



## SYSTEMATIC REVIEW OPEN ACCESS

# Perioperative Mechanical Circulatory Support for Cardiac Assistance in Thoracic Surgery: A Scoping Review

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## ABSTRACT

**Background:** Patients with pre-existing severe cardiovascular comorbidities are often deemed ineligible for potentially life-saving thoracic surgeries and are referred to other conservative therapies. However, this patient population may theoretically benefit from the timely perioperative implantation of temporary mechanical circulation support (tMCS) to both mitigate the surgical stress and stabilize hemodynamics. We performed a scoping review to summarize the evidence regarding the use of tMCS in thoracic surgery.

**Methods:** We conducted a systematic search across PubMed/MEDLINE, EMBASE, Cochrane Central Register of Controlled Trials, Web of Science, Scopus, and Google Scholar from their inception, aided by a search string encompassing a combination of terms for the key research concepts: i) tMCS devices; ii) thoracic surgery procedures (except lung transplantation); and iii) the adult population.

**Results:** Fifteen studies pertinent to the research question, which summarized data from 28 patients, were retrieved for inclusion. In 14 patients, tMCS implantation occurred as a “pre-emptive” strategy, while the remaining patients had tMCS implanted either intra and/or postoperatively as a “bail-out” strategy. Specifically, 14 patients required an intra-aortic balloon pump, 10 veno-arterial extracorporeal membrane oxygenation, two required a multidevice strategy, and one cardiopulmonary bypass. The relative risk analysis revealed that the mortality rate in the pre-emptive group was half that of the bail-out group. Additionally, the risk of both infectious and vascular complications was lower in the pre-emptive group compared to the bail-out tMCS strategy.

**Conclusion:** We found that the timely implantation of tMCS in thoracic surgery—either to mitigate patients' heightened cardiovascular risk or as a rescue strategy in the event of life-threatening surgical complications—may lead to better patient outcomes, as well as allowing them to undergo curative surgery with an acceptable safety profile, characterized by overall good survival rates and a low incidence of device-related complications.

## 1 | Introduction

Patients with concomitant severe cardiovascular comorbidities (e.g., advanced heart failure) may be denied lifesaving noncardiac surgical procedures due to their heightened risk of perioperative major adverse cardiac events (MACE) which

span myocardial infarction, ventricular arrhythmias, and acute cardiovascular decompensation. As such, the occurrence of MACE results from a combination of the patient's individual risk profile and the inherent surgical stress (e.g., sympathetic changes in the vascular tone, alterations in coagulation and hemostasis, and dysregulated inflammatory

Viviana Teresa Agosta and Jacopo D'Andria Ursoleo contributed equally to this study.

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response) [1]. This can elevate the overall perioperative risk to an unacceptable level, rendering patients ineligible for surgery [2, 3]. This issue is particularly significant today, as the global population ages and the incidence of cardiovascular diseases continues to rise [4, 5].

In the cardiac surgery setting, this patient population often benefits from the routine implantation of temporary mechanical circulatory support (tMCS) to either support their cardiac function and prevent acute hemodynamic decompensation, or to manage perioperative complications [4]. Although the effectiveness of tMCS varies depending on the device being implanted, it still aims to reduce myocardial oxygen consumption and left ventricular workload while increasing cardiac output and mean arterial pressure (MAP), thereby playing a crucial role in stabilizing the hemodynamics of perioperative patients [4, 5]. Building on this, tMCS is theoretically positioned to extend beyond its conventional use in cardiac surgery operating rooms, catheterization laboratories, and the cardiac intensive care unit (ICU) to include noncardiac surgical procedures.

In thoracic surgery, tMCS has been primarily used to substitute the respiratory function during lung transplants, rather than to support patient hemodynamics. In this setting, the use of tMCS to manage and support patients at high risk of or who experience perioperative cardiovascular complications remains limited and potentially underexploited, particularly when compared to its more extensive application in other noncardiac surgery settings (e.g., abdominal surgery) [3, 6].

While this intervention may improve both short- and long-term outcomes for a large patient subpopulation who would otherwise be ineligible for surgery, the current evidence remains fragmented, and a systematic synthesis of the available literature is still lacking.

Therefore, we conducted a scoping review of the available evidence regarding the use of tMCS in thoracic surgery (with the exclusion of lung transplantation procedures), aiming to evaluate its potential implementation both as a rescue strategy for unexpected perioperative hemodynamic instability and as a preoperative strategy to mitigate cardiovascular surgical risk in complex cases. Moreover, we seek to determine whether, in selected cardiovascular patients, a prophylactic approach relying upon a pre-emptive tMCS implantation strategy would further improve their perioperative outcomes.

## 2 | Materials and Methods

### 2.1 | Search Strategy

This scoping review was conducted in accordance with the Joanna Briggs Institute (JBI) and the Preferred Reporting Items for Systematic Review and Meta-Analyses (PRISMA) guidelines [7, 8], alongside its related extension for Scoping Reviews (PRISMA-ScR) (Table S1) [9].

A research protocol for the present scoping review was written and approved by all the authors and was published in the *Health Science Reports* journal [10].

Additional details on the systematic search performed, alongside inclusion and exclusion criteria, the process of study selection, data retrieval, and statistical analysis, and the assessment of the risk of bias are included in the [Supporting Information](#) file ([Supporting Information](#) on the Research Methodology) [10].

### 2.2 | Classification of the Retrieved Studies

Retrieved studies written in English were categorized into two groups based on the timing and strategy of tMCS implantation, namely: i) the first group, labeled as “pre-emptive,” included cases where tMCS was implanted to enable surgery due to the patient’s anticipated heightened cardiac risk; ii) the second group involved “bail-out” tMCS implantation, which was necessitated by unexpected intra or postoperative cardiac events.

## 3 | Results

The comprehensive literature search of the PubMed/MEDLINE, EMBASE, Cochrane Central Register of Controlled Trials, Web of Science, Scopus, and Google Scholar online databases yielded 647 articles. Of these, 15 investigations were ultimately retrieved and included in the present scoping review, summarizing data from a total of 28 patients (Figure 1).

### 3.1 | General Characteristics of the Included Studies

Among the 15 studies retrieved, 11 (73%) were case reports [3, 5, 11–19], two (13%) were case series [20, 21], one (7%) was a retrospective study [22], and one (7%) was a prospective study [23].

Most (93%) were published between 2005 and 2023 [3, 5, 12–23], with the exception of one study (7%) published in 1979 [11].

Most (46.7%) of the studies were conducted in Asia [13, 14, 16, 17, 19, 20, 23], while Europe and the United States each accounted for the provenance of 26.7% of the studies [3, 5, 11–13, 15, 21, 22].

The majority of patients required IABP implantation (14 patients, 52%) [5, 11, 13, 19, 21]. In 10 cases (35%), veno-arterial (V-A) ECMO was needed [3, 15, 17, 18, 20, 22, 23]. Two patients (7%) required a multidevice approach [14, 16], and in one case (4%) cardiopulmonary bypass (CPB) was established [12].

Fourteen (50%) patients received preoperative tMCS implantation as a “pre-emptive” strategy, while the remaining patients underwent “bail-out” (Figure 2).

Four studies (27%) reported on the anticoagulation strategies used, or the lack thereof, in the context of tMCS support [3, 12, 19, 23]. Heparin was the most frequently utilized anticoagulant, as documented in three studies (75%) [3, 12, 23]. Conversely, anticoagulation was not administered in one study (25%) [19]. In the remaining 11 studies (73%), information regarding anticoagulation therapy was not provided [5, 11, 13–18, 20–22].

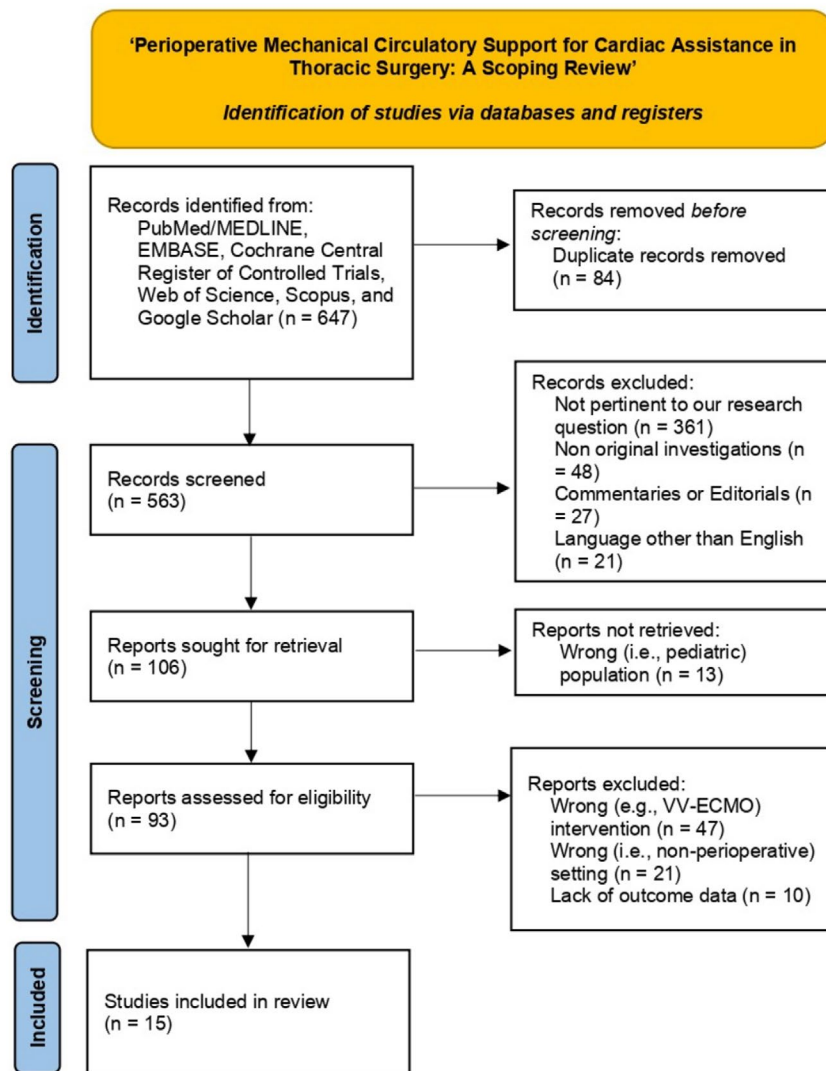


**FIGURE 1** | Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) 2020 flow diagram for the study selection process. [Color figure can be viewed at [wileyonlinelibrary.com](https://onlinelibrary.wiley.com)]

A summary of the respective findings is presented in Tables 1 and 2.

### 3.2 | Pre-emptive tMCS

Six studies encompassing data from 14 (50%) patients who received preoperative tMCS implantation as a “pre-emptive” strategy were included [3, 5, 11, 18, 19, 21].

The majority of patients (11 of 14, 79%) were male. All the studies were case reports or case series and were conducted between 1979 and 2022.

#### 3.2.1 | IABP

Four studies for a total of 12 patients reported the pre-emptive IABP implantation for perioperative hemodynamic management [5, 11, 19, 21]. All studies were published between 1979 and 2016. Seventy-five percent of the patients were male. The median age was 63.5 years (IQR: 60–69.5).

These patients were characterized by significant concomitant cardiac diseases, that is, in seven patients (58.3% of the total), severe two- or three-vessel coronary artery disease (CAD); [5, 11, 21] and in four patients (33.3% of the total), a recent history of cardiopulmonary resuscitation (CPR) [19], subsequent to myocardial infarction in two cases and to coronary artery bypass grafting (CABG) in one case; myocardial infarction in one patient (8.3%) [19]. For the majority of seven patients with severe CAD, a myocardial revascularization approach before thoracic surgery was deemed inappropriate, and thoracic surgery was prioritized due to concerns about the potential progression of their underlying oncologic malignancy. Moreover, of the 12 patients, seven exhibited a severely depressed ejection fraction (EF, i.e.,  $\leq 25\%$ ). Additional preoperative echocardiographic data were available for five patients only, detailing the extent and location of hypo- or akinetic areas.

In summary, IABP was implanted in seven patients (58.3%) due to severe CAD, including the case of one patient with CAD alongside severe left ventricle (LV) dysfunction [5, 11, 19, 21]; in three patients (25%) due to low EF alongside severe LV dysfunction [19], and in two patients due to isolated low EF only (16.7%) [5, 19].

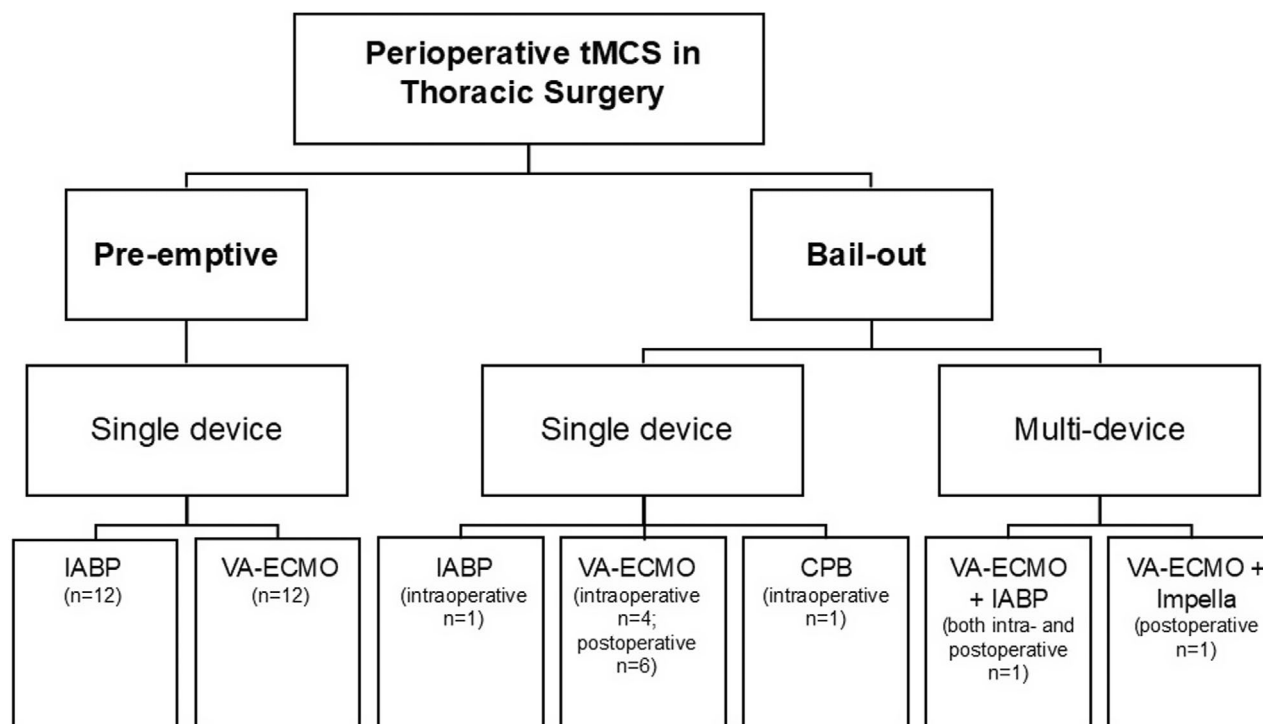


**FIGURE 2** | Schematic representation of the type of temporary mechanical circulatory support (tMCS) described in the selected studies, primarily classified based on the timing and implantation strategy (i.e., pre-emptive or bail-out). CPB, cardiopulmonary bypass; IABP, intra-aortic balloon pump; pt(s), patient(s); tMCS, temporary mechanical circulatory support; VA-ECMO, veno-arterial extracorporeal membrane oxygenation.

Interestingly, limited data were available concerning the patient's intraoperative anesthetic management. Two patients required neither transfusions nor inotropic support, while data for the other patients were not available.

Data regarding the duration of tMCS were available for 11 patients, with a median duration of tMCS of 24 h (IQR: 24–48 h). Criteria for IABP weaning were described in two patients (i.e., hemodynamic stability and metabolic state). In five additional cases, although the authors noted that formal weaning criteria were not explicitly defined, patients were weaned based on indicators of adequate cardiac function, including hemodynamic stability without inotropic support, absence of arrhythmias, regular urinary output, and normal arterial blood gas values. For two patients, device removal was possible because of hemodynamic stability and with the aim of preventing IABP-associated adverse events. For the remaining patients, no weaning criteria for tMCS were documented. Among the 12 patients included, seven did not experience IABP-related complications, while in the remaining five cases, device-related complications were not reported by the study authors.

The median hospital stay was 10 days (IQR: 7, 12, with data available for 11 of 12 patients). The need for ICU admission was reported for three patients only.

Regarding the outcome, the majority of patients (9, 75% of the total) were alive upon hospital discharge. One patient (8.3%) died due to respiratory failure [11], while cardiac death was specifically ruled out in the remaining two patients (16.7%) [5].

### 3.2.2 | V-A ECMO

Only two patients underwent thoracic surgery with pre-emptive V-A ECMO [3, 18]. All patients were male and required a thoracotomy. Both investigations were published between 2017 and 2022. In the report by Novellis et al. [3], the authors described the case of a 73-year-old man with severe postischemic dilated cardiomyopathy who underwent elective left upper lobectomy with concomitant angioplasty of the pulmonary artery and lymphadenectomies. After the induction of general anesthesia, V-A ECMO was implanted with peripheral cannulation due to the evidence of a severely depressed left ventricular ejection fraction (LVEF, i.e., 29%). To allow for LV unloading, an epinephrine infusion was started. At the end of the surgery, V-A ECMO was removed, and the patient was transferred to the ICU before being discharged to the surgical ward 36 h later.

Tzafos et al. [18] described the case of a 33-year-old man who was previously evaluated for lung volume resection surgery (LVRS) for the management of emphysema. Initially, the surgery was not performed due to substance abuse. Eighteen months later, an acute decompensation of cor pulmonale brought the man to the emergency department with hypoxia and unstable hemodynamics. Antibiotic therapy was started, and due to the persistence of circulatory and respiratory failure, V-A ECMO was implanted and subsequently upgraded to veno-arterio-venous ECMO (VAV-ECMO) to improve oxygenation. Two days after ECMO implantation, right- and left-sided LVRS were performed separately. On the fifth day following the first surgery, ECMO support was downgraded from VAV-ECMO to veno-venous ECMO (V-V ECMO), which was then weaned on the eighth day

**TABLE 1** | Pre-emptive tMCS implantation: Characteristics of the retrieved studies, patient data, perioperative management, and outcomes.

| Author, year       | Study design | No. of pts | Age, (y) | Sex | Preoperative concomitant cardiac disease | Main indication for surgery and surgical procedure performed | Surgical approach       | Reason for tMCS implantation       | Anticoagulation type and dosage | tMCS duration (h) | Intraoperative inotropes and vasopressors (type and dose) | ICU stay (d)          | In-hospital stay (d) | Patient status at latest follow-up available |
|--------------------|--------------|------------|----------|-----|------------------------------------------|--------------------------------------------------------------|-------------------------|------------------------------------|---------------------------------|-------------------|-----------------------------------------------------------|-----------------------|----------------------|----------------------------------------------|
| LABP               |              |            |          |     |                                          |                                                              |                         |                                    |                                 |                   |                                                           |                       |                      |                                              |
| Bonchek, 1979 [12] | Case reports | 1          | 65       | F   | Three vessels CAD, prior VF, CCHF        | Coin lesion in the lower lobe of right lung: resection       | Mediastinoscopy         | CAD                                | n/a                             | 24                | n/a                                                       | n/a (admitted in ICU) | 21                   | Died of respiratory insufficiency            |
|                    |              | 1          | 60       | M   | Three vessels CAD                        | Lesion in the right upper lung field, pleural reaction       | Bilateral thoracotomies | CAD, severe LV dysfunction         | n/a                             | 24                | n/a                                                       | n/a                   | 5                    | Alive at hospital discharge                  |
|                    |              | 1          | 66       | F   | Two vessels CAD                          | Nodule in the upper lobe of the left lung: resection         | Thoracotomy             | CAD                                | n/a                             | n/a               | n/a                                                       | n/a                   | 10                   | Alive at hospital discharge                  |
| Chiu, 2005 [21]    | Case reports | 1          | 62       | M   | Three vessels CAD                        | Lung carcinoma: left upper lobectomy                         | Thoracotomy             | CAD                                | n/a                             | 48 postop.        | n/a                                                       | n/a                   | 10                   | Alive at hospital discharge                  |
|                    |              | 1          | 70       | M   | Three vessels CAD                        | Lung carcinoma: right upper lobectomy                        | Thoracotomy             | CAD                                | n/a                             | 48 postop.        | n/a                                                       | n/a                   | 15                   | Alive at hospital discharge                  |
| Ahmadi, 2014 [19]  | Case series  | 1          | 48       | M   | Previous MI                              | Postintubation tracheal stenosis: resection and anastomosis  | n/a                     | Very low EF                        | No i.v. heparin                 | 10 postop.        | n/a                                                       | n/a                   | n/a                  | Alive at hospital discharge                  |
|                    |              | 1          | 42       | M   | Previous CPR                             | Poststenotic tracheal dilatation: resection and anastomosis  | n/a                     | Severe LV dysfunction, very low EF | No i.v. heparin                 | 24 postop.        | n/a                                                       | n/a                   | 11                   | Alive at hospital discharge                  |
|                    |              | 1          | 74       | F   | Previous MI, CPR                         | Postintubation tracheal stenosis: resection and anastomosis  | n/a                     | Severe LV dysfunction, very low EF | No i.v. heparin                 | 48 postop.        | n/a                                                       | n/a                   | 7                    | Alive at hospital discharge                  |

(Continues)

TABLE 1 | (Continued)

| Author, year      | Study design | No. of pts | Age, (y) | Sex | Preoperative concomitant cardiac disease | Preoperative EF | Main indication for surgery and surgical procedure performed            | Surgical approach | Reason for tMCS implantation | Anticoagulation type and dosage                                            | tMCS duration (h)           | Intraoperative inotropes and vasopressors (type and dose) | ICU stay (d)          | In-hospital stay (d) | Patient status at latest follow-up available |
|-------------------|--------------|------------|----------|-----|------------------------------------------|-----------------|-------------------------------------------------------------------------|-------------------|------------------------------|----------------------------------------------------------------------------|-----------------------------|-----------------------------------------------------------|-----------------------|----------------------|----------------------------------------------|
|                   |              | 1          | 62       | M   | Previous MI, CPR                         | 20%             | Postintubation tracheal stenosis; resection and anastomosis             | n/a               | CAD                          | No i.v. heparin                                                            | 48 postop.                  | n/a                                                       | n/a                   | 10                   | Alive at hospital discharge                  |
|                   |              | 1          | 68       | M   | CABG, CPR                                | 25%             | Postintubation tracheal stenosis; resection and anastomosis             | n/a               | Very low EF                  | No i.v. heparin                                                            | 24 postop.                  | n/a                                                       | n/a                   | 12                   | Alive at hospital discharge                  |
| Burgio, 2016 [5]  | Case reports | 1          | 60       | M   | Postischemic cardiomyopathy              | 25%             | Lung nodule; atypical resection                                         | Thoracoscopy      | Very low EF                  | n/a                                                                        | 24                          | None                                                      | 2                     | 5                    | No cardiac death                             |
|                   |              | 1          | 73       | M   | Two-vessels CAD                          | 40%             | Sup lung Rx lobectomy                                                   | n/a               | CAD                          | n/a                                                                        | 24                          | None                                                      | 2                     | 12                   | No cardiac death                             |
| V-A ECMO          |              |            |          |     |                                          |                 |                                                                         |                   |                              |                                                                            |                             |                                                           |                       |                      |                                              |
| Tzafo, 2017 [18]  | Case report  | 1          | 33       | M   | Dilated RV; TI, pulmonary hypertension   | n/a             | Bilateral lobe consolidations, emphysema; lung volume reduction surgery | Thoracotomy       | Cor pulmonale                | n/a                                                                        | 192                         | n/a                                                       | n/a                   | 35                   | Alive at hospital discharge                  |
| Novellis 2022 [3] | Case report  | 1          | 73       | M   | Two-vessels CAD                          | 29%             | Left-upper lung carcinoma; lobectomy                                    | Thoracotomy       | Very low EF                  | i.v. heparin (bolus) to achieve an ACT > 200". No reversal with protamine. | At the end of the procedure | Epinephrine 0.05 mg/kg/min                                | n/a (admitted in ICU) | 3                    | Alive at hospital discharge                  |

Abbreviations: ACT, activated clotting time; CABG, coronary artery bypass graft; CAD, coronary artery disease; CCHF, chronic congestive heart failure; CPR, cardiopulmonary resuscitation; d, days; EF, ejection fraction; F, female; h, hours; IABP, intra-aortic balloon pump; ICU, intensive care unit; i.v., intravenous; LV, left ventricular; M, male; MI, myocardial infarction; n, number; n/a, not available; postop., postoperative; RV, right ventricular; Rx, right; Sup, superior; TI, tricuspid insufficiency; tMCS, temporary mechanical circulatory support; V-A ECMO, veno-arterial extracorporeal membrane oxygenation; VF, ventricular fibrillation; y, years.

**TABLE 2** | Bail-out tMCS: Characteristics of the retrieved studies, patient data, implantation timing and reason, perioperative management, and outcomes.

| Author, year        | Study design | No. of pts | Age (y) | Sex | Main indication for surgery and surgical procedure performed | Surgical approach | Reason for tMCS implantation                                           | Anticoagulation type and dosage                                                                | tMCS duration (h)         | Intraoperative inotropes and vasopressors (type and dose)                           | ICU stay (d)          | In-hospital stay (d) | Pt status at latest follow-up available |
|---------------------|--------------|------------|---------|-----|--------------------------------------------------------------|-------------------|------------------------------------------------------------------------|------------------------------------------------------------------------------------------------|---------------------------|-------------------------------------------------------------------------------------|-----------------------|----------------------|-----------------------------------------|
| CPB                 |              |            |         |     |                                                              |                   |                                                                        |                                                                                                |                           |                                                                                     |                       |                      |                                         |
| Anderson, 2011 [12] | Case report  | 1          | 45      | F   | Posterior mediastinal mass                                   | VATS              | Pericardial effusion, complete compression of the LA: tamponade effect | i.v. heparin, reversed with protamine                                                          | At the end of the surgery | Epinephrine (bolus), norepinephrine, vasopressin, phenylephrine                     | n/a (admitted in ICU) | n/a                  | Alive 90 d later                        |
| IABP                |              |            |         |     |                                                              |                   |                                                                        |                                                                                                |                           |                                                                                     |                       |                      |                                         |
| Ahmadi, 2014 [19]   | Case series  | 1          | 64      | M   | Post-intubation tracheal stenosis: resection and anastomosis | n/a               | Cardiogenic shock                                                      | No i.v. heparin                                                                                | 6 postop.                 | n/a                                                                                 | n/a                   | 10                   | Alive at the hospital discharge         |
| Awari, 2022 [13]    | Case report  | 1          | 68      | M   | Lung mass                                                    | Bronchoscopy      | PEA                                                                    | n/a                                                                                            | 72                        | Epinephrine infusion (0.5 mg/kg/min), intermittent epinephrine boluses (200-500 mg) | 3                     | 6                    | Alive at the hospital discharge         |
| V-A ECMO            |              |            |         |     |                                                              |                   |                                                                        |                                                                                                |                           |                                                                                     |                       |                      |                                         |
| H. Lee, 2017 [23]   | Prospective  | 1          | 66      | M   | Lung carcinoma: lobectomy                                    | n/a               | Cardiogenic shock                                                      | i.v. heparin 100 UI/kg (bolus), followed by i.v. heparin infusion to achieve an ACT > 140-160" | n/a                       | n/a                                                                                 | n/a                   | n/a                  | Alive at the hospital discharge         |
|                     |              | 1          | 63      | M   | Lung carcinoma: bilobectomy                                  | n/a               | Hypovolemic shock                                                      | i.v. heparin 100 UI/kg (bolus), followed by i.v. heparin infusion to achieve an ACT > 140-160" | n/a                       | n/a                                                                                 | n/a                   | n/a                  | Alive at the hospital discharge         |

(Continues)

TABLE 2 | (Continued)

| Author, year        | Study design  | No. of pts | Age (y) | Sex | Main indication for surgery and surgical procedure performed                      | Surgical approach | Reason for tMCS implantation | Anticoagulation type and dosage                                                                | tMCS duration (h) | Intraoperative inotropes and vasopressors (type and dose) | ICU stay (d)          | In-hospital stay (d) | Pt status at latest follow-up available |
|---------------------|---------------|------------|---------|-----|-----------------------------------------------------------------------------------|-------------------|------------------------------|------------------------------------------------------------------------------------------------|-------------------|-----------------------------------------------------------|-----------------------|----------------------|-----------------------------------------|
|                     |               | 1          | 65      | M   | Lung carcinoma: pneumonectomy                                                     | n/a               | Ventricular fibrillation     | i.v. heparin 100 UI/kg (bolus), followed by i.v. heparin infusion to achieve an ACT > 140-160" | n/a               | n/a                                                       | n/a                   | n/a                  | Alive at the hospital discharge         |
|                     |               | 1          | 65      | M   | Lung carcinoma: bilobectomy                                                       | n/a               | Cardiogenic shock            | i.v. heparin 100 UI/kg (bolus), followed by i.v. heparin infusion to achieve an ACT > 140-160" | n/a               | n/a                                                       | n/a                   | n/a                  | Dead to decannulation                   |
|                     |               | 1          | 24      | M   | Tuberculosis: pneumonectomy                                                       | n/a               | Cardiogenic shock            | i.v. heparin 100 UI/kg (bolus), followed by i.v. heparin infusion to achieve an ACT > 140-160" | n/a               | n/a                                                       | n/a                   | n/a                  | Alive at the hospital discharge         |
| Harris, 2018 [22]   | Retrospective | 1          | 67      | M   | Left-sided empyema: decortication                                                 | Thoracoscopy      | Hemorrhagic Shock            | n/a                                                                                            | 48                | n/a                                                       | n/a                   | 38                   | In-hospital death                       |
| Rinieri, 2020 [15]  | Case report   | 1          | 56      | M   | Pulmonary nodule: segmentectomy                                                   | VATS              | Cardiac arrest               | n/a                                                                                            | 24                | Epinephrine                                               | 7                     | 18                   | Alive 60 d later                        |
| Sakakura, 2021 [17] | Case report   | 1          | 21      | M   | AMM (teratoma): resection                                                         | Thoracotomy       | Hemorrhagic shock            | n/a                                                                                            | n/a               | n/a                                                       | n/a                   | 14                   | Alive 1 y later                         |
| Leow, 2021 [20]     | Case series   | 1          | 23      | M   | AMM, SVC obstruction, PA compromise, compression of airway and left phrenic nerve | Bronchoscopy      | PEA                          | n/a                                                                                            | 192               | Noradrenaline 0.1 mcg/kg/min                              | n/a (admitted in ICU) | 58                   | Alive at the hospital discharge         |

(Continues)

TABLE 2 | (Continued)

| Author, year                                | Study design | No. of pts | Age (y) | Sex | Main indication for surgery and surgical procedure performed | Surgical approach | Reason for tMCS implantation | Anticoagulation type and dosage                            | tMCS duration (h)                          | Intraoperative inotropes and vasopressors (type and dose) | ICU stay (d) | In-hospital stay (d) | Pt status at latest follow-up available |
|---------------------------------------------|--------------|------------|---------|-----|--------------------------------------------------------------|-------------------|------------------------------|------------------------------------------------------------|--------------------------------------------|-----------------------------------------------------------|--------------|----------------------|-----------------------------------------|
| Combined tMCS (i.e., multi-device strategy) |              |            |         |     |                                                              |                   |                              |                                                            |                                            |                                                           |              |                      |                                         |
| IABP + V-A ECMO                             |              |            |         |     |                                                              |                   |                              |                                                            |                                            |                                                           |              |                      |                                         |
| S. Lee, 2011 [14]                           | Case report  | 1          | 51      | M   | Squamous carcinoma IIIa: lobectomy                           | Thoracotomy       | n/a                          | 1) Cardiac arrest<br>2) Cardiac arrest: Takostubo syndrome | 1) IABP: 48 postop.<br>2) ECMO: 26 postop. | Inotropes                                                 | 11           | 20                   | Alive 1 y 6 months later                |
| V-A ECMO + Impella                          |              |            |         |     |                                                              |                   |                              |                                                            |                                            |                                                           |              |                      |                                         |
| Hara, 2023 [16]                             | Case report  | 1          | 75      | M   | Thoracic mass nodule: robot-assisted left lower lobectomy    | Thoracoscopic     | n/a                          | Postop. IHCA                                               | 1) V-A ECMO: 144<br>2) IABP Impella: 192   | n/a                                                       | n/a          | 109                  | Alive 1 y later                         |

Abbreviations: ACT, activated clotting time; AMM, anterior mediastinal mass; CPB, cardiopulmonary bypass; d, days; F, female; h, hours; IABP, intra-aortic balloon pump; ICU, intensive care unit; i.v., intravenous; L.A, left atrium; M, male; n., number; n/a, not available; PA, pulmonary artery; PEA, pulseless electrical activity; postop, postoperative; SVC, superior vena cava; tMCS, temporary mechanical circulatory support; y, years; V-A ECMO, veno-arterial extracorporeal membrane oxygenation; VATS, video-assisted thoracoscopic surgery.

after the first surgery. Five weeks after the first surgery, the patient was discharged to a rehabilitation facility.

In both cases, the authors did not report any ECMO-related complications. Despite significant variations in the length of in-hospital stays, both patients were discharged alive.

### 3.3 | Bail-Out tMCS

Ten studies (for a total of 14 patients) reporting on the use of tMCS as a rescue (i.e., “bail-out”) strategy for cases of intraoperative hemodynamic instability were retrieved [12–17, 19, 20, 22, 23]. The majority of patients (13 of 14, 99%) were male. All the studies were conducted between 2011 and 2023, and most of them (8 of 10) were case reports or case series [12–17, 19, 20], with one retrospective study [22] and one prospective study only [23].

#### 3.3.1 | CPB

A 2011 report by Anderson et al. [12] described the use of CPB as a rescue therapy during video-assisted thoracoscopic surgery (VATS). A previously healthy 45-year-old woman underwent surgery to perform the biopsy of a mediastinal mass, which caused minimal airway compression, right pleural effusion, leftward cardiac displacement, left atrial encroachment, and esophageal compression.

As part of the preoperative planning, guide wires were placed in both the femoral artery and vein before anesthesia induction to facilitate potential cannulation as a bail-out strategy. Anesthesia induction was then performed in a sitting position to mitigate the occurrence of potential respiratory and cardiovascular symptoms. Immediately after induction, a rapid decline in both hemodynamic and respiratory function occurred despite fluid resuscitation, inotropic, and vasopressor support.

Transesophageal echocardiography revealed a near-complete left atrial compression by the mass. CPB was initiated 20 min after the onset of respiratory and hemodynamic decompensation. Following pleural and pericardial drainage, CPB was terminated at the conclusion of the procedure. The patient was transferred to the ICU with stable hemodynamics without inotropes and/or vasopressors.

During the preoperative work-up, V-A ECMO was considered as well, but CPB was ultimately preferred due to its faster weaning process, considering the necessity for urgent radiation therapy, scheduled for the following day. The patient was discharged alive from the hospital, with the most recent follow-up data available at 3 months postoperatively.

#### 3.3.2 | IABP

The use of IABP as a bail-out strategy was reported in two cases, both describing male patients undergoing elective thoracic surgical procedures.

Ahmadi et al. [19] described the case of a 64-year-old man undergoing tracheal anastomosis and resection due to postintubation stenosis, who had a history of myocardial infarction, with a known enlarged LV and LVEF of 20%. The patient experienced sudden intraoperative cardiogenic shock, requiring the insertion of IABP. The IABP was removed 6 h postoperatively, and the patient was discharged without any additional complications.

In a second report by Awari et al. [13], the authors described the case of a 68-year-old man undergoing bronchoscopy for a lung mass. This patient had significant cardiovascular comorbidities. Following fiberoptic intubation, the patient experienced hypotension, bradycardia, and desaturation followed by cardiac arrest. CPR was initiated, and epinephrine was administered. Despite multiple episodes of return to spontaneous circulation (ROSC) within the first hour, the patient experienced recurrent pulseless electrical activity (PEA). Electrocardiogram findings suggested a potential ischemic event, and transesophageal echocardiography revealed regional wall motion abnormalities and an EF of 10%. A coronary angiography identified the culprit lesions, which were treated with percutaneous coronary intervention. The IABP was inserted prior to the transfer of the patient to the ICU. Upon ICU admission, despite ongoing epinephrine infusion, the patient exhibited bradycardia and cardiovascular decompensation. Further clinical and laboratory findings pointed to an underlying thyroid disorder, which was later confirmed to be Hashimoto's thyroiditis. Within 8 h, hemodynamic parameters began to improve, allowing for a de-escalation of inotropes and vasopressor doses. By the second day, vasopressors were weaned, the IABP was removed, and the patient was transferred to the ward on postoperative day four. The patient was discharged on day six, without neurological sequelae.

### 3.3.3 | V-A ECMO

A total of five articles were identified, all published between 2017 and 2021, describing the use of V-A ECMO as a rescue therapy in patients developing perioperative acute cardiovascular decompensation. These studies included a total of nine patients, all male, with a median age of 63 years (IQR: 23.5-65.5).

Among them, four had lung carcinoma which required lobectomy or pneumonectomy [23]. One patient underwent pneumonectomy due to tuberculosis [23], another underwent thoracoscopic decortication for empyema [22], and one underwent thoracoscopic segmentectomy for a pulmonary nodule [15]. Two patients who presented with an anterior mediastinal mass (AMM) underwent thoracotomy for surgical excision in one case and bronchoscopy in the other [17, 20]. The surgical approach for the remaining patients was not reported.

Peripheral cannulation was employed in all cases presented, except for one patient, where the cannulation technique of choice was not documented.

In the study by Lee et al. [23], encompassing a total of five patients, V-A ECMO was implanted postoperatively within a maximum of 4 days after surgery for the following reasons: cardiogenic shock in three cases, hypovolemic shock in one, and ventricular fibrillation (VF) in the remaining one. The patient implanted for cardiogenic

shock died during the decannulation process, while the others survived until hospital discharge. However, this prospective study lacked detailed information on the duration of ECMO support, ICU stay, and in-hospital stay for each patient.

In a retrospective study by Harris et al. [22], the authors described 18 patients in which ECMO was implanted after thoracic surgery. While most patients were supported with V-V ECMO, it is relevant to our review the case of a patient with empyema, in which V-A ECMO support was required to manage the hemorrhagic shock developed during surgery. However, the patient was unable to be weaned from ECMO and ultimately died on the 38th postoperative day.

In the report by Rinieri et al. [15], the authors reported the case of a patient who underwent VATS for segmentectomy. Asystole occurred immediately after the placement of the first thoracic port. The approach then was converted to open thoracotomy to exclude cardiac bleeding and to allow for internal resuscitation. After 4 min of no-flow, internal cardiac massage was started, followed by the occurrence of VF. After 45 min of low flow, V-A ECMO was implanted, resulting in ROSC. The coronary angiography revealed CAD, and a redo thoracotomy was required to achieve pericardial hemostasis. ECMO weaning for cardiac recovery began on day two. The patient was discharged from the hospital on the 18th postoperative day with an EF of 45% and no signs of central neurological impairment.

Sakakura et al. [17] described the case of a 21-year-old patient diagnosed with a mediastinal tumor and scheduled for excision. During surgery, the mass was found to be expanding around the pericardium, thus compressing the heart. While dissecting the tumor, the rupture of the pulmonary trunk resulted in hemorrhagic shock and the need for internal cardiac massage. V-A ECMO was implanted after 20 min of low flow. Complete tumor resection was successfully achieved, and the patient awoke the following day without neurological deficits. The patient was discharged 14 days later. Patient survival was confirmed at the 1-year follow-up assessment.

In a case series, Leow et al. [20] reported the case of a patient with an AMM compressing the superior vena cava, great vessels, pulmonary artery, airways, and causing diaphragmatic paralysis. Due to the impending risk of airway compromise, the patient's right femoral artery and vein were percutaneously cannulated in preparation for ECMO before surgery. Distal to the armored endotracheal tube, marked compression of the carina, as well as of the right and left main bronchus, was evident. At the end of surgery, the patient was transferred to the ICU, where maintaining adequate ventilation was challenging due to external compression. This led to a cardiac arrest in PEA. After ROSC and with norepinephrine continuously infused, V-A ECMO was initiated to manage hemodynamic instability. The patient was decannulated after 8 days but developed an infection at the ECMO site, which required surgical intervention. He survived and was discharged 58 days postoperatively.

### 3.3.4 | Combined tMCS (i.e., MultiDevice Strategy)

Two case reports described the combined use of multiple tMCS as a rescue therapy.

Lee et al. [14] reported the case of a 51-year-old man undergoing lobectomy for squamous cell carcinoma. During the dissection of the left lower lobe, the patient experienced ST-segment elevation, alongside hypotension and bradycardia, followed by cardiac arrest. The surgical team performed internal cardiac massage while placing IABP. Sinus rhythm and subsequently an acceptable hemodynamic state were restored. After surgery, the patient was transferred to the ICU, where another cardiac arrest occurred, requiring the implantation of V-A ECMO. Echocardiography revealed apical ballooning and severe left ventricular dysfunction, while coronary angiography ruled out CAD, leading to a diagnosis of stress-induced cardiomyopathy. Once vital signs were stabilized, inotropic support was weaned. V-A ECMO was removed 26 h after surgery, followed by IABP removal 48 h after surgery. The patient developed compartment syndrome, necessitating fasciotomy of the right lower extremities. The patient was discharged on the 20th day postoperatively with normal echocardiographic findings and survived for 18 months.

In a subsequent case report by Hara et al. [16] the authors described a 75-year-old patient with no prior cardiovascular comorbidities who underwent robot-assisted left lower lobectomy. However, the patient experienced a cardiac arrest on the second postoperative day. After the return of spontaneous circulation (ROSC), an echocardiogram showed an EF of 30%, alongside diffuse LV hypokinesis. Coronary angiography revealed critical stenosis in two coronary vessels, which were stented. Due to the profound cardiogenic shock, V-A ECMO was implanted, with the additional necessity of IABP to stabilize hemodynamic parameters and unload the LV. However, the IABP support was shortly thereafter upgraded to an Impella 5.0 device to further improve LV unloading and hemodynamics. Over the following days, the weaning process from both V-A ECMO and Impella 5.0 was started, and V-A ECMO and Impella 5.0 were removed after 6 and 8 days, respectively. The patient was discharged alive 109 days postoperatively.

### 3.4 | Relative Risk Analysis of Mortality and Complications in Pre-Emptive Versus Bail-Out tMCS Strategies

The relative risk (RR) for three primary clinical outcomes (i.e., mortality, infectious complications, and vascular complications) along with a composite outcome (encompassing all complications) was calculated to compare the pre-emptive and bail-out tMCS implantation strategies (Figure 3). Although not statistically significant, a trend was observed suggesting fewer complications in patients who received pre-emptive tMCS implantation compared to those treated with the bail-out approach. Specifically, the mortality rate in the pre-emptive group was half that of the bail-out group (RR: 0.5; 95% confidence interval [CI]: 0.05–4.9;  $p=0.55$ ). Similarly, the risk of infectious complications was lower in the pre-emptive group (RR: 0.33; 95% CI: 0.014–7.54;  $p=0.69$ ), as was the risk of vascular complications (RR: 0.33; 95% CI: 0.014–7.54;  $p=0.69$ ). For the composite outcome of any complication, the pre-emptive strategy showed an RR of 0.25 (95% CI: 0.03–1.966;  $p=0.187$ ). Despite these trends, none of the results reached statistical significance.

## 4 | Discussion

### 4.1 | Key Findings

The main findings of the present scoping review can be summarized as follows: (i) the perioperative use of tMCS in the setting of thoracic surgery for cardiac and hemodynamic support is rare and the evidence remains fragmented; (ii) the most commonly used type of tMCS for this purpose is the IABP; (iii) nearly 50% of tMCS is employed as a bail-out strategy rather than prophylactically; and (iv) despite this, tMCS is associated with improved patient survival and a low rate of complications (Figure 4).

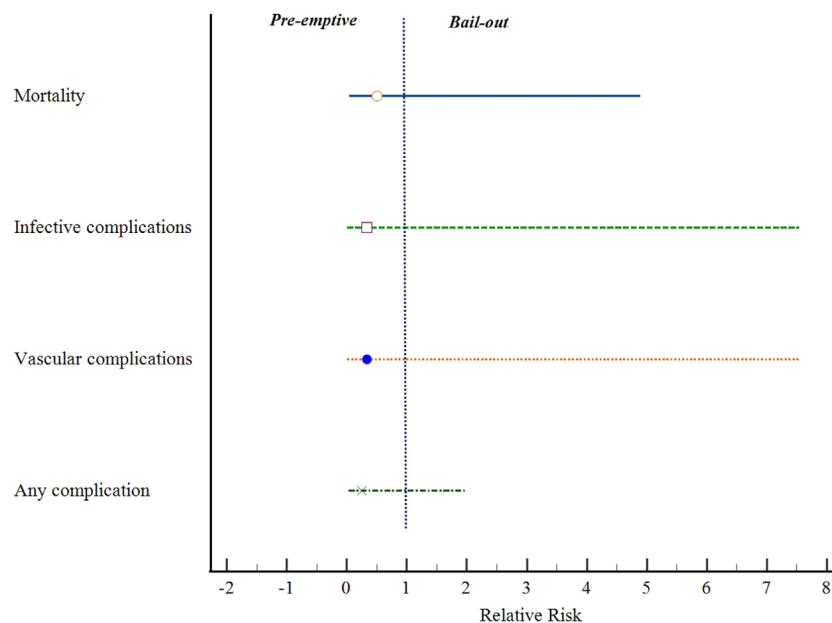


**FIGURE 3** | Relative risk of postoperative complications in the pre-emptive tMCS group versus bail-out. The vertical line at 1.0 indicates no difference in risk between groups, while error bars represent 95% confidence intervals. [Color figure can be viewed at [wileyonlinelibrary.com](https://onlinelibrary.wiley.com)]

# PERIOPERATIVE MECHANICAL CIRCULATORY SUPPORT FOR CARDIAC ASSISTANCE IN THORACIC SURGERY:

## A scoping review



### BACKGROUND

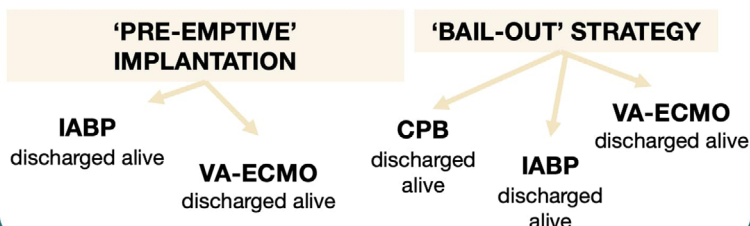
- High-risk cardiac patients are often denied **potentially curative non-cardiac surgeries**
- tMCS is often used to **stabilize complex cardiac patients** in cardiac surgery
- Can tMCS **improve outcomes in high-risk cardiac patients** undergoing thoracic surgery?

### METHODS

- Systematic database search of:  
*PubMed/MEDLINE, EMBASE, Cochrane Central Register of Controlled Trials, Web of Science, Scopus, Google Scholar*
- Adult patients undergoing thoracic surgery requiring perioperative tMCS implantation for circulatory support

### RESULTS

- 15 studies retrieved, 28 patients
- 15 IABP • 10 VA-ECMO • 1 CPB • 2 multi-device strategy



### CONCLUSION

- Perioperative circulatory support with tMCS may be feasible in thoracic surgery
- Complex cardiovascular patients may benefit from prophylactic tMCS implantation, enabling them to undergo lifesaving surgeries
- Further research focusing on outcomes and safety of tMCS in thoracic surgery is needed

**FIGURE 4** | Visual abstract presenting main article structure, objective, research methodology, and results. CPB, cardiopulmonary bypass; IABP, intra-aortic balloon pump; tMCS, temporary mechanical circulatory support; VA-ECMO, veno-arterial extracorporeal membrane oxygenation. [Color figure can be viewed at [wileyonlinelibrary.com](https://onlinelibrary.wiley.com/doi/10.1111/ao.14873)]

Our scoping review aimed to systematically describe the perioperative use of tMCS in complex patients undergoing thoracic surgery, while also highlighting the crucial role tMCS may play in maintaining hemodynamic stability and managing perioperative cardiac complications.

While heart disease is known to increase the risks associated with thoracic surgeries, specific statistics detailing the added risks posed by different underlying cardiac conditions are still lacking. As a result, patients with significant cardiac issues are often deemed ineligible for upfront surgery and referred to other less effective therapies as first-line treatment (e.g., chemotherapy and/or radiation therapy). Such exclusions may ultimately impact the overall prognosis of these patients. To support this assumption, it is demonstrated that elderly patients with early-stage small-cell lung cancer who underwent surgery had superior overall survival compared to those treated with radiotherapy alone [24].

The pathophysiological substrate underlying the rationale for the timely use of perioperative tMCS in this patient population lies in its ability to provide hemodynamic support, while also improving both pulmonary congestion and coronary perfusion, alongside reducing the occurrence of end-organ hypoperfusion.

As such, each specific tMCS device exhibits different hemodynamic implications. The IABP improves coronary perfusion by increasing MAP and lowers myocardial oxygen consumption by reducing the afterload [25]. Nevertheless, for the IABP to be effective, it requires a degree of residual left ventricular function, in the presence of which it can allow for improvement in the cardiac output [25]. A greater increase in cardiac output can also be provided by Impella (Abiomed, Denver, MA), which is a percutaneous or surgically implanted short-term ventricular assist device. V-A ECMO is a closed-circuit system that supports both oxygenation and circulation but increases cardiac afterload, and this often leads to the need for additional concomitant circulatory support—spanning inotropes, Impella, or IABP—for ventricular unloading [25]. In comparison, CPB is typically reserved for emergencies where hemodynamic instability is compounded by hemorrhagic shock. CPB has the ability to suction blood from the surgical field, though its use in patients with oncologic malignancies may pose them with an increased risk of cancer dissemination and is therefore discouraged [26]. While both V-A ECMO and CPB provide circulatory and respiratory support, CPB necessitates full heparinization, which can result in a higher bleeding risk and limits patient mobility, potentially delaying early treatments like radiotherapy [25]. As such, the use of ECMO support during noncardiac surgeries carries notable risks, including a significant potential for complications

such as hemorrhage [27]. Hence, bleeding is the most frequent complication in the context of tMCS. It affects up to 20% of patients and is often associated with major vessel injury during cannulation or anticoagulation therapy. Among these, severe bleeding events (e.g., intracerebral hemorrhage) are the most concerning, occurring in approximately 3% of ECMO patients based on ELSO registry data [28, 29]. However, when ECMO is employed prophylactically in patients with hemodynamic stability undergoing elective high-risk noncardiac procedures (i.e., thoracic surgeries), the bleeding risk may still remain within acceptable limits [26]. This rationale is further supported by evidence from cardiac surgery, where short-term use of extracorporeal support (i.e., conventional CPB) is typically not linked to severe coagulopathy, though some degree of platelet consumption, clotting factor activation, and fibrinolysis can occur [26]. Consequently, to further mitigate these risks, the implementation and adherence to validated point-of-care transfusion protocols are strongly recommended [30, 31].

## 4.2 | Relationship With Previous Literature

Given these considerations, the IABP is the most frequently used tMCS, as it was implemented in 50% of the cases to manage or prevent heart dysfunction during the perioperative period. The use of tMCS to support patients at high risk of perioperative cardiovascular complications has been widely applied in various noncardiac surgical settings, particularly in abdominal surgery. As such, the prophylactic use of IABP has been reported in 10 patients with underlying conditions spanning acute myocardial infarction, multivessel CAD, or aortic stenosis who were scheduled to undergo different surgical procedures (i.e., subtotal gastrectomy, nephrectomy, urgent colectomy or cholecystectomy, exploratory laparotomy, abdominal mass resection, and esophagogastrectomy) [32–35]. A decision-analytic model developed by Georgeson et al. assessed the balance between the risks of life-threatening postoperative complications and the potential complications associated with IABP placement. Interestingly, the model concluded that patients classified as Goldman class IV or Detsky class III—who are at exceptionally high risk for severe postoperative complications and cardiac death during major surgical procedures—are likely to derive significant benefit from intraoperative IABP support [36]. The widespread use of the IABP can be attributed to several factors: it is cost-effective, easy to deploy and remove (even after surgery), has few side effects, enhances coronary perfusion, and has a long history of clinical experience since 1979. Moreover, the IABP has led to an excellent prognosis even when used as a bail-out strategy.

Notably, among the 11 patients who received V-A ECMO, only two (18%) were implanted preoperatively as part of a planned perioperative strategy for patients. Theoretically, in the present review, at least 50% more patients might have benefited from a prophylactic approach rather than a bail-out strategy [15, 20], as their underlying CAD likely triggered the occurrence of intraoperative cardiogenic shock. In the remaining cases, V-A ECMO was implanted postoperatively for the following reasons: cardiogenic or hypovolemic shock and arrhythmias. Intraoperatively, the primary reason for V-A ECMO use was hemorrhagic shock during surgical dissection, suggesting that a hybrid approach—that is, in which femoral vessels are accessed preoperatively

with small-bore catheters to allow rapid emergent tMCS deployment—could be reasonable when the risk of massive hemorrhage is high.

While there is a growing body of literature on the use of Impella for managing cardiogenic shock in both the catheterization laboratory and the ICU [37, 38], there is limited experience regarding its role for hemodynamic stabilization in noncardiac surgery, and there are currently no studies which specifically evaluate the use of Impella in thoracic surgery. Guarracini et al. [39] reported the case of a 74-year-old man with advanced heart failure undergoing abdominal surgery, in whom Impella CP was preoperatively placed. Notably, the device was removed before extubation in the operating room. This case highlights that the prophylactic use of tMCS can be successfully limited to the intraoperative period only, when surgical stress, risk of bleeding, and susceptibility to acute decompensated heart failure are most likely to arise. Surgery can in fact exacerbate the underlying patient conditions and existing comorbidities (e.g., through fluid retention), potentially leading to sudden hemodynamic deterioration and adverse cardiac events. Montisci et al. [40] described a similar case of a 58-year-old man with a recent revascularized ST-elevation myocardial infarction (STEMI) complicated by cardiogenic shock. In this case, an Impella 5.0 was implanted, and the patient successfully underwent abdominal surgery. Similarly, Tavilla et al. described a case in which a patient successfully underwent off-pump coronary artery bypass grafting for acute myocardial infarction complicated by cardiogenic shock while supported by an Impella 5.5 device. The case highlighted the feasibility of performing off-pump coronary revascularization in the context of three-vessel disease without necessitating device displacement throughout the perioperative period [41]. Farhat et al. [42] reported that Impella successfully provided hemodynamic support in patients with chronic heart failure undergoing major vascular surgery.

Interestingly, compared to other types of surgery, thoracic surgery can be even more challenging. The requirement for one-lung ventilation—which may cause hypoxia, hypercapnia, and pulmonary hypertension—can in fact become a significant precipitating factor for the occurrence of cardiovascular events in patients with impaired native cardiovascular reserve. This assumption is further supported by Loop et al., who noted that while the primary indications for extracorporeal life support (ECLS) in thoracic surgery are airway resections and reconstructive procedures in patients with obstructive tracheobronchial diseases, rarer indications include lung surgeries in patients with poor pulmonary reserve or cases where one-lung ventilation is difficult or impossible [43]. These findings are also corroborated by Makdisi et al., who extensively reviewed the indications and outcomes associated with the nonemergent use of ECMO [44]. As such, ECLS technology, as an effective tool for managing oxygenation, hypercapnia, and hemodynamic support, has shown potential for increased application in elective pulmonary procedures. Furthermore, ECLS has gained traction in managing select life-threatening thoracic emergencies—both traumatic (i.e., blunt thoracic trauma, chest wall fractures, and penetrating lung injuries) and nontraumatic (i.e., mediastinal masses, acute lung injury, aspiration, embolisms, and acute or chronic heart failure). In such cases, ECLS shows promise as a valuable organ support strategy, providing a bridge to recovery

or facilitating decisions on definitive therapy, intervention, or surgery. Furthermore, by enabling rapid volume resuscitation and rewarming, it also helps prevent the lethal triad of trauma (i.e., hypothermia, hypoperfusion, and acidosis) [45].

The use of a combination of tMCS in the postoperative period also addresses the need to enhance hemodynamic support (e.g., by unloading the left ventricle or when a single tMCS device is insufficient to maintain adequate circulatory function). It is reasonable to begin in the operating theater with a less invasive form of tMCS (i.e., IABP) and then escalate to more complex combinations if necessary. In this review, we encountered two distinct cases involving a combined approach to provide tMCS. In the first case, the patient was initially supported with IABP, after which V-A ECMO was added to achieve comprehensive hemodynamic stabilization [14]. In contrast, the second case involved the use of an Impella alongside V-A ECMO [16]. The Impella was introduced to mitigate the increase in left ventricular end-diastolic pressure, which can result from the pressurization effects associated with V-A ECMO.

Interestingly, we observed that 14 of 28 (50%) patients received tMCS in emergency conditions. Although the outcome was excellent with only one death in the postoperative period, it is the authors' opinion that a multidisciplinary preoperative planning may enable the timely implantation of a tMCS (i.e., ideally before surgery) in high-risk patients, which can in turn result in a lower rate of perioperative complications and improved patient outcomes.

It is evident from various settings outside of thoracic surgery that the prophylactic use of tMCS, rather than its emergency deployment, is associated with lower morbidity and mortality.

An increased awareness of this possibility among clinicians can both expand surgical opportunities for patients with severe cardiac disease and reduce the rate of perioperative cardiac complications by identifying patients who would benefit from tMCS.

### 4.3 | Study Limitations and Future Directions

The methodological strengths of this review include a well-defined research question and a focused analysis of a specific population, alongside a predefined research protocol and a thorough assessment of the risk of bias for the retrieved observational studies.

Nevertheless, our investigation is not devoid of drawbacks. First, a comprehensive analysis of the collected studies has revealed that the retrieved articles frequently lack information on device management and patient outcomes. Additionally, in most cases, the studies were inadequate to provide a thorough description of the determinants of weaning from tMCS, which were frequently described in general terms. Moreover, the small sample size of patients ( $n = 28$ ) in the retrieved studies, combined with the lack of coherence in the data subsets, contributes to the heterogeneity of our findings and significantly limits their generalizability. Additionally, the absence of a proper control group in the included investigations prevented a formal meta-analytic comparison, as improvements

in patient outcomes cannot be demonstrated without a control group. As such, it is also worth mentioning that the majority of the existing literature on tMCS implantation in thoracic surgeries retrieved for inclusion in the present review is composed of case reports, case series, and observational studies, many of which involved limited sample sizes. These study designs are inherently more prone to reporting biases (i.e., publication bias) where positive outcomes are preferentially published while negative or less favorable outcomes may remain underreported. Such potential underrepresentation of negative experiences—whether isolated or systematic—should be considered when interpreting our findings. Hence, a key limitation of our study is its purely descriptive design, which—combined with the limited availability of definitive data and guidelines on the perioperative use and indications for tMCS in thoracic surgery—restricts the ability to perform a definitive evaluation of the potential advantages and disadvantages of the two tMCS strategies under investigation (i.e., pre-emptive and bail-out), ultimately hindering our study's capacity to draw firm conclusions regarding the comparative efficacy and outcomes of the aforementioned approaches.

Furthermore, detailed information regarding tMCS-related complications remains scarce. While five patients did not report device-related complications, an ECMO site infection and compartment syndrome were noted. The remaining studies failed to report even the absence of device-related adverse events, hindering our understanding of the overall safety profile of tMCS.

Of the 28 patients analyzed, follow-up data beyond hospital discharge were reported for five cases. The scarcity of this type of data, particularly regarding cardiac status postdischarge, limits our ability to fully understand the long-term implications of this intervention.

Lastly, in future studies, it would also be important to consider the number of patients deemed ineligible for thoracic surgery due to cardiovascular comorbidities, as there is a lack of data on the percentage of patients with severe cardiac dysfunction who are excluded from such procedures that could potentially benefit from incorporating tMCS into their treatment plan. In this regard, this scoping review systematically synthesized the available literature on the use of tMCS for cardiovascular support in thoracic surgery. Specifically, we aimed to raise awareness among thoracic surgeons and anesthesiologists by advocating for the adoption of innovative strategies (i.e., timely tMCS implantation), which have already demonstrated effectiveness in both cardiac surgery and interventional cardiology settings [26].

## 5 | Conclusions

In this scoping review, we found that the timely implantation of tMCS in thoracic surgery may lead to better patient outcomes, as well as allow them to undergo curative surgery with an acceptable safety profile, characterized by overall good survival rates and low incidence of device-related complications. The most common indications for tMCS implantation identified were either to mitigate patients' heightened cardiovascular risk (i.e., pre-emptive) or when life-threatening surgical complications occurred (i.e., bail-out). However, the available data remain sparse

and are predominantly derived from individual case reports, case series, and small observational studies, with a likely underreporting of negative or less favorable outcomes. This underscores that—at present—the use of tMCS for cardiac assistance in thoracic surgery remains largely anecdotal. Consequently, our investigation needs to be considered as hypothesis-generating only.

## Author Contributions

**Viviana Teresa Agosta:** investigation, data curation, and writing – original draft. **Jacopo D'Andria Ursoleo:** conceptualization, investigation, supervision, writing – original draft, and writing – review and editing. **Alice Bottussi:** investigation and writing – review and editing. **Samuele Bugo:** investigation, data curation, and writing – original draft. **Fabrizio Monaco:** conceptualization, supervision, and writing – review and editing.

All authors have read and approved the final version of the manuscript.

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## Ethics Statement

The authors have nothing to report.

## Consent

The authors have nothing to report.

## Conflicts of Interest

The authors declare no conflicts of interest.

## Data Availability Statement

Further information is available from the corresponding authors upon request.

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### Supporting Information

Additional supporting information can be found online in the Supporting Information section.