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Risk Factors For Mortality In Patients Undergoing Thoracic Surgery: A Systematic Review

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Abstract

Despite advances in surgical techniques, anesthesia, and perioperative care, complications and mortality in thoracic surgery patients still occur. This study aims to identify risk factors for mortality in patients undergoing thoracic surgery. The database was searched for articles published in 2019–2024 using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Protocols method, and 12 articles met the inclusion criteria. Quality assessment was performed using the Newcastle-Ottawa Scale. A total of 25 mortality risk factors were identified and grouped into three categories, namely preoperative (n = 17), intraoperative (n = 3), and postoperative (n = 5), with preoperative factors as the most dominant category. These results indicate that a thorough evaluation of the patient's condition before surgery, as well as risk mitigation during and after surgical intervention are very important in reducing mortality rates. These findings can be used as a basis for the development of risk stratification and clinical decision making in thoracic surgery patients.

Keywords: Thoracic Surgery, Mortality, Risk Factors

1. Introduction

Thoracic surgery is an operative procedure aimed at diagnosing and managing conditions affecting the thoracic organs, including the esophagus, trachea, diaphragm, thoracic wall (including the ribs and surrounding muscles), mediastinum, heart, and lungs. Over the past few years, thoracic surgery has undergone significant development.[1] In the past three decades, thoracic surgeons have adopted the concept of minimally invasive surgery. Several minimally invasive procedures include robot-assisted thoracic surgery, video-assisted thoracic surgery (VATS), virtual-assisted lung mapping, and other techniques. Despite advances in surgical techniques, anesthesia, and perioperative care, complications in thoracic surgery continue to occur.[2]

One of the most frequently performed types of thoracic surgery is lung cancer surgery. The 30-day mortality rate in this population ranges from less than 1% for sublobar resection, nearly 4% for pneumonectomy, and 6% for lung transplantation.[3] A study by Chan *et al*. on patients undergoing cardiac surgery reported a mortality rate of 2.2%. The most common causes of death were heart failure (38.7%), renal failure (15.6%), and stroke (13.9%). Postoperative mortality risk factors included blood transfusion (80.1%), reoperation (65%), and prolonged ventilation (62.2%).[4]

The risks and benefits must be carefully considered in thoracic surgery procedures. This is particularly important since most patients undergoing thoracic surgery are elderly, over 60 years old. Therefore, more thorough consideration is needed, as this population has a higher risk of complications, which may increase the risk of mortality.[5] Although several observational studies have examined mortality risk factors in thoracic surgery

patients, no systematic review has comprehensively categorized these risk factors based on clinical phases (preoperative, intraoperative, and postoperative) or the patient's clinical conditions. Most prior studies have focused on specific interventions or isolated risks without providing an integrated analysis. This study contributes by systematically analyzing and categorizing mortality risk factors in thoracic surgery patients to provide a more applicable overview for clinical practice compared to previous narrative or single-risk studies.

2. Method

This study is a systematic review based on secondary data from published studies investigating mortality risk factors in patients undergoing thoracic surgery. The systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses Protocols (PRISMA-P). Literature searches were carried out on March 15, 2024, using databases such as PubMed and Cochrane. The search strategy employed the following keywords: ("Thorax Surgery" OR "Thoracic Surgery" OR "Cardiothoracic Surgery") AND [("Risk Factor" AND "Mortality") OR "Mortality Risk Factor" OR "Risk Factor for Mortality" OR "Risk Factor of Mortality"]. Initial screening continued with title and abstract keyword analysis. A total of 702 articles were initially identified. Duplicate articles were removed, and remaining articles were assessed based on predetermined inclusion and exclusion criteria.

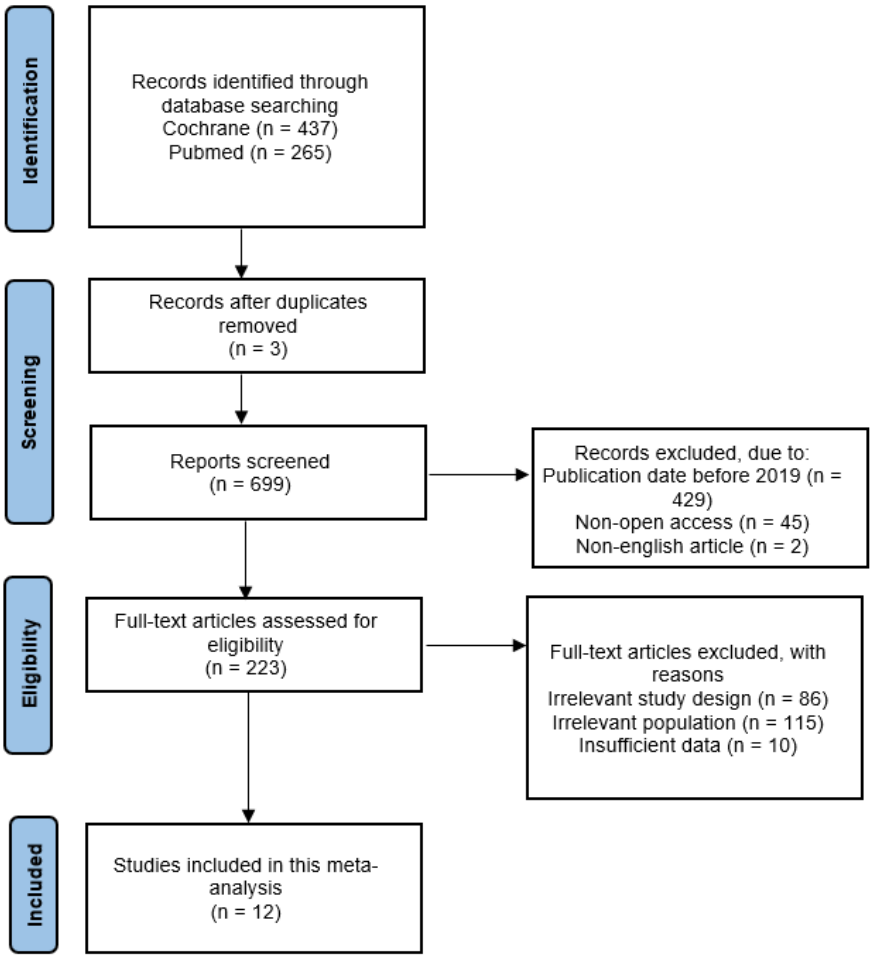

Figure 1. *Flow Chart* PRISMA

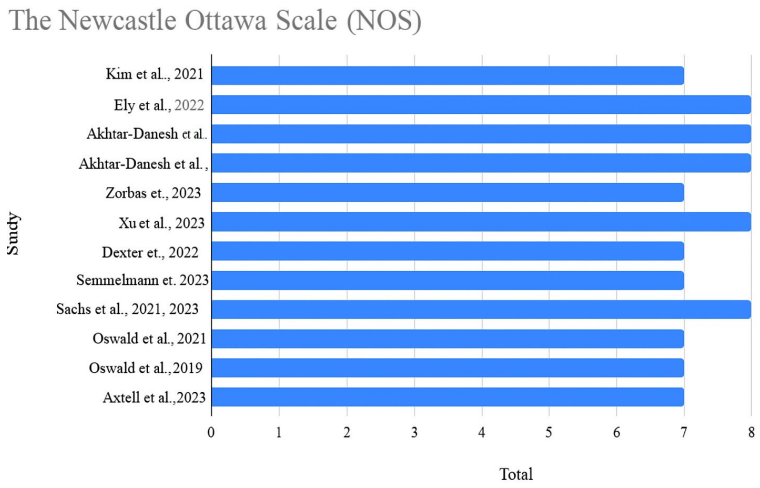

Figure 2. Risk of Bias Assessment Newcastle-Ottawa Scale

Inclusion criteria for this review were original full-text cohort studies published between 2019 and 2024, accessible in English. The study population was adult patients (aged >18 years) undergoing thoracic surgery. Studies that did not include data on mortality parameters, cross-tabulations, or the strength of association between risk factors and mortality were excluded. Article selection and quality assessment were conducted independently by the first author based on the predefined criteria. The selected articles were then reviewed by two senior researchers (MI and EN) to ensure consistency and validity of the selection process.

Following eligibility assessment, data synthesis and extraction were conducted. Extracted data included author name, year, study location, article title, study design, population characteristics (age, sex, type of surgery/procedure), comorbidities or associated risk factors, mortality outcomes, and the strength of associations between risk factors and mortality. Risk of bias was assessed using the Newcastle-Ottawa Scale (NOS). The NOS was employed to evaluate the quality of included cohort studies. In this review, studies with an NOS score ≥5 were considered high-quality publications.[6]

3. Result

The literature search yielded 702 articles matching the defined keywords across the selected databases. After screening based on inclusion and exclusion criteria, a total of 12 relevant articles discussing mortality risk factors in thoracic surgery patients were included (Figure 1). The sample sizes across studies varied, ranging from 85 to 128,723 participants, with reported mortality rates between 1.28% and 26.98%. The majority of patients were over 60 years old and predominantly male (Table 1). Risk of bias was assessed using the Newcastle-Ottawa Scale (NOS) for cohort studies. All included articles were considered high quality, with NOS scores ≥5 (Figure 2).

A total of 25 mortality risk factors in thoracic surgery patients were identified. For the purpose of clinical interpretation, these factors were grouped into three main categories: preoperative, intraoperative, and postoperative. Preoperative factors were the most prevalent (17 out of 25), followed by postoperative (5 factors), highlighting the importance of comprehensive patient assessment before and after thoracic surgical procedures.

Table 1. Study Characteristics

No.	Author, Year, Country	Study Title	Study Design	Population Description	Procedure Performed	Sample Size	Mean Age	Sex Distribution	Mortality Rate
1.	Kim *et al.,* 2021, South Korea[9]	Multivariate Analysis of Risk Factor for Mortality and Feasibility of Extracorporeal Membrane Oxygenation in High-Risk Thoracic Surgery	Retrospective cohort	Patients undergoing thoracic surgery assisted by extracorporeal membrane oxygenation (January 2011–October 2018)	Thoracic surgery with extracorporeal membrane oxygenation (ECMO)	63	50.38 ± 16.16	Male (66,7%)	17 patients (26,98%)
2.	Ely *et al*., 2022, USA[24]	Effect of Thoracic Surgery Regionalization on Long-Term Survival After Lung Cancer Resection	Retrospective cohort	Patients undergoing major lung resections at Kaiser Permanente (2011–2017)	Lobectomy, bilobectomy, or pneumonectomy	1.627	69 (62–75)	Male (42,3%)	295 patients (18,13%)
3.	Nagano *et al*., 2021, Japan[29]	Outcomes of Video-Assisted Thoracic Surgical Lung Biopsy for Interstitial Lung Disease	Retrospective cohort	Interstitial lung disease (ILD) patients undergoing surgical lung biopsy using Video-Assisted Thoracic Surgery (VATS) method (2008–2019)	Video-assisted lung biopsy	85	68 (19–80)	Male (59%)	15 patients (17,64%)
4.	Akhtar-Danesh *et al.,* 2022, Canada[48]	Venous Thromboembolism in Surgical Lung Cancer Patients: A Provincial Population-Based Study	Retrospective cohort	Patients with non-small cell lung cancer (NSCLC) undergoing thoracic surgery	Lung cancer resection	12.626	60–79	Male (46,9%)	-

5.	Zorbas *et al.,* 2023, USA[16]	A simple prediction score for postoperative mortality after decortication	Retrospective cohort	Patients undergoing partial or total decortication based on ACS-NSQIP database (2015–2017)	Video thoracoscopy or thoracotomy decortication	2.315	57,6 ± 16,1	Male (67,3%)	129 patients (6%)
6.	Xu *et al*., 2023, China[14]	Unplanned reoperation after pulmonary surgery: Rate, risk factors and early outcomes at a single center	Retrospective cohort	Patients undergoing reoperation after pulmonary resection (Shanghai Chest Hospital, 2012–2021)	Lobectomy, segmentectomy, wedge resection, pneumonectomy, sleeve resection, bullectomy	247	61 (52–67)	Male (78,1%)	17 patients (6,88%)
7.	Dexter *et al*., 2023, USA[42]	Does Operative Duration of Lobectomy for Early Lung Cancer Increase Perioperative Morbidity?	Retrospective cohort	Patients with primary lung cancer undergoing lobectomy	Lobectomy	17.852	67,1±9,6	Male (45%)	236 patients (1,32%)
8.	Pathy *et al*., 2022, India[15]	Thoracoscore: Does it predict mortality in the Indian scenario? – A retrospective study	Retrospective cohort	Patients undergoing open lung surgery via thoracotomy (2014–2018)	Open thoracotomy lung surgery	394	41.6±13.74	Male (68,5%)	13 patients (3,3%)
9.	Semmelmann *et al*., 2023, Germany[47]	The Impact of Postoperative Pulmonary Complications on Perioperative Outcomes in Patients Undergoing Pneumonectomy: A Multicenter	Retrospective cohort	Patients undergoing non-cardiac thoracic surgery (2017–2021)	Pneumonectomy	152	62.1 ± 10.5	Male (73,6%)	11 patients (7,24%)

10.	Sachs *et al.,* 2021, Sweden[10]	Retrospective Cohort Study of the German Thorax Registry Sex and Survival After Surgery for Lung Cancer: A Swedish Nationwide Cohort	Retrospective cohort	Lung cancer patients undergoing lung resection (Swedish National Quality Register for Thoracic Surgery)	Pulmonary resection	6.536	67.1 ± 9.1	Male (44%)	196 patients (2,3%)
11.	Oswald *et al*., 2019, UK[33]	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	Prospective cohort	Lung cancer patients undergoing diagnostic or curative thoracic surgery (March 2010–October 2015)	Thoracic surgery for lung cancer (curative/diagnostic)	932	74 (69–78)	Male (55%)	36 patients (3,86%)
12.	Axtell *et al*., 2023, USA[12]	Association Between Interstitial Lung Disease and Outcomes After Lung Cancer Resection	Retrospective cohort	Patients undergoing pulmonary resection for *non-small cell lung cancer* (2009–2019)	Pulmonary resection	128.723	68 ± 10	Male (44,5%)	1.649 patients (1,28%)

Table 2. Mortality Risk Factors in Thoracic Surgery Patients

No.	Risk Factor	No. of Studies	Author, Year, Country	Effect Size (95% CI)	N(%)/Mean/Median
			Preoperative Factors		
1.	Age (years)	6	Kim *et al*., 2021, South Korea	OR = 7,47 (1.17–47.85)	50.38 ± 16.16
			Ely *et al*., 2022, USA	HR = 1,03 (1,02–1,04)	69 (62–75)
			Nagano *et al*., 2021, Japan	HR = 1,03 (0,919–1,15)	68 (19–80)
			Zorbas *et al*., 2023, USA	OR = 4,18 (2,63–6,65)	57,6 ± 16,1
			Oswald *et al*., 2019, UK	OR=1,08 (1,03–1,1)	74 (69–78)
			Axtell *et al*., 2023, USA	OR = 1,05 (1,04–1,05)	68 ± 10
2.	Male sex	1	Nagano *et al*., 2021, Japan	HR = 5,35 (0,796–36,0)	40 (59%)
3.	Female sex	2	Sachs *et al*., 2021, Sweden	HR = 0,73 (0,67–0,79)	3.661 (56%)
			Axtell *et al.,* 2023, USA	OR = 0,63 (0,56–0,71)	71.388 (55,5%)
4.	Smoking history	1	Axtell *et al*., 2023, USA	OR = 1,57 (1,24–1,99)	109.464 (85,03%)
5.	Anemia	1	Xu *et al*., 2023, China	HR = 4,048 (0,855–19,163)	10 (4,04%)
6.	COPD	2	Zorbas *et al*., 2023, USA	OR = 1,69 (1,05–2,73)	38 (29,5%)
			Axtell *et al*., 2023, USA	OR = 1,33 (1,14–1,55)	20.775 (16,13%)
7.	Impaired lung function (FEV_1 <60%)	2	Semmelmann *et al*., 2023, Germany	OR = 21 (4,2–103)	16 (10,5%)
			Axtell *et al*., 2023, USA	OR = 1,49 (1,27–1,74)	16.085 (12,49%)
8.	Interstitial lung disease (ILD)	1	Axtell *et al*., 2023, USA	OR = 3,94 (3,09–5,01)	1.873 (1,45%)
9.	Idiopathic pulmonary fibrosis (IPF)	1	Nagano *et al*., 2021, Japan	HR = 14,7 (2,20–97,5)	17 (20%)
10.	Pulmonary arterial hypertension (PAH)	2	Pathy *et al*., 2022, India	OR = 6,2 (1,4–26,65)	29 (7,36%)
			Axtell *et al*., 2023, USA	OR = 1,72 (1,35–2,19)	2.278 (1,76%)
11.	Congestive heart failure (CHF)	2	Zorbas *et al*., 2023, USA	OR = 1,93 (1,02–3,64)	20 (15,5%)
			Axtell *et al*., 2023, USA	OR = 1,68 (1,38–2,03)	4.020 (3,12%)
12.	Chronic kidney disease (CKD)	1	Zorbas *et al*., 2023, USA	OR = 3,37 (1,79–6,36)	22 (17,1%)
13.	Ischaemic heart disease (IHD)	2	Oswald *et al*., 2019, UK	OR = 2,9 (1,2–7,0)	113 (12,1%)
			Axtell *et al*., 2023, USA	OR = 1,31 (1,15–1,49)	27.536 (21,39%)
14.	Advanced cancer stage (stage IV)	2	Ely *et al*., 2022, USA	HR = 3,56 (1.77–7,15)	16 (0,98%)
			Axtell *et al*., 2023, USA	OR = 2,24 (1,55–3,23)	2.387 (1,85%)
15.	History of thoracic surgery	1	Axtell *et al*., 2023, USA	OR = 1,47 (1,27–1,69)	18.684 (14,5%)
16.		2	Ely *et al*., 2022, USA	HR = 2,42 (1,39–4,21)	1.104 (67,85%)

	Charlson comorbidity index (≥3)		Nagano *et al*., 2021, Japan	HR = 1,01 (0,48–2,11)	6 (7,05%)
17.	ASA score (≥3)	1	Zorbas *et al*., 2023, USA	OR = 2.51 (1.51 – 4.17)	127 (98.4%)
18.	Thoracoscore	1	Pathy *et al*., 2022, India	OR = 4,1 (1,79–9,35)	1.39 ± 1.52
			Intraoperative Factors		
19.	Operative duration (minutes)	1	Dexter *et al*., 2023, USA	OR = 1,70 (1,27–2,29)	178 ± 84
20.	Operative duration (>2 hours)	1	Xu *et al*., 2023, China	HR = 1,007 (0,998–1,016)	123 (48,8%)
21.	Blood transfusion	3	Zorbas *et al*., 2023, USA	OR = 1,94 (1,05–3,61)	17 (13,2%)
			Xu *et al*., 2023, China	HR = 1.295 (0,437–3.835)	61 (24,69%)
			Axtell *et al*., 2023, USA	OR = 3,46 (2,84–4,22)	2.543 (1,97%)
22.	Reoperation (>24 hours)	1	Xu *et al*., 2023, China	HR = 3,917 (1,183–12,970)	100 (40,48%)
23.	Reoperation (any)	1	Pathy *et al*., 2022, India	OR = 17,9 (3,94–81,59)	23 (5,83%)
			Postoperative Factors		
24.	Venous thromboembolism (VTE)	1	Akhtar-Danesh *et al*., 2022, Canada	HR = 2,03 (1,77–2,34)	344 (2,73)
25.	Prolonged mechanical ventilation	2	Zorbas *et al*., 2023, USA	OR = 3,71 (1,99–6,91)	22 (17,1%)
			Semmelmann *et al*., 2023, Germany	OR = 8,4 (2–34)	13 (8,55%)
26.	Cardiac arrest	1	Kim *et al*., 2021, South Korea	OR = 24,44 (1.82–327.60)	9 (52,9%)
27.	Sepsis	1	Zorbas *et al*., 2023, USA	OR = 2,01 (1,31–3,07)	75 (58,1%)
28.	Postoperative pulmonary complications (PPC)	2	Semmelmann *et al*., 2023, Germany	OR = 13 (3,2–52)	32 (21,05%)
			Oswald *et al*., 2019, UK	OR = 6,1 (2,6–14,6)	130 (13,9%)

Preoperative factors included patient characteristics and underlying medical conditions prior to surgery. Advanced age was associated with decreased physiological reserve and a higher risk of complications. Male sex was linked to higher smoking prevalence and a greater incidence of cardiovascular comorbidities. Organ system disorders such as chronic obstructive pulmonary disease (COPD), impaired lung function (FEV1 <60%), interstitial lung disease (ILD), and idiopathic pulmonary fibrosis (IPF) significantly increased mortality risk. Systemic diseases such as anemia, pulmonary arterial hypertension (PAH), congestive heart failure (CHF), chronic kidney disease (CKD), ischemic heart disease (IHD), and immunocompromised states like sepsis were also identified as meaningful predictors. Other contributing factors included American Society of Anesthesiologists (ASA) score ≥3, higher Thoracoscore, advanced cancer stage, and elevated Charlson Comorbidity Index. A history of previous thoracic surgery was also associated with increased mortality risk, likely due to adhesions, altered anatomy, and higher complication rates intra- and postoperatively.

Intraoperative factors referred to variables arising during surgery. Prolonged operative time was consistently associated with higher risks of complications such as bleeding, ventilation requirements, and infection. The need for intraoperative blood transfusion significantly correlated with mortality, possibly reflecting active bleeding and transfusion-induced immunosuppression. Unplanned reoperations within 24–48 hours showed high odds ratios for mortality, indicating high-risk and complex clinical scenarios.

Postoperative factors included events and interventions after surgery that directly impacted patient prognosis. Postoperative pulmonary complications (PPCs), such as atelectasis, pneumonia, and respiratory failure, were major contributors to mortality. Prolonged mechanical ventilation was linked to increased mortality risk due to respiratory complications and muscle weakness. Cardiac arrest, though rare, had a nearly absolute mortality rate when resuscitation was delayed or unsuccessful. Venous thromboembolism (VTE) was another significant complication, often due to patient immobility and vascular manipulation during surgery, contributing to fatal pulmonary embolism in the postoperative period.

4. Discussion

Patient-Related Factors

Several patient-related characteristics have been shown to significantly increase the risk of mortality in individuals undergoing thoracic surgery. This systematic review identified six studies reporting an association between older age and higher postoperative mortality. Frailty, often associated with aging, reflects diminished physiological reserves, reducing the body's ability to maintain homeostasis following surgical stress. Elderly patients are also more likely to experience preoperative anemia, which often necessitates transfusions. Additionally, wound and infection risks are higher in older patients, with infection rates reaching up to 11%. These outcomes are associated with increased prevalence of diabetes, emergency procedures, prolonged hospitalization, and an age-related decline in immune response.[7–9]

Male sex has also been associated with higher mortality. A national study by Sachs *et al*. reported increased mortality risk in males, potentially due to a higher prevalence of smoking. Cardiovascular diseases, which are more prevalent in men, are known to increase the risk of lung cancer mortality.[10]

Smoking history is a notable mortality risk factor. Axtell *et al*. reported a 1.57-fold increase in mortality among thoracic surgery patients with a smoking history. Smokers are more likely to experience postoperative complications due to comorbidities and the detrimental effects of smoking on cardiovascular and pulmonary systems, as well as impaired wound healing.[11,12] A history of previous thoracic surgery also increases mortality risk, likely due to pleural adhesions and altered anatomy, which can complicate the surgical procedure and increase the risk of bleeding or bronchopleural fistula (BPF).[13–15]

Several studies in this review employed scoring systems to predict postoperative mortality in thoracic surgery patients. Zorbas *et al*. found that an ASA score ≥3 increased the risk of death by 2.51 times. Higher ASA scores are associated with greater blood loss, increased transfusion requirements, longer postoperative ventilation, ICU stays, complications, and mortality.[16–19] In addition to ASA, the Charlson Comorbidity Index (CCI), which combines age and comorbid conditions, is widely used to evaluate patient prognosis, especially in cancer cases.[20] Thoracoscore, which incorporates variables such as age, sex, ASA score, functional status, dyspnea score, surgery priority, procedure class, diagnosis group, and comorbid score, also serves as a predictive tool for mortality in thoracic surgery.[15,21,22]

Disease-Related Factors

Underlying diseases significantly contribute to increased mortality following thoracic surgery. Advanced cancer stage is associated with a higher mortality risk, likely due to metastasis, increased infection risk (such as pneumonia or sepsis), pulmonary bleeding, and pulmonary embolism.[12,23,24]

Pulmonary function impairments—such as COPD, ILD, IPF, and reduced FEV1 (<60%)—affect gas exchange and elevate the risk of respiratory complications. Inflammation, mucociliary dysfunction, and gas exchange abnormalities are believed to increase postoperative pulmonary complications and mortality in COPD patients.[25,26] ILD leads to lung fibrosis, compromising tissue healing and increasing the risk of postoperative air leaks and pleural effusion. Interstitial changes may also cause pulmonary hypertension, emphysema, or obstructive sleep apnea, further elevating postoperative complication risk.[27–29]

Cardiovascular disorders such as CHF, PAH, and IHD can worsen patient hemodynamics during and after surgery. CHF impairs the ability to increase cardiac output in response to surgical stress, leading to intraoperative desaturation. Fluid retention and hemodynamic instability are common intraoperative challenges.[12,16,30,31] PAH increases the risk of intraoperative bleeding due to elevated pressure and fragile pulmonary vessels.[12,15,32] IHD directly contributes to perioperative mortality through increased risks of myocardial ischemia, infarction, conduction abnormalities, arrhythmias, and cardiac arrest.[12,33–35]

CKD is associated with a 3.37-fold increase in mortality risk. This is due to potential complications such as postoperative acute kidney injury, electrolyte imbalances, anesthetic accumulation, impaired wound healing, and heightened infection susceptibility.[16,36–38]

Anemia is linked to a 2–3-fold increase in respiratory and infectious complications. Anemia reduces tissue oxygenation capacity, and although treatable with blood transfusion, transfusions themselves carry risks. Evidence suggests increased complications

in transfused patients due to immunomodulation, fluid overload, and possible tumor recurrence. Current guidelines advise correcting anemia preoperatively without transfusion unless hemoglobin is below 70 g/L.[12,14,16,39]

Sepsis, whether present pre- or postoperatively, is a critical trigger for multi-organ failure leading to death. Postoperative sepsis in cardiothoracic surgery commonly results from surgical site infections or hospital-acquired infections, including ventilator-associated pneumonia, bloodstream infections, and soft tissue infections.[16,40,41]

Surgical-Related Factors

Surgical factors also have a significant impact on patient prognosis. Operative duration has been associated with increased morbidity, prolonged hospital stay, and mortality, as reported in the studies by Dexter *et al*. and Xu *et al*. in this systematic review. Longer surgeries are linked to pulmonary complications such as pneumonia, acute respiratory distress syndrome (ARDS), reintubation, ICU admission, and extended hospitalization. Prolonged surgery also correlates with a higher likelihood of perioperative blood transfusion, indicating possible bleeding or technical complications. Licker et al. found that operations lasting over 120 minutes were associated with increased postoperative cardiopulmonary complications.[14,42,43]

Reoperation, especially within 24–48 hours, showed significantly higher odds of mortality, reflecting worsening clinical conditions and increased surgical complexity. These patients often required more blood products, prolonged ventilation, and longer ICU stays. Pleural adhesions, which are more common in reoperations, increase the risks of bleeding, pneumothorax, and empyema, and may lead to death. Furthermore, reoperations carry a higher risk of bronchopleural fistula (BPF), with reported mortality rates between 11% and 18%.[13–15]

Intraoperative blood transfusions, while sometimes necessary to manage bleeding, have been shown to contribute to increased mortality. Transfused red blood cells may induce transfusion-related immunomodulation (TRIM) due to the presence of cytokines, lipids, and bioactive substances, most likely from allogeneic leukocytes. This immunomodulation can result in either immune activation, leading to transfusion-related lung injury, or immune suppression, increasing vulnerability to infections. Additionally, stored red blood cells lose deformability and exhibit increased vascular adhesion, impairing microcirculatory flow and oxygen delivery.[44]

Perioperative Care-Related Factors

Several perioperative care factors after surgery have also been found to influence mortality. Postoperative pulmonary complications (PPCs), as described by Semmelmann *et al*. and Oswald *et al*., are among the most common causes of postoperative mortality. PPCs are defined as any clinically significant pulmonary abnormalities occurring postoperatively that negatively affect patient outcomes. These range from self-limiting issues like mild atelectasis or bronchospasm to severe, life-threatening conditions such as pneumonia or respiratory failure.[45]

Prolonged mechanical ventilation (PMV) was also reported as a mortality risk factor in studies by Zorbas *et al*. and Semmelmann *et al*. PMV is defined as requiring extubation after more than three spontaneous breathing trials or more than 14 days of ventilation. PMV can lead to complications such as limb muscle atrophy, functional impairment, and diaphragmatic dysfunction. Furthermore,

baseline respiratory drive may be altered depending on underlying pulmonary diseases or causes of respiratory failure. Brainstem lesions, for example, may disrupt central respiratory drive, leading to hypoventilation or respiratory acidosis, ultimately resulting in ventilator dependence.[46,47]

Venous thromboembolism (VTE) is a serious postoperative complication that can lead to fatal pulmonary embolism. Surgical positioning and limited postoperative mobility due to chest tubes or incisional pain increase the risk of VTE. Intraoperative vascular manipulation, including clamping and ligation of pulmonary arteries, may also result in in situ thrombosis. Such thrombi can cause pulmonary embolism, potentially resulting in death.[48]

Postoperative cardiac arrest, though rare, is associated with extremely high mortality, particularly when resuscitation is delayed or ineffective. Cardiac arrest may be triggered by intraoperative mass manipulation that exacerbates cardiac dysfunction. During cardiac arrest, many patients suffer from brain injury due to hypoxia or irreversible cardiopulmonary failure resulting from delayed resuscitation.[9,49]

This study has several limitations. First, most of the included studies were retrospective cohort designs, which are prone to selection and information bias and offer limited control over confounding variables. Second, heterogenity among the study populations, surgical procedures, and definitions of mortality and complications may affect the generalizability of the results. Lastly, this systematic review did not include a quantitative meta-analysis due to differences in study design and reporting, and thus, the conclusions are descriptive in nature.

5. Conclusion

This systematic review identified 25 risk factors associated with mortality in patients undergoing thoracic surgery, which were categorized into three groups: preoperative, intraoperative, and postoperative factors. The most prominent category was preoperative factors, including advanced age, chronic diseases, and the patient's functional status. Intraoperative factors such as prolonged operative time, the need for blood transfusion, and reoperation also showed strong associations with mortality. Postoperative mortality was linked to pulmonary complications, prolonged mechanical ventilation, venous thromboembolism, and cardiac arrest.

These findings emphasize the importance of a multidisciplinary approach to risk assessment and management—beginning with a thorough preoperative evaluation, continued with intraoperative risk mitigation, and followed by optimized perioperative care. This comprehensive strategy could contribute significantly to reducing mortality rates. The results of this review may serve as a foundation for developing risk screening protocols, guiding clinical decision-making, and implementing multidisciplinary strategies to improve postoperative outcomes in thoracic surgery patients.

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