	Readmitted for wound infection, pneumothorax and shortness of breath[b]	Respiratory failure
30	Cardiovascular	PPC[b]	Respiratory failure
31	Cardiovascular, psychological[a]	PPC, readmitted for shortness of breath	Cerebral infarction
32	Cardiovascular, current smoking	–	Unknown
33	Psychological	Readmitted for pneumonia	Unknown
34	Gastrointestinal	–	Unknown
35	–	–	Unknown
36	Cardiovascular, pulmonary	–	Unknown

[a] Factors linked to cause of death.
[b] Factors linked to cause of death.

Strengths and limitations

We achieved a high recruitment and follow up rate among patient from a diverse geographical area, thus creating a study population likely to be representative of the patient population at large. Data was collected prospectively and PPC diagnosis was performed using a validated scoring system. Mortality was confirmed via the NHS Spine database and as such the mortality rate should be accurate.

The number of deaths was lower than expected causing the study to have fewer cases to analyse for cause of death. In addition in some cases we could not ascertain the cause of death or readmission from another healthcare provider. The wide geographical area is a limitation because readmissions at distant sites were more difficult to confirm. This could introduce bias if readmissions were missed in these patients. The readmission rate of 9.5% is comparable to other studies performed using databases shared across regions [15,17].

As an observational study the ability to determine causality as opposed to association is limited. Mortality would not be caused by the fact a patient is admitted however a causal relationship is clearly possible between suffering a postoperative pneumonia that leads to readmission (the most common cause of readmission) and subsequent death due to pneumonia (the most common cause of death). Equally suffering a PPC as an inpatient and subsequent death from pneumonia could be seen as having a causal relationship.

Conclusions

In summary, following lung cancer resection with curative intent patients most commonly die from pneumonia, lung cancer or ARDS/Multi organ failure (MOF). Postoperative mortality is not simply due to fixed factors; the impacts of age, gender and surgical procedure on postoperative survival are reduced when more clinical details are examined. Readmission within 30 days is most commonly due to pneumonia, shortness of breath and pain. Strategies to prevent in hospital PPC and pneumonia after discharge may in turn prevent readmission and deaths following lung cancer resection. Further research into the effects of lung resection on the immune system and immunomodulatory agents in surgical lung cancer patients is warranted. Further research studies into psychological interventions, postoperative analgesia, immune function, and detailed causes of readmission are needed.

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None declared.

List of abbreviations

HDU	high dependency unit
PPC	postoperative pulmonary complication
BMI	body mass index
ASA	American Society of Anaesthesiologists

FEV1	forced expiratory volume in one second
COPD	chronic obstructive pulmonary disease
IHD	ischaemic heart disease
ARDS	acute respiratory distress syndrome
VTE	venous thromboembolism
MOF	multi organ failure
ITU	intensive therapy unit

Declarations

Ethics approval and consent to participate

We received institutional approval for this research.

Consent for publication

Not applicable.

Availability of data and material

Competing interests

None declared.

Authors' contributions

JHS, AK, PA and JW collected patient data. JHS, NO and BN analysed and interpreted patient data and were main contributors in writing the manuscript. All authors read and approved the final manuscript.

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