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Review article

Unplanned Readmission After Lung Resection Surgery: A Systematic Review☆

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ABSTRACT

Urgent readmissions have a major impact on outcomes in patient health and healthcare costs. The associated risk factors have generally been infrequently studied. The main objective of the present work is to identify pre- and perioperative determinants of readmission; the secondary aim was to determine readmission rate, identification of readmission diagnoses, and impact of readmissions on survival rates in related analytical studies.

The review was performed through a systematic search in the main bibliographic databases. In the end, 19 papers met the selection criteria.

The main risk factors were: sociodemographic patient variables; comorbidities; type of resection; postoperative complications; long stay.

Despite the great variability in the published studies, all highlight the importance of reducing readmission rates because of the significant impact on patients and the healthcare system.

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Reingreso no planificado tras cirugía de resección pulmonar: revisión sistemática

Palabras clave:
Reingreso hospitalario
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Factores de riesgo
Revisión sistemática

RESUMEN

Los reingresos urgentes suponen un impacto importante sobre los resultados en la salud de los pacientes y los costes sanitarios. Los factores de riesgo asociados a reingreso tras cirugía de resección pulmonar han sido poco estudiados. El principal objetivo del presente trabajo es la identificación de factores pre- y perioperatorios determinantes de reingreso; secundariamente, determinación de tasa de reingresos, identificación de diagnósticos de reingreso, e impacto de los reingresos sobre las tasas de supervivencia en los estudios que lo analizaban.

La revisión se realizó mediante búsqueda sistemática en las principales bases de datos bibliográficas. Finalmente, 19 trabajos cumplieron los criterios de selección.

Los principales factores de riesgo fueron: variables sociodemográficas de los pacientes; comorbilidades; tipo de resección; complicaciones postoperatorias; estancia prolongada.

A pesar de la gran variabilidad en los estudios publicados, todos destacan la importancia de reducir los índices de reingreso por su significativo impacto sobre pacientes y sistema sanitario.

Introduction

The Quality Plan of our National Healthcare System contemplates the rate of readmission after surgical procedures as a relevant marker of care quality.[1] The adjusted rates of potentially avoidable readmissions are sufficiently solid to justify their inclusion to monitor hospital quality[2,3]; a high rate of readmissions could indicate inadequate care, with poor care results and a loss of efficiency.[4] Thus, avoidable readmissions are estimated as an indirect indicator of quality and are assumedly an opportunity for significant savings in potential costs for the healthcare system,[5] while also recognizing their impact on patient health outcomes, both in terms of quality of life as well as survival.[6]

Several studies have been published about readmissions after various surgical procedures in general, trauma and cardiovascular surgery; meanwhile, other studies have grouped together different major surgeries from different specialties, including pulmonary lobectomy.[6,7] However, the specific risk factors associated with readmission, the rate of readmissions and their correlating diagnoses after lung resection surgery have generally not been extensively studied. Recently, several papers have been published analyzing readmissions after lung resection surgery. The main objective of this study is to identify pre- and perioperative determinants for readmission. Secondary objectives were to analyze readmission rates, identify the diagnoses associated with readmission, and calculate the impact of readmissions on survival rates in the studies that analyzed this variable.

Methods

The review was carried out following the guidelines of the Preferred Reporting Items For Systematic Reviews and Meta-Analyses (PRISMA)[8] in order to answer the following questions: what is the readmission rate in lung resection surgery?; what are the diagnoses of the patients who are readmitted after a pulmonary resection?; and, is it possible to identify perioperative risk factors predicting readmission? The review protocol was registered in the International Prospective Register of Systematic Reviews (PROSPERO),[9] under record number CRD42017059341.

Search Strategy

The search was carried out until March 2017 in five bibliographic databases (PubMed, US National Library of Medicine-National Institute of Health; Embase, Elsevier; The Cochrane Library and Cochrane Library Plus, Cochrane Collaboration; Spanish Bibliographic Index in the Health Sciences (IBECS); Virtual Health Library (BVS), Carlos III Health Institute), and an additional search was conducted in Tripdatabase and Google Scholar.

The search terms in Spanish were ''readmisión'' and ''cirugía'', as well as ''readmission'' and ''lung surgery'' in English. The searches excluded ''transplants'' and were limited to studies in humans, with no time restriction.

Inclusion and Exclusion Criteria

The scope of the study was readmission after lung resection surgery in human adults. Therefore, the inclusion criteria were studies conducted on unplanned readmissions in adult humans (18 and older) who had undergone pulmonary resection surgery (any technique). We excluded the studies about readmission in thoracic surgery focused on other types of surgical interventions other than lung resections, as well as studies in which readmission was not the main objective of the study but was used as an indicator of quality to evaluate certain programs or was used in the comparison of results between different hospital teams.

All article types were included, excluding editorials, letters to the editor or redundant papers.

Measurement of Results

The main result of interest was the identification of pre- and perioperative factors that led to readmission.

The secondary outcomes were the rate of unplanned readmissions after lung resection surgery and the readmission diagnoses. Another result assessed was the influence of readmissions on survival rates, although not all the studies analyzed this variable.

Study Selection; Data Extraction

Study titles and/or abstracts were retrieved by applying the search strategy in the different bibliographic databases consulted; these were then examined independently by two authors of the review (GT and LO). The full texts of these potentially eligible studies were obtained and evaluated independently by two members of the review team (GT and LO). Any disagreement was resolved through discussion with a third reviewer (MB). A standardized form was used to extract the data from the included studies, and two reviewers extracted data independently (GT and JL); any discrepancies were resolved by discussion with a third author (MB).

Quality Assessment (Risk of Bias)

The methodological quality of the studies was assessed independently by two researchers (JL and MB) using the Cochrane Collaboration[10] bias risk assessment tool. Using this tool, we evaluated: selection bias (patient inclusion criteria, including losses and exclusions from the analysis, reporting the reasons for these losses and exclusions); detection bias (establishing the criteria for identifying the main event: readmission); attrition (identifying the sources for obtaining the data, with possible bias due to quantity, nature or incomplete data management); information bias (possible selectively reported results); and other biases (any important observation of possible unforeseen biases). Possible disagreements were resolved with the participation of a third review author (GT).

Data Analysis

Given the heterogeneity in the data analysis, a narrative synthesis was undertaken of the results from the studies analyzed (data from heterogeneous studies grouped into a meta-analysis can produce erroneous results).[11]

Results

Bibliographic Search

After filtering and eliminating duplicates of the 904 papers initially identified, 579 articles were obtained (Fig. 1). In the end, the full texts of 37 articles were reviewed, 18 of which were excluded for different reasons (Table 1). Thus, 19 studies met the selection criteria and were included in the review.[5–7,12–27]

Characteristics of the Included Studies

All the studies analyzed presented a retrospective cohort design, with the exception of one case–control study[19] and one prospective cohort study with a one-year follow-up.[27] One retrospective cohort study had been published as a communication at a national congress.[22] Table 2 shows the main characteristics of the study designs.

In many studies, recruitment was from large databases, some from a hospital setting[12,13,19,20,27] and one was a multicenter study.[21] Significant variability was observed in the type of lung resection included in the studies, as well as in the indications for lung resection, being restricted to patients with bronchogenic carcinoma in many cases, or to all types of indications in many others. The criterion of readmission was established in the majority of the studies as that occurring during the 30 days following patient discharge after the initial admission, while in other studies a 90-day period was established[5,12,19] and in some cases the 30-day period was established after surgery[7,18,22]; in yet another study, the limit was 28 days,[15] and two authors carried out the study with 30- and 90-day periods after hospital discharge.[21,23,24]

The study design profiles reveal the main biases that could be derived from patient selection: several studies restricted patient age (including patients over 65[21] or 66[6,14,16,23]); others excluded patients who had prolonged hospital stays for a certain period after admission[7,26]; some articles were very large population studies that included different types of surgery, including abdominal,[6,7,21,23] vascular[7] or cardiac,[6] although they provided detailed readmission information in thoracic surgery, fulfilling the criteria for inclusion in the review.

Another potential source of bias was the possible incomplete collection of data and their selective reporting: only six of the studies made specific mention of the loss of patients[5,7,14,18,26,27]; and, regarding the readmitting hospital, two studies did not specify whether the possibility of readmission at a different hospital had been considered,[22,25] and three papers collected only the readmissions at the hospital where the initial admission had occurred.[17,21,26]

Readmission Rates

The rate of readmissions within 30 days ranged between 4.3%[17,25] and 15%,[14] including the studies that established a criterion of 28 days after discharge[15] and 30 days after surgery.[7,18,22] The articles that analyzed readmission within 90 days obtained a rate that ranged between 7%[5] and 23%[23]; excluding the study at the lower end of the range,[5] all the other 90-day studies placed the readmission rate above 18%. The only study done in Spain that met the inclusion criteria of this study (Varela et al.,[13] 2004) reported a readmission rate of 6.9%.

Risk Factors Associated With Readmission

Table 3 provides a synopsis of the main results found by the different authors; Table 4 demonstrates the complete list of variables analyzed in the different studies, providing details about those that were significant for the different authors with

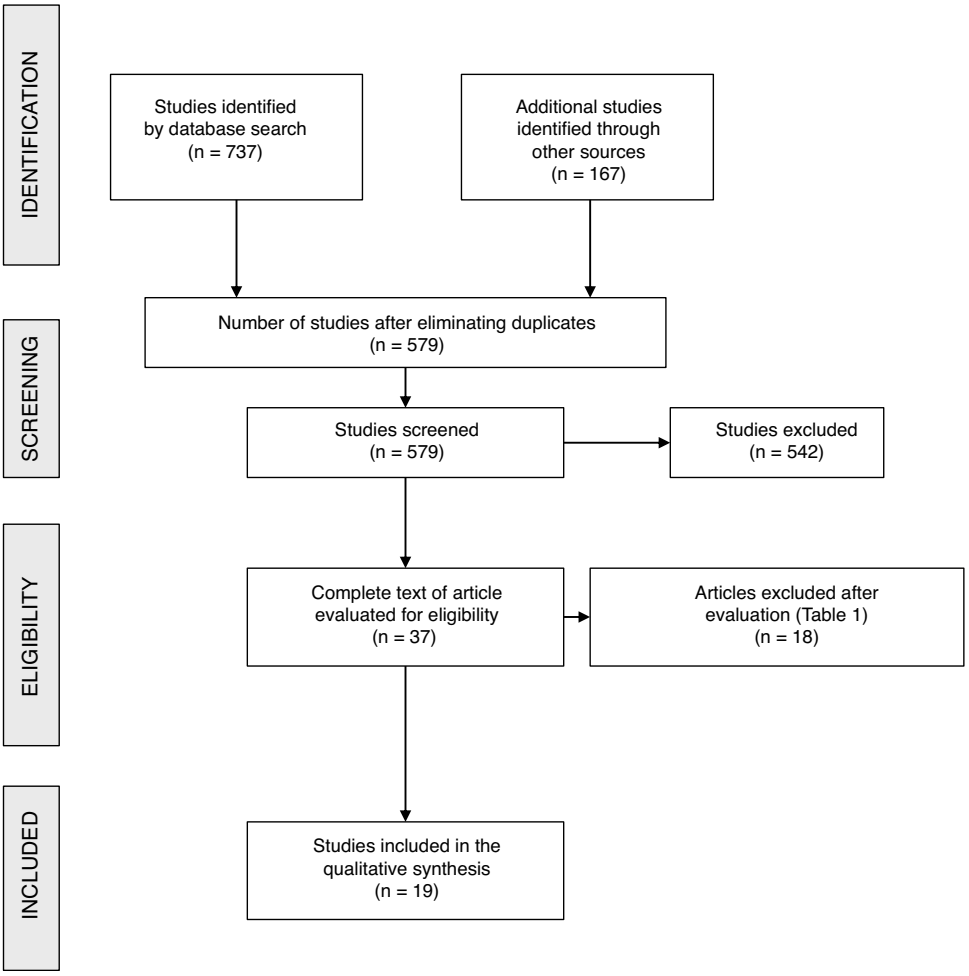

Fig. 1 – Bibliometric search and article selection; PRISMA flow diagram.

their statistical result, and Table 5 schematically reflects the risk factors leading to readmission.

Regarding sociodemographic variables as determining factors for readmission, several studies showed an association with sex, which was male in all cases[14,17,19,23–26]; advanced age was also associated with readmission in several of the articles[5,14,16,17,19,23,26]; one study also found a relationship between being single/unmarried and the risk of readmission.[14]

According to results presented by different authors, a patient's socioeconomic situation was also associated with the probability of readmission (estimated as discharge to a care facility,[7,23,27] place of residence,[15,16,23,25] or even insurance[24,25]).

The hospital of the initial admission,[21] hospital volume,[23] and non-teaching hospitals[25] were also associated with readmission in certain studies.

As for the clinical characteristics of the patients, the presence of comorbidities was associated with readmission (in a broad sense for some authors,[14,17,20,23–26] and more specifically for others – diabetes mellitus,[7] congestive heart failure,[16] chronic obstructive pulmonary disease [COPD],[16,20] more than two comorbidities[15,21]). The ASA classification was associated with the risk of readmission in two studies,[7,22] tobacco habit only in one,[19] and two of the studies found a correlation with respiratory function tests (forced expiratory volume in one second [FEV1])[27]; and a parameter described by the authors themselves, the "lung age", based on the results of said respiratory tests[19]). Radiotherapy[17] and neoadjuvant chemoradiotherapy[16] were found to be risk factors in isolated studies.

Regarding the surgical variables, pneumonectomy was identified as a determining factor for readmission in several of the studies,[12–14,17,22] while another found differences between the different types of resection.[16] As for the approach, several

Table 1 – Reasons for exclusion of eligible articles after evaluation of the complete text.

Articles excluded after complete evaluation (n = 18):
No results from thoracic surgery (*n* = 6)
Readmission as a quality indicator:
Evaluation of clinical practice guidelines (*n* = 7)
Evaluation of hospital volume (*n* = 1)
Effect of the place of readmission on the results (*n* = 1)
Letter to the Editor (*n* = 1)
Editorial (*n* = 1)
Communication at a medical conference with data included in a later article (*n* = 1)

Table 2 – Main Characteristics Regarding the Design of the Studies.

1st Author/year/country	Study type	Database	Period of readmission	Lung resection type	Indication	Other characteristics	Patients lost	Readmission hospital
[12] Handy (2001) USA	COHr	Hospital	90 d	All	All		Not specified	Any
[13] Varela (2004) Spain	COHr	Hospital	30 d	Major (N-L)	All		Not specified	Any
[14] Farjah (2009) USA	COHr	SEER-Mc	30 d	All	NSCLC	Age $\geq$ 66 yrs	Specified	Any
[5] Freeman (2013) USA	COHr	PIDb	90 d	L	NSCLC		Specified	Any
[7] Lucas (2013) USA	COHr	ACS-NSQIP	30 d (post-op)	Pulmonary and non-pulmonary	All	GDS, VS, TS Excl. Hospital stay $>$ 10 d	Specified	Any
[15] McDevitt (2013) Ireland	COHr	NCR, HIPE	28 d	All	NSCLC		Not specified	Any
[16] Hu (2014) USA	COHr	SEER-Mc	30 d	All	NSCLC	Age $\geq$ 66 yrs	Not specified	Any
[6] Gonzalez (2015) USA	COHr	MedPAR	30 d	All	All	GDS, CS, TS Age $\geq$ 66 yrs	Not specified	Any
[17] Puri (2015) USA	COHr	NCDB-ACS	30 d	All	NSCLC	Stage I-III	Not specified	Hospital II
[18] Rajaram (2015) USA	COHr	ACS-NSQIP	30 d (post-op)	Major (Pn-L)	All		Specified	Any
[19] Ogawa (2015) Japan	CC	Hospital	90 d	Major (Pn-L)	NSCLC		Not specified	Any
[20] Assi (2015) USA	COHr	Hospital	30 d	L	All		Not specified	Any
[21] Langan (2015) USA	COHr	Multicentric	30 and 90 d	Major (?)	NSCLC	GDS, TS Age $\geq$ 65 yrs	Not specified	Hospital II
[22] Ward (2015) USA	COHr	ACS-NSQIP	30 d (post-op)	All	All	Communication at national congress (ACS 2015)	Not specified	Not specified
[23] Stitzenberg (2015) USA	COHr	SEER-Mc	30 and 90 d	All	NSCLC	GDS, TS Age $\geq$ 66 yrs	Not specified	Any
[24] Stiles (2016) USA	COHr	SIDB-HCUP	30 and 90 d	L	All		Not specified	Any
[25] Medbery (2016) USA	COHr	NCDB-ACS	30 d	L	NSCLC	Stage $\leq$ T2N0M0	Not specified	Not specified
[26] Rosen (2016) USA	COHr	NCDB-ACS	30 d	L	NSCLC	Excl. Hospital stay $>$ 36 d	Specified	Hospital II
[27] Dickinson (2017) USA	COHp	Hospital	30 d	All	All		Specified	Any

The corresponding bibliographic reference appears with each author.
yrs: years; ACS-NSQIP: American College of Surgeons-National Surgical Quality Improvement Program; NSCLC: non-small cell lung cancer; CC: case–control; GDS: general and digestive surgery; COHp: cohort, prospective; COHr: cohort, retrospective; TS: thoracic surgery; VS: vascular surgery; CS: cardiac surgery; d: days; Excl.: excluded; HIPE: Hospital In-Patient Enquiry; L: lobectomy; MedPAR: Medicare Provider Analysis and Review; Pn: pneumonectomy; NCDB-ACS: National Cancer Data Base- American College of Surgeons and American Cancer Society; NCR: National Cancer Registry; PIDb: Premier Inpatient Database; SEER-Mc: Surveillance, Epidemiology and End Results-Medicare; SIDB-HCUP: State Inpatient Database-Healthcare Cost and Utilization Project; ?: not defined; II: admission rate

Table 3 – Studies about readmission after lung resection surgery, with a synopsis of the main results presented.

1st author/year/country	*n*	Readmission	Exitus readmission	Risk factors	Main causes of readmission	Survival	Observations
[12] Handy (2001) USA	374	18.9% (90 d)	11.6%	Pneumonectomy	Respiratory complications, infections	Exitus 5 a.: -Readmission: 11.6% -No readmission 4%	
[13] Varela (2004) Spain	727	6.9%	6%	Postoperative complications, Pneumonectomy	Respiratory complications	N/A	
[14] Farjah (2009) USA	21 067	15%	N/A	Age > 80 yrs, unmarried, male, Pneumonectomy, Comorbidities, Advanced stage	N/A	Exitus 2.5 a.: -Readmission: 33% -No Readmission: 19%	
[5] Freeman (2013) USA	4296	7% (90 d)	N/A	Hospital stay < 5 d or >16 d Age >78 a.	Respiratory, atrial fibrillation	N/A	
[7] Lucas (2013) USA	TS: 3375 (GDS, VS, TS: 230 864)	TS: 11.1% (global: 7.8%)	N/A	ASA, alb. <3.5 mg/dL, DM, complications, urgent, discharged to rehab, prolonged hospital stay	N/A	N/A	Predictive model: St/2 + ASA TS: ROC = 0.507
[15] McDevitt (2013) Ireland	1284	10% (28 d)	3.36%	Residence, Comorbidities > 2, Tumor stage III-IV	Respiratory complications, cardio/ cerebrovascular, infections	N/A	
[16] Hu (2014) USA	11 432	12.8%	N/A	Patient comorbidity (CHF and COPD), resection type, neoadjuvant chemoradiotherapy, socioeconomic factors (age; residence in place with moderate population)	Respiratory (respiratory failure, pneumonia, pneumothorax), cardiac complications	Exitus 90 d: -Readmission: 14.4% -No Readmission: 2.5%	28.3% readmissions at other hospitals
[6] Gonzalez (2015) USA	TS: 90 188 (TS, CAB, colectomy: 1 033 255)	TS:10.8%	2.66%	Complications: influence time until readmission. Other factors not analyzed	Postoperative complications, cardiac complications	Exitus 90 d: -Readmission: 10.8% -No Readmission: 3.7%	Mortality declines as time until readmission increases
[17] Puri (2015) USA	129 893	4.3%	3.9%	Age, Male, pre-op radiotherapy, Comorbidity (Charlson-Deyo), Pneumonectomy	N/A	Exitus 30 d: -Readmission: 3.9% -No Readmission: 2.8% Exitus 90 d: -Readmission: 7% -No Readmission: 3.3%	

Table 3 (*Continued*)

1st author/year/country	*n*	Readmission	Exitus readmission	Risk factors	Main causes of readmission	Survival	Observations
[18] Rajaram (2015) USA	1847	9.3%	N/A	Complications	Respiratory complications	N/A	No differences VATS-TT
[19] Ogawa (2015) Japan	979	22.1% (90 d)	3.2%	Male, ''lung age'' and ''age difference'', tobacco habit rate, intraoperative bleeding, complications, histologic type, prolonged hospitalization (total and postoperative)	Respiratory complications	5-yr survival: - No Readmission: 78% -Readmission: 44%	Proposed predictive model (complications and Readmission 90 d): Age difference = Biological ''lung age''
[20] Assi (2015) USA	213	13%	N/A	Readmission in ICU, Charlson-Deyo > 0, COPD	N/A	N/A	Approach (TT-VATS) and complications: No risk factor
[21] Langan (2015) USA	TS: 1032 (GDS, TS: 2797)	TS: 10.5% (30 d) 18% (90 d)	N/A	Comorbidities > 2, complications > 2, hospital of initial admission	Infections, gastrointestinal and pulmonary complications	N/A	Risk factors, similar at 30 and 90 d
[22] Ward (2015) USA	8930	7.4%	N/A	ASA: 3, Pneumonectomy, complications	Air leak (VATS), infections (TT)	N/A	Approach (TT-VATS): No risk factor
[23] Stitzenberg (2015) USA	TS: 20 362 (GDS, TS: 29,719)	13% (30 d) 23% (90 d)	N/A	Age, male, stage, comorbidity, no home discharge, hospital stay, complications (90 d, not 30 d), hospital volume and residence-hospital distance (30 d, not 90 d)	Respiratory complications (dyspnea, pneumonia, thoracic pain) Cardiac (arrhythmia, CHF)	Exitus 90 d: -Readmission: 14.6% -No Readmission: 9% Exitus 1 yr: -Readmission: 30% -No Readmission: 15%	Risk factors and causes for readmission similar for 30 and 90 d
[24] Stiles (2016) USA	22 647	11.5% (30 d) 19.8% (90 d)	4.7%	Male, insurance, comorbidities, hospital stay	Respiratory, cardiovascular, postoperative complications	N/A	Approach (TT-VATS) Charlson-Deyo and complications: No risk factor
[25] Medbery (2016) USA	19 711	4.3%	N/A	Male, Comorbidities, socioeconomic level, insurance, residence, VATS (univariate: non-teaching hospital, hospital stay)	N/A	N/A	Special attention to influence of socioeconomic factors on readmission

Table 3 (*Continued*)

1st author/year/country	*n*	Readmission	Exitus readmission	Risk factors	Main causes of readmission	Survival	Observations
[26] Rosen (2016) USA	59 734	4.5%	N/A	Male, age (bivariate), Charlson-Deyo, Comorbidities, grade, advanced stage	N/A	N/A	Special attention to influence of hospital stay reduction program: No more readmissions (VATS nor TT)
[27] Dickinson (2017) USA	505	8.3%	0%	FEV1, operative time, postoperative pain scale 12–24 h $\geq$ 6, perioperative furosemide, transfusion, air leak $>$ 5 d, discharge to rehab	Respiratory complications	N/A	Prospective study with 1 yr of follow-up

The corresponding bibliographic reference appears together with the author.

yrs: years; alb. albumin; ASA: American Society of Anesthesiologists; CAB: coronary artery bypass; c: C-statistic; GDS: general and digestive surgery; TS: thoracic surgery; VS: vascular surgery; d: days; DM: diabetes mellitus; Ex.Readmission: Exitus during readmission; n: sample size; FEV1: forced expiratory volume in one second; CHF: congestive heart failure; N/A: not analyzed; preop.: preoperative; ROC: Receiver Operating Characteristic curve; TT: thoracotomy; ICU: intensive care unit; VATS: video-assisted thoracoscopic surgery; vol.: volume.

Table 4 – Variables analyzed in the different studies analyzed, showing those that were significant for the different authors in the multivariate analysis (or univariate if that was the resulted given) with OR values and corresponding *p* value for each significant variable.

1st author/yr/country	Variables analyzed	Risk factors	OR (range) – 95% CI – *Univariate results*	P value	Observations
[12] Handy (2001) USA	Demographics Comorbidity Type of surgery Associated procedures Histopathology Tumor stage (if cancer) Postoperative complications Operative mortality Hospital stay	Pneumonectomy	*36% vs 17%*	P = .005	Univariate analysis: Pneumonectomy: 36% readmission *vs* Other resections: 17% readmission
[13] Varela (2004) Spain	Age	Postoperative complications		P < .001	Multivariate
	Body mass index	Pneumonectomy	2.42 (1.36–4.66)	P = .008	
	Type of surgery				
	ppoFEV1%		3.83 (1.98–7.45)		
	Postoperative complications				
	Hospital stay				
[14] Farjah (2009) USA	Age	Age > 80 yrs	1.29 (1.11–1.51)	P = .001	Multivariate
	Sex	Not married	1.19 (1.08–1.32)	P = .001	
	Race	Male	1.30 (1.18–1.43)	P < .001	
	Low income	Residence: Midwest	1.19 (1.04–1.36)	P = .001	
	Low level of education	Residence: South	1.51 (1.29–1.78)	P < .001	
	Not married	Pneumonectomy	1.42 (1.17–1.74)	P = .001	
	Residence	Comorbidity (Charlson-Klabunde): 1	1.31 (1.17–1.46)	P < .001	
	Previous cancer	Comorbidity (Charlson-Klabunde): 2	1.80 (1.56–2.07)	P < .001	
	Comorbidity (Charlson-Klabunde)	Comorbidity (Charlson-Klabunde): 3			
	Histopathology	Advanced stage: IIIB	2.10 (1.76–2.150)	P < .001	
	Stage	Advanced stage: IV	1.43 (1.20–1.70)	P < .001	
	Neoadjuvant		2.01(1.70–2.37)	P < .001	
	Type of resection				
[5] Freeman (2013) USA	Demographic	Hospital stay < 5 days	1.61 (N/A)	P = .001	Multivariate
	Comorbidity (Charlson)	Hospital stay > 16 day	1.37 (N/A)	P = .001	
	ECOG scale	Age > 78 yrs	1.49 (N/A)	P < .001	
	Postoperative complications				
	Operative mortality				
	Hospital stay				
[7] Lucas (2013) USA	Demographic	ASA 2	2.02 (1.82–2.24)	N/A	Attributable population risk: ASA: 66.1%
	Indications	ASA 3	3.92 (3.55–4.33)		
	Preoperative risk factors	ASA 4	6.66 (5.99–7.42)		
	Details of surgery	Albumin < 3.5 mg/dL	2.07 (1.99–2.16)		12.6%
	30-day results	Diabetes mellitus	1.61 (1.55–1.68)		8.8%
		Complications	2.67 (2.55–2.79)		9.7%
		Urgent surgery	1.47 (1.42–1.53)		10.3%
		Prolonged hospital stay	3.50 (3.38–3.62)		47.9%
		Discharge to rehab	2.82 (2.68–2.96)		7.8%

Table 4 (*Continued*)

1st author/yr/country	Variables analyzed	Risk factors	OR (range) – 95% CI – *Univariate results*	*P* value	Observations
[15] McDevitt (2013) Ireland	Demographic	Residence in poor area	1.56 (1.11–2.20)	P = .0095	Multivariate
	Married/single	Comorbidities > 2	2.38 (1.43–3.96)	P = .011	
	Socioeconomic situation	Tumor stage III-IV	1.62 (1.13–2.34)	P = .039	
	Comorbidities				
	Tobacco habit				
	Stage				
	Resection type				
	Hospital characteristics				
	Destination at discharge				
[16] Hu (2014)	Demographic	Cardiac insufficiency	1.56 (1.32–1.83)	P < .001	Multivariate
USA	Socioeconomic factors	COPD	1.47 (1.29–1.67)	P < .001	
	Comorbidities	VATS lobectomy	0.74 (0.58–0.95)	P = .018	
	Stage	Neoadjuvant chemoradiotherapy	1.52 (1.19–1.93)	P < .001	
	Type of resection	Age > 85 yrs	1.47 (1.11–1.94)	P = .025	
	Mortality	Residence in area with moderate population density	1.24 (1.03–1.50)	P = .032	
[6] Gonzalez (2015)	Demographics	Impact on time until readmission:	*13% vs 17%/16%*		Univariate:
USA	Dates of admission, discharge and death	Age > 80 yrs	*50% vs 41%/46%*		No readmission group *vs*
	Diagnosis	Female sex	*35% vs 39%/42%*	P = .526	Readmission group:
	Procedure	Comorbidities > 3	*15% vs 21%/22%*	P = .002	<5 d/21–30 d after
	Complications	Major complications		P = .084	discharge (*p* value
	Time until readmission			P = .449	referred to the
	Mortality				difference between
					intervals of the
					readmission group)
[17] Puri (2015) USA	Demographics	Age: 70–74 yrs	1.168 (1.066–1.280)	P = .001	Multivariate
	Socioeconomic factors	Age: 75–79 yrs	1.256 (1.142–1.381)	P < .001	
	Comorbidities (Charlson-Deyo)	Age ≥ 80 yrs	1.205 (1.080–1.345)	P = .001	
	Tumor variables	Male	1.159 (1.094–1.228)	P < .001	
	Type of resection	Preoperative radiotherapy	1.213 (1.064–1.383)	P = .004	
	Mortality	Charlson-Deyo Index: 1	1.354 (1.272–1.441)	P < .001	
	Survival	Charlson-Deyo Index: ≥2	1.592 (1.466–1.728)	P < .001	
	Teaching/non-teaching hospital	Pneumonectomy	1.685 (1.476–1.923)	P < .001	
[18] Rajaram (2015) USA	Demographics	Complications	4.89 (3.05–6.04)	P < .001	Multivariate
	ASA				
	Body mass index				
	Comorbidities				
	Tobacco habit				
	Type of surgery				
	Recent chemoradiotherapy				
	Disseminated tumor				
	Postoperative complications				

Table 4 (*Continued*)

1st author/yr/country	Variables analyzed	Risk factors	OR (range) – 95% CI – *Univariate results*	P value	Observations
[19] Ogawa (2015) Japan	Demographics "Lung age" "Age difference" Comorbidities Tobacco habit Surgery type Tumor variables Stage Complications Hospital stay Mortality Survival	Male "Lung age" "Age difference" Tobacco habit Bleeding Complications Squamous histology type Total hospitalization Postoperative hospitalization	*63% vs 85%* *73.3 yrs vs 87 yrs* *7.0 yrs vs 12.3 yrs* *32 yrs vs 47 yrs* *130 mL vs 240 mL* *36% vs 82%* *18% vs 33%* *18 d vs 21 d* *14 d vs 17 d*	*P* = .018 *P* = .009 *P* = .012 *P* = .002 *P* < .001 *P* < .001 *P* < .013 *P* = .003 *P* = .001	Univariate: No readmission group *vs* Readmission group _____ Multiple logistic regression: "Lung age" *P* = .040 "Age difference" *P* = .040 Bleeding *P* = .030 Complications *P* < .001
[20] Assi (2015) USA	Demographics Body mass index Comorbidities (Charlson) Chronic lung disease Respiratory function tests Tumor type Stage Neoadjuvant Epidural, paravertebral catheter Approach Type of resection Complications Hospital stay in ICU Admission in ICU Total hospital stay Destination at discharge Mortality Time until readmission Mortality readmission	ICU readmission Charlson-Deyo > 0 COPD	10.4 (1.1–103.5) 1.5 (1.04–2.03) 4.91 (1.96–13.46)	*P* = .04 *P* = .03 *P* = .0006	Multivariate
[21] Langan (2015) USA	Demographic Insurance type Comorbidities Type of surgery Complications Admitting hospital	Comorbidities > 2 Complications > 2 Hospital "E"	 30 d: 1.7 (1.19–2.49) 90 d: 1.8 (1.34–2.54) 30 d: 1. 6 (1.16–2.29) 90 d: 1.6 (1.19–2.15) 30 d: 0.6 (0.43–0.88) 90 d: 0.6 (0.41–0.76)	N/A	Multivariate Hospital "E", a participating hospital

Table 4 (*Continued*)

1st author/yr/country	Variables analyzed	Risk factors	OR (range) – 95% CI – *Univariate results*	*P* value	Observations
[22] Ward (2015) USA	Demographic	ASA: 3	1.75 (1.383–2.227)	P < .0001	Multivariate
	ASA	Pneumonectomy	1.52 (1.004–2.308)	P = .048	
	Type of surgery	Superficial wound infection	3.59 (2.083–6.217)	P < .0001	
	Cancer *vs* no cancer	Deep wound infection	14.9 (2.854–77.874)	P = .0014	
	Complications	Infection of organ/cavity	11.11 (5.44–22.72)	P < .0001	
	Mortality	Pneumonia	3.1 (2.337–4.114)	P < .0001	
		Thromboembolism	4.59 (2.941–7.176)	P < .0001	
		Sepsis	3.62 (2.256–5.812)	P < .0001	
		Reoperation	4.25 (3.161–5.736)	P < .0001	
[23] Stitzenberg (2015) USA	Demographics	Age	75–79 yrs: 1.23 (1.09–1.38)	P < .001	Multivariate
	Married/single		≥ 80 yrs: 1.24 (1.08–1.41)	P < .01	
	Residence	Sex	Fem.: 0.64 (0.59–0.70)	P < .001	
	Distance to hospital	Stage	N + : 1.12 (1.02–1.23)	P < .05	
	Hospital volume		M + : 1.44 (1.20–1.74)	P < .001	
	Type of insurance	Comorbidity	CH.I.1: 1.13 (1.03–1.25)	P < .05	
	Stage		CH.I. ≥ 2: 1.46 (1.32–1.63)	P < .001	
	Comorbidities (Charlson)	Discharge not to home	Hosp: 1.61 (1.42–1.81)	P < .001	
	Complications		Resid: 3.25 (2.54–4.16)	P < .001	
	Hospital stay	Hospital stay	1.03 (1.03–1.04)	P < .001	
	Mortality	Complications (90 d, not 30 d)	90 d: 1.08 (1.03–1.12)	P < .001	
	Destination at discharge	Hospital volume			
	Readmission, 30 and 90 d		Q2: 1.25 (1.11–1.41)	P < .001	
		Distance home to hospital (30 d, not 90 d)	Q3: 1.15 (1.02–1.29)	P < .05	
			Q4: 1.26 (1.12–1.43)	P < .001	
			Q2: 1.14 (1.01–1.28)	P < .05	
			Q4: 1.27 (1.12–1.45)	P < .001	
[24] Stiles (2016) USA	Demographic	Male	1.19 (1.11–1.28)	P < .0001	Multivariate
	Hospital stay	Medicaid			
	Comorbidities (Charlson-Deyo)	Comorbidities:	1.29 (1.09–1.52)	P < .004	
	Type of surgery	Weight loss			
	Complications	Electrolyte disorder	1.34 (1.05–1.69)	P = .02	
	Type of insurance	Iron-deficiency anemia	1.22 (1.01–1.46)	P = .04	
		Blood-loss anemia	1.32 (1.16–1.49)	P < .01	
		Peripheral vasculopathy	1.89 (1.16–3.09)	P = .01	
		Complicated diabetes	1.21 (1.06–1.38)	P < .01	
		Complicated HTN	1.14 (1.03–1.25)	P = .01	
		Non-complicated HTN	1.47 (1.09–1.99)	P < .01	
		Hospital stay:	1.12 (1.03–1.22)	P < .01	
		6–8 d			
		≥9 d	1.42 (1.25–1.61)	P < .01	
			1.88 (1.62–1.27)	P < .01	

Table 4 (*Continued*)

1st author/yr/country	Variables analyzed	Risk factors	OR (range) – 95% CI – *Univariate results*	*P* value	Observations
[25] Medbery (2016) USA	Demographics	Male	1.23 (1.07–1.43)	$P = .004$	Multivariate
	Socioeconomic (income, education, place of residence)	Charlson-Deyo ≥ 1	1.23 (1.06–1.42)	$P = .006$	
	Comorbidities (Charlson-Deyo)	Socioeconomic level			
	Type of surgery	$< $30 000	1.51 (1.18–19.92)	$P < .001$	
	Hospital stay	$30 000–34 999	1.38 (1.12–1.71)	$P = .003$	
	Type of hospital	$35 000–45 999	1.23 (1.03–1.48)	$P = .025$	
	Type of insurance	Private insurance	0.79 (0.67–0.93)	$P = .004$	
		Residence:			
		Urban (*vs* metropolitan)	0.71 (0.57–0.88)	$P = .002$	
		Rural (*vs* metropolitan)	0.47 (0.26–0.84)	$P = .011$	
		VATS	1.42 (1.20–1.65)	$P < .001$	
[26] Rosen (2016) USA	Demographic	Male			Multivariate
	Comorbidities (Charlson-Deyo)	Charlson-Deyo:		$P < .001$	
	Type of insurance	1	1.16 (1.07–1.26)		
	Socioeconomic (income, education)	≥2		$P < .001$	
	Hospital stay (discharge practices)		1.19 (1.09–1.30)	$P < .001$	
	Type of surgery	Grade 4 malignancy	1.38 (1.23–1.55)		
	Tumor variables (histology, grade, stage)	Advanced stage		$P = .041$	
		III	1.4 (1.01–1.92)		
	Hospital variables (type, volume, location)	IV		$P = .0027$	
			1.21 (1.07–1.37)	$P = .016$	
			1.38 (1.06–1.79)		
[27] Dickinson (2017) USA	Demographics	ppoFEV1% (median)	*82(33–147) vs 75(39–107)*	$P = .042$	Intermixed univariate with multivariate results
	Place of residence	Operative time (minutes, median)	*130.8(84.2) vs 161.3(84.3)*	$P = .031$	
	Comorbidities	Post-op pain scale 12–24 h ≥ 6			
	Type of surgery	Perioperative furosemide	OR: 2.696 (1.372.5.299)	$P = .004$	
	Operative time	Transfusion			Univariate:
	Readmission ICU	Air leak > 5 d	*23% vs 48%*	$P = .0008$	No readmission group
	Post-op pain scale	Discharge to home	*4% vs 16.7%*	$P = .003$	*vs*
	Perfusion:		*5.8% vs 14.3%*	$P = .027$	Readmission group
	Furosemide post-op		OR: 0.323 (0.113–0.937)	$P = .0375$	
	Transfusion				Multivariate: OR
	Mortality				
	Complications				
	Destination at discharge				
	Day of week of discharge				
	Hospital stay				
	Discharge with pleural drain or urinary cath.				

The corresponding bibliographic reference appears together with the author.

yrs: years; ASA: American Society of Anesthesiologists; d: days; COPD: chronic obstructive pulmonary disease; Fem.: female; HTN: hypertension; CI: confidence interval; CH.I.: Charlson index; M + : distant metastasis; N/A: not analyzed, not available; N+: node involvement; OR: odds ratio; post-op: postoperative; ppoFEV1%: predicted post-op forced expiratory volume in one second %; Q: quartile; Hosp.: hospital; V.: variables; VATS: video-assisted thoracic surgery; *vs*: *versus*; ICU: intensive care unit; $: US dollars.

Table 5 – Risk factors for readmission.

Sociodemographic factors	Socioeconomic variables	Hospital characteristics	Comorbidities	Preoperative variables	Perioperative surgery	Tumor variables	Postoperative complications	Hospital stay
Age[5,14,16,17,19,23,26]	Discharge to rehab[7,23,27]	Admitting hospital[21]	Comorbidities in general[14,17,20,23–26]	FEV1[27]	Pneumonectomy[12–14,17,22]	Advanced stage[14,15,23,26]	Complications in general[7,13,18,19,21–23] ([a 23]: A 90 d, NO a 30 d)	Prolonged[7,17,19,23,25]
Male sex[14,17,19,23–26]	Place of residence[15,16,23,25]	Hospital volume[23]	Diabetes mellitus[7]	*Lung age*[19]	Type of resection[16]	Histologic type[19]	Complications > 2[21]	<5 d, >16 d[5]
Unmarried[14]	Insurance[24,25]	Non-teaching hospital[25]	Congestive heart failure[16]	RxT neoadj[17]	TT = VATS[18,0,20,22,24,26]	Grade[26]	Readmission in ICU[20]	
			COPD[16,20]	CTX-RxT neoadj[16]	VATS[25]		Blood transfusion[27]	
			Comorbidities > 2[15,21]	Albumin < 3.5 mg/dL[7]	Operative bleeding[19]		Air leak > 5 d[27]	
			ASA[7]; ASA = 3[22]		Operative time[27]		Pain ≥ 6 (VAS) 12–24 h after surgery[27]	
			Tobacco habit[19]		Perioperative furosemide[27]		No correlation with readmission[20,24]	
					Urgent[7]		Impact on readmission, not on time until readmission[6]	

The corresponding bibliographic reference appears in superscript.

ASA: *American Society of Anesthesiologists*; VATS: video-assisted thoracoscopic surgery; d: days; VAS: visual-analog scale; COPD: chronic obstructive pulmonary disease; CTx: chemotherapy; RxT: radiotherapy; TT: thoracotomy; ICU: Intensive Care Unit; FEV1: forced expiratory volume in one second.

[a] In this article, the complications are found to be risk factors for readmission in the 90-day post-op period but a 30-day period was not considered.

studies did not find differences in risk of readmission between thoracotomy and video-assisted thoracoscopic surgery (VATS)[18,20,22,24,26]; however, one study suggested that VATS was a risk factor for readmission,[25] while another found a protective effect.[16] The study by Lucas et al.[7] was the only paper that identified the urgent nature of the surgery as a risk factor for readmission.

Perioperative events were considered significant risk factors by two authors: Ogawa et al. (intraoperative bleeding)[19] and Dickinson et al. (operative time, perioperative use of furosemide and transfusion).[27]

Several authors described postoperative complications as being very significant determinants for readmission,[7,13,18,19,21–23] although with a few clarifications in certain cases: Langan et al. found them to be a risk factor when there were more than two complications,[21] and Stitzenberg et al. found them to be a significant factor for readmission within 90 days, but not within 30 days.[23] Furthermore, Assi et al. only found readmission in the ICU to be a determining factor,[20] and Dickinson et al. associated readmission particularly with blood transfusion, air leak longer than 5 days, and pain intensity in the 12–24 h postoperative period that was 6 or greater on the visual–analog scale.[27] However, Gonzalez et al. only analyzed the possible correlation of complications over the time to readmission, with no observed relationship between the two events[6]; likewise, Assi et al.[20] and Stiles et al.[24] also found no correlation between complications and readmission after a specific evaluation.

Pathological characteristics and tumor stage have also been associated with the risk of readmission by some authors, including both the histological type[19] or the degree of malignancy,[26] as well as advanced tumor stage.[14,15,23,26]

A prolonged postoperative hospital stay was identified as a risk factor by several authors[7,17,19,23,25] and differentially (when it was less than 5 days or greater than 16 days) by Freeman et al.[5]

In the studies evaluating readmission within 30 and 90 days, two determined that the risk factors were similar for readmission in both time periods,[21,23] and the article by Stitzenberg et al.[23] also found similar causes for readmission in both periods.

Main Causes of Readmission

The most frequent causes of readmission were respiratory in origin (respiratory failure, dyspnea, pneumonia, pneumothorax, chest pain)[5,12,13,15,16,18,19,21,23,24,27] followed by cardiovascular complications (arrhythmias, heart failure).[5,6,15,16,23,24] Only a few studies identified infectious causes as significant.[12,15,21,22] Postoperative complications were a cause of readmission in two studies,[6,24] and one study identified gastrointestinal causes.[21]

Impact on Survival

The impact of readmission on survival was analyzed by several authors, determining 5-year survival rates (78% in the non-readmission group [NRG] *vs* 44% in the readmission group [RG])[19] or the mortality rate at different time periods, as shown in Table 6.

In addition to the impact of readmission, the study by Farjah et al.[14] found that prolonged hospital stay and hospitalization in care centers also have a significant effect on mortality.

Table 6 – Mortality rate for different time periods.

Period	% Exitus GR	% Exitus NRG
30 days[17]	3.9	2.8
90 days[6,16,17,23]	7–14.6	2.5–9
1 year[23]	30	15
2.5 yrs[14]	33	19
5 yrs[12]	11.6	4

Next to the time period, the corresponding bibliographic reference appears in superscript.
NRG: no readmission group; GR: readmission group.

Hu et al.[16] did not find higher 90-day mortality among patients who were readmitted two or more times during the first 60 days (16.2%) than those who were only readmitted once (13.8%, $P = .295$); also. the greater risk is determined by readmission during the first 30 days (OR: 5.79, $P < .001$). Similarly, the mortality rate showed no differences between patients who were readmitted at the hospital where they were operated on (13.6%) *versus* those who were readmitted at other medical centers (16.4%, $P = .16$). According to the results of this study, readmission for postoperative problems did not lead to higher mortality when these were due to other unrelated diagnoses (OR: 1.22, $P = .21$).

In a study focusing on the impact of the time elapsed until readmission, Gonzalez et al. found that the risk of mortality within 90 days increased if the readmission occurred during the first 5 days after discharge (OR: 8.12; 95% CI: 7.26–9.09), compared to when the readmission occurred after 21 days (OR: 5.97, 95% CI: 5.16–6.90). This effect was also detected on 30- and 60-day mortality rates.

The study by Puri et al.[17] also showed that readmission was an independent risk factor for both 30-day mortality (OR: 1.20; 95% CI: 1.01–1.42) as well as 90-day mortality (HR: 1.37, 95% CI: 1.28–1.47).

However, the retrospective study by Dickinson et al.[27] including patients who had undergone surgery over the course of a year did not find a significant difference in mortality between the readmission group and the group that did not present readmission during the 30 days after discharge (HR: 1.13; 95% CI: 0.43–2.93; $P = .8$).

Discussion

To give an idea of the specific impact of readmissions on the national healthcare system, in addition to their impact on patients themselves, it is estimated that 19% of all patients are readmitted in the first 30 days after discharge, with an annual economic impact for the US Medicare system of 17 billion dollars.[28]

In Spain, according to data from the Ministry of Health, Social Services and Equality, based on data from the Minimum Basic Data Set, in the last year analyzed (2013) the hospital readmission rate was 7.48% for all Major Diagnostic Categories, a figure that has been gradually increasing in successive years.[29]

Readmissions are more frequent in medical care processes (often related with emergency admissions) than in surgical treatment (usually scheduled and with previously prepared patients). As a result, approximately 75% of all readmissions are due to medical processes.[28,30,31] However, the factors associated with readmissions and the diagnoses leading to readmission after lung surgery have not been extensively studied.

In the literature, most of the studies published on postoperative readmission focus on the readmission rates of specific processes and in specific populations, with widely varying methodologies and study population characteristics.[32] Almost all of the studies evaluated in this review have been population-based retrospective cohort studies, based on large national databases in many cases. This type of studies presents an important risk of selection bias: for instance, population studies based on the Medicare database, which registers patients over 65, can only have data from older patients[6,14,16,23]; studies that use the National Surgical Quality Improvement Program (NSQIP) database analyze readmission after the surgical intervention,[33] not only after hospital discharge[7,18,22] (possible attrition bias); studies based on the National Cancer Data Base (NCDB) have a good probability of detection bias by collecting only the readmissions occurring at the hospital where the initial admission took place.[17,25,26] This limitation was also presented by the multicenter study published by Langan et al.[21] (in general, it is estimated that approximately one-third of readmissions occur at a different hospital than where the initial admission took place, as observed in several of the studies analyzed,[5,12,13,16,27] mainly due to geographical reasons or insurance, depending on the healthcare system). Other inclusion criteria in the different studies that were presented heterogeneously were the type of surgery that the patients underwent and the indication for surgery (bronchogenic carcinoma, or other pathologies).

The readmission rates found by the different studies analyzed showed a variability that is probably explained by the disparate methodological aspects that we have just discussed, ranging from the characteristics of the population studied, databases used or participating hospitals, to the type of surgery conducted and its indications.[32]

Regarding the risk factors for readmission (Tables 4 and 5), the different studies on readmission after lung resection confirmed the following main factors: patient sociodemographic and socioeconomic variables; comorbidities; resection type, especially pneumonectomy, with no differences found in terms of the approach (thoracotomy *vs* video-assisted thoracoscopic surgery); postoperative complications; and prolonged hospital stay. In general terms, these findings correlate with published studies about readmission after different surgical procedures in different specialties.[34,30]

The main causes of readmission found were medical complications, especially respiratory, followed by cardiac complications. This aspect also agrees with articles published about readmissions in different types of surgical procedures, which usually conclude that the majority of postoperative admissions are due to medical complications in up to 70% of cases.[35]

The impact on survival is another significant dimension of postoperative readmission, as confirmed by all the studies in the series that analyzed this variable, which concurs with published data for both medical and surgical procedures in general.[30]

In short, the majority of studies published on readmission after lung resection surgery are widely heterogeneous in the methodology used and in the characteristics of the population studied. Nevertheless, all of them emphasize the importance of reducing postoperative readmission rates due to their impact on the healthcare system, patient survival and quality of life.

Authors' Contributions

Study design: García-Tirado, Júdez-Legaristi, Landa-Oviedo, Miguelena-Bobadilla.

Data collection: García-Tirado, Júdez-Legaristi, Landa-Oviedo.

Analysis and interpretation of the results: García-Tirado, Júdez-Legaristi.

Article composition: García-Tirado, Miguelena-Bobadilla.

Critical review and approval of the final version: García-Tirado, Júdez-Legaristi, Landa-Oviedo, Miguelena-Bobadilla.

Conflict of Interests

The authors have no conflicts of interests to declare.

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