Interventional procedure overview of VA ECMO for postcardiotomy cardiogenic shock in adults

Contents

Table 1 Abbreviations

Abbreviation	Definition
AHF	Acute heart failure
AMI	Acute myocardial infarction
ARDS	Acute respiratory distress syndrome
CABG	Coronary artery bypass grafting
CI	confidence interval
CPB	Cardiopulmonary bypass
CPR	Cardiopulmonary resuscitation
ECPR	Extracorporeal cardiopulmonary resuscitation
ELSO	Extracorporeal life support organisation
GI	Gastrointestinal
HTx	Heart transplant
IABP	Intra-aortic balloon pump
ICU	Intensive care unit
IQR	Interquartile range
OPCABG	Off-pump coronary artery bypass grafting
OR	Odds ratio
PCI	Percutaneous coronary intervention
PCS	Postcardiotomy cardiogenic shock
PE	Pulmonary embolism
PGF/PGD	Primary graft failure/dysfunction (following heart transplantation)
PSM	Propensity score matched
RR	Relative risk
RRT	Renal replacement therapy
RV	Right ventricle
SD	Standard deviation
VA ECMO	Venoarterial extracorporeal membrane oxygenation
VAD	Ventricular assist device

The condition, current treatments, unmet need and procedure

Information about the procedure, condition, current practice and unmet need is available in section 2 and 3 of NICE's interventional procedures consultation document on VA ECMO for postcardiotomy cardiogenic shock in adults

Outcome measures

The main outcomes included survival or mortality.

Evidence summary

Population and studies description

This interventional procedure overview is focused on VA ECMO in postcardiotomy cardiogenic shock. Two additional overviews have been developed focusing on VA ECMO use in severe acute heart failure and as extracorporeal cardiopulmonary resuscitation (ECPR). Some of the evidence includes a mix of indications and has been presented in more than one overview.

This interventional procedures overview is based on approximately 46,300 people from 4 systematic reviews (Biancari 2018, Wang 2018, Kowalewski 2020, Alba 2021), 2 retrospective registry studies (Kowalewski 2021, Loungani 2021), 1 multicentre retrospective study (Bonacchi 2020) and 3 single centre retrospective studies (Chen 2017, Chen 2020, Danial 2023). There were 29 overlaps accounting for 3,830 people in primary studies included across 4 systematic reviews (Biancari 2018, Wang 2018, Kowalewski 2020, Alba 2021). No primary studies included in the key evidence were also included in the systematic reviews. This is a rapid review of the literature, and a flow chart of the complete selection process is shown in figure 1. This overview presents 10 studies as the key evidence in table 2 and table 3, and lists 16 other relevant studies in table 5.

The 4 systematic reviews of observational studies included in the key evidence included studies from Asia, Australia, Europe, North America and South America (Wang 2018, Alba 2021), however 2 systematic reviews did not report study

location (Biancari 2018, Kowalewski 2020). Registry studies in the key evidence were done from the Extracorporeal Life Support Organization (ELSO) which collates data worldwide (Kowalewski 2021), and from the RESCUE registry collating data from 3 centres across the US. The included propensity matched retrospective study was done at a single centre in Taiwan (Chen 2017), and the 2 other single-centre studies included were done in China and France (Chen 2020, Danial 2023). A multicentre retrospective study from Europe (Bonacchi 2020) was also included.

All key evidence studies included people who needed VA ECMO after cardiac surgery. Two systematic reviews (Wang 2018, Kowalewski 2020), 1 registry study (Kowalewski 2021) and 1 single centre retrospective study (Chen 2020) specifically reported on patients with postcardiotomy cardiogenic shock (PCS). One systematic review (Alba 2021), and 1 single centre retrospective study (Danial 2023) included people with cardiogenic shock of multiple aetiologies, and 1 registry study included people who had VA ECMO for several aetiologies (Loungani 2021).

The systematic review by Biancari et al. (2018) included 31 observational studies reporting on 2,986 adults needing VA ECMO after cardiac surgery. Most primary studies included in this study had populations with a mix of cardiac surgery procedures (29 studies) and 2 studies included isolated coronary surgery patients. The mean age was 58 years and 31% of the population were female. Meta-analyses of the studies pooled survival outcomes from studies with follow-ups of 30 days and hospital discharge.

The systematic review by Wang et al. (2018) included 20 observational studies reporting on 2,877 people with postcardiotomy cardiogenic shock who had ECMO treatment. Risk of bias across studies included in the review was considered high as all studies were retrospective in nature. The baseline characteristics (age and percentage male) of the people in the included studies

was not reported. Meta-analyses of the studies reported pooled survival outcomes at hospital discharge, at 1-year, and midterm survival (defined as 3 to 5 years).

The systematic review by Kowalewski et al. (2020) included 54 observational studies reporting on 4,421 people with postcardiotomy refractory cardiogenic shock. It included people who had CABG, valvular surgery and combined surgery at specialist heart transplant and non-heart transplant centres. Studies were considered to have a moderate to severe risk of bias. The age of people included in the studies ranged from 41 to 77 years, and 49% to 93% of the population were female. Meta-analyses of the studies pooled survival outcomes from studies with follow-up to hospital discharge.

The systematic review by Alba et al. (2021) included 306 observational studies reporting on 29,289 people with cardiogenic shock of any aetiology. This included 8,231 people with postcardiotomy cardiogenic shock. Risk of bias across studies was considered low in 219 (72%), moderate in 81 (26%), and high in 6 (2%) studies. The age of people included in the studies ranged from 47 to 61 years, and 22% to 59% of the population were female. Meta-analyses of the studies pooled short-term outcomes from studies with follow-ups of 30 days and hospital discharge.

The single centre retrospective study by Chen et al. (2017) was the only comparative study included in the key evidence. It used propensity score matching (PSM) to compare outcomes between people admitted for cardiac surgery (CABG or valve surgery) who had PCS and ECMO (n=1,137) and those who did not have PCS (or ECMO) following cardiac surgery (n=5,685). The mean age was 64 years and 71% of the population were male. Outcomes were reported for a follow-up period until hospital discharge and up to 10 years.

The retrospective ELSO registry study by Kowalewski et al. (2021) reported efficacy and safety outcomes for 7,185 adults having VA ECMO for intra-operative failure to wean from CPB due to right, left or biventricular failure, and post-operative refractory cardiogenic shock or cardiac arrest during the hospitalisation after the surgical procedure. This included people whose primary procedure was CABG, valvular surgery, heart transplant and combined surgery. The mean age was 56 years and 68% of the population were male. Outcomes were reported for a follow-up period until hospital discharge.

The retrospective RESCUE registry study by Loungani et al. (2021) reported efficacy and safety outcomes for 723 adults treated with VA ECMO, including those with persistent circulatory failure postcardiotomy (31%). The mean age was 57 years and 70% of the population were male. Outcomes were reported for a follow-up period until hospital discharge.

The single centre retrospective study done in France by Danial et al. (2023) included 1,253 adults treated with peripheral VA ECMO for cardiogenic shock, 297 of which were postcardiotomy patients (excluding primary graft dysfunction [PGF] following heart transplant). The mean age was 55 years and 30% of the population were female. Outcomes were reported for a follow-up period until hospital discharge and 5 years.

The single centre retrospective study done in China by Chen et al. (2020) included 121 people who had VA ECMO for postcardiotomy cardiogenic shock following CABG surgery. ECMO was needed for delayed cardiogenic shock in the ICU for 63 people, inability to wean from CPB in 39 people, and cardiac arrest in 19 people. The median age was 62 years and 79% of the population were male. Outcomes were reported for a follow-up period until hospital discharge and 36 months.

The multicentre retrospective study done in Europe by Bonacchi et al (2020) included 209 adults having ECLS following cardiac surgery. Prior to having ECMO, 17% people had thoracic aortic surgery, 14% CABG, 13% CABG plus mitral valve surgery, amongst other procedure types. The mean age was 68 years and 30% of the population were female. Outcomes were reported for a median follow-up period of 39 months (range 1 to 168 months).

Table 2 presents study details.

Figure 1 Flow chart of study selection

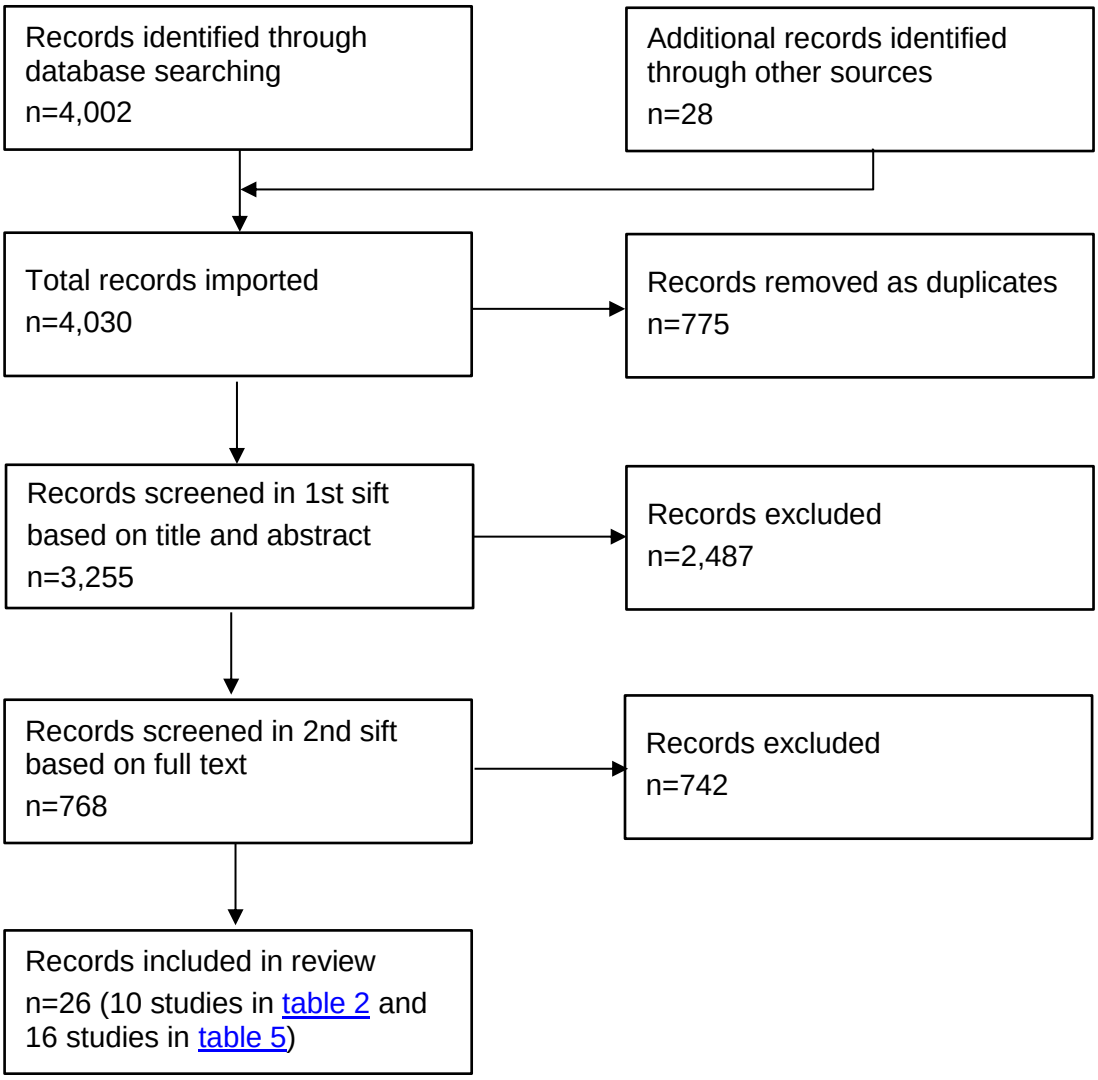

Table 2 Study details

Study no.	First author, date country	Characteristics of people in the study (as reported by the study)	Study design	Inclusion criteria	Intervention	Follow up
1	Biancari, 2018 Countries not reported	**n=2,986** Mean age=58.1 years Female= 30.9% Procedure types prior to ECMO: • Isolated coronary surgery (2 studies) • Mixed cardiac surgery procedures (29 studies) • Proportion of HTx patients in included studies: 4.4% (28 studies, n=2,879)	Systematic review and meta-analysis of 31 studies. Search date: Sept 2016	Adults who required VA ECMO after cardiac surgery procedure.	VA ECMO	1 year
2	Wang 2018, USA, Taiwan, Germany, Italy, China	**n=2,877** Mean age not reported Male % not reported Procedure types prior to ECMO: • CABG: 18 studies • Valve procedure: 14 studies • Aortic surgery: 6 studies • Heart transplant: 5 studies • Other: 9 studies	Systematic review and meta-analysis of 20 retrospective studies.	People after cardiac surgery with postcardiotomy cardiogenic shock (PCS).	VA ECMO	In-hospital, 1 year

Study no.	First author, date country	Characteristics of people in the study (as reported by the study)	Study design	Inclusion criteria	Intervention	Follow up
3	Kowalewski 2020 Countries not reported	**n=4,421** Age (years): Range 41 to 77 Male %: Range 49 to 93 <u>Procedure types prior to ECMO:</u> • CABG • Valvular surgery • Combined surgeries	Systematic review and meta-analysis of 54 retrospective studies. Search date: March 2018	Postcardiotomy refractory cardiogenic shock	VA ECMO	In-hospital
4	Alba, 2021 Europe, Asia, North America, South America, Australia	**n=29,289** Age (years): Range 47 to 61 Female %: Range 22 to 59 <u>Indication</u> • ECPR: 7,814 (113 cohorts) • Post-AMI: 7,774 (80 cohorts) • **<u>Postcardiotomy: 8,231 (64 cohorts)</u>** • Post-HTx: 771 (25 cohorts) • Heart failure: 3,567 (33 cohorts) • Myocarditis: 906 (13 cohorts) Pulmonary embolism: 221 (10 cohorts)	Systematic review and meta-analysis of 306 observational studies. Search date: June 2019	Adults (aged 18 and over) with **cardiogenic shock of any aetiology**, with VA ECMO implantation.	VA ECMO Concomitant IABP: Range 20 to 67%	30 day or in-hospital

Study no.	First author, date country	Characteristics of people in the study (as reported by the study)	Study design	Inclusion criteria	Intervention	Follow up
5	Chen, 2017 Taiwan	**n=1,137 ECMO** (5,685 propensity matched cohort) Mean age (years)=63.8 (SD 13.2) Male=71.2% <u>Procedure types prior to ECMO:</u> • CABG alone: 63.9% (728) • Valve alone: 24.2% (275) • CABG + Valve: 11.8% (134)	Propensity score-matched retrospective single centre study.	Adults (aged over 18 years) admitted for cardiac surgery (CABG or valve surgery)	Intervention: VA ECMO (people with PCS) Comparator: No VA ECMO (people without PCS) (propensity score matched)	In-hospital, 10 years
6	Kowalewski, 2021 Worldwide	**n=7,185** Mean age (years)=56.3 (range 18 to 86) Male=67.5% Procedure types prior to ECMO: • CABG: 26.8% • Valvular surgery: 25.6% • Heart transplant: 20.7% • CABG with valve: 13.4% • CABG with VAD: 8.5%	Retrospective ELSO Registry study Search date: 2010 to 2018	Adults over 18 years old undergoing a single run VA ECMO for refractory PCS. People with pre-operative ECMO were excluded.	VA ECMO initiated for intra-operative failure to wean from CPB due to right, left or biventricular failure, and post-operative refractory cardiogenic shock or cardiac arrest during the hospitalisation after the surgical procedure.	In-hospital

Study no.	First author, date country	Characteristics of people in the study (as reported by the study)	Study design	Inclusion criteria	Intervention	Follow up
7	Loungani, 2021 US	**n=723** Median age (years)=57 Male=69.6% <u>Indication</u> • Postcardiotomy (30.7%) • Cardiomyopathy (26.1%) • MI (16.9%) • Non-cardiogenic shock (11.3%) • HTx/graft dysfunction (8.2%) • Other cardiogenic shock (6.8%)	Retrospective RESCUE Registry study Search date: 2007 to 2017	Adult patients (over 18 years old) treated with ECMO.	VA ECMO	In-hospital
8	Danial, 2023 France	**n=1,253** (n=297 postcardiotomy excluding PGF) Mean age (years)=54.8 (SD:14.9) Female=30%	Single centre retrospective study Search date: 2015 to 2018	Adult patients (over 18 years old) treated with peripheral VA ECMO for cardiogenic shock.	VA ECMO	In-hospital, 5 year

Study no.	First author, date country	Characteristics of people in the study (as reported by the study)	Study design	Inclusion criteria	Intervention	Follow up
		Indication • **Postcardiotomy excluding PGF (n=297)** • PGF (n=245) • AMI (n=233) • Cardiomyopathy (n=171) • Fulminant myocarditis (n=47) • Massive PE (n=41) • Sepsis induced cardiogenic shock (n=29) • Refractory vasoplegia shock (n=9) • Drug overdose (n=25) • Arrhythmic storm (n=30) • Other/unknown aetiology (n=126)				
9	Chen, 2020 China	**n=121** Median age (years)=62 (IQR: 55 to 67) Male=79% Indication	Single centre retrospective study. Search date: 2012 to 2016	People post-CABG who had VA ECMO for PCS.	VA ECMO	Discharge, 36 months

Study no.	First author, date country	Characteristics of people in the study (as reported by the study)	Study design	Inclusion criteria	Intervention	Follow up
		• Unable to wean from CPB (n=39) • Delayed cardiogenic shock in ICU (n=63) • Cardiac arrest (n=19)				
10	Bonacchi, 2020 Europe	**n=209** Mean age (years)=67.52 (SD:15.8) Female=30.1% <u>Procedure types prior to ECMO:</u> • CABG: 13.9% (29) • OPCABG: 4.5% (9) • Aortic valve (AV): 5.7% (12) • Mitral valve (MV): 9.5% (20) • Thoracic aortic: 17.2% (36) • Type A dissection: 6.2% (13) • CABG+AV: 7.6% (16) • CABG+MV: 13% (27) • AV+MV: 10.5% (22) • AV+ thoracic aortic: 6.7% (14) • Other surgery: 11.5% (24)	Multicentre retrospective study. Search date: 2004 to 2018	Adults (18 years old and over) having post-cardiac surgery ECLS	ECLS	Median follow-up was 38.8 (1 to 168) months

Table 3 Study outcomes

First author, date	Efficacy outcomes	Safety outcomes
Biancari, 2018	**Pooled hospital survival** Meta-analysis random effects model, 31 studies (n=2,986) • 36.1% (95% CI 31.5 to 40.8), I^2=84% **Pooled 1-year survival (Kaplan-Meier estimate)** Meta-analysis random effects model, 11 studies (n=1,290) • 30.9% (95% CI 24.3 to 37.5), I^2=82% **Pooled weaning from VA ECMO** Meta-analysis random effects model, 24 studies (n=2,049) • 59.5% (95% CI 54.6 to 64.3), I^2=77% **Pooled rate of post-ECMO HTx** Meta-analysis random effects model, 21 studies (n=1,685) • 1.9% (95% CI 1.0 to 2.8), I^2=50% **Pooled hospital survival of post-ECMO HTx recipients** Meta-analysis random effects model, 7 studies (n=18) • 66.2% (95% CI 48.2 to 84.1), I^2=0%	**Pooled rate of reoperation for bleeding** Meta-analysis random effects model, 18 studies (n=1,779) • 42.9% (95% CI 34.2 to 51.5), I^2=93% **Pooled rate of major neurological events** Meta-analysis random effects model, 16 studies (n=1,736) • 11.3% (95% CI 7.8 to 14.8), I^2=79% **Pooled rate of limb ischaemia** Meta-analysis random effects model, 16 studies (n=1,909) • 10.8% (95% CI 8.0 to 13.5), I^2=70% **Pooled rate of lower limb amputation** Meta-analysis random effects model, 5 studies (n=330) • 1.1% (95% CI 0.0 to 2.3), I^2=0% **Pooled rate of deep sternal wound infection/mediastinitis** Meta-analysis random effects model, 4 studies (n=490) • 14.7% (95% CI 4.0 to 25.4), I^2=92%

First author, date	Efficacy outcomes	Safety outcomes
	Pooled rate of post-ECMO VAD implantation Meta-analysis random effects model, 21 studies (n=1,685) • 2.3% (95% CI 1.3 to 3.4), I^2=57% **Pooled hospital survival of post-ECMO VAD recipients** Meta-analysis random effects model, 9 studies (n=45) • 45.6% (95% CI 28.0 to 63.1), I^2=43%	**Pooled rate of renal replacement therapy** Meta-analysis random effects model, 19 studies (n=1,979) • 47.1% (95% CI 38.9 to 55.2), I^2=92%
Wang 2018	**Pooled survival to hospital discharge** Meta-analysis random effects model, 20 studies (n=2,877) • 34% (95% CI 30 to 38), I^2=71.8% **Pooled 1-year survival rate** Meta-analysis random effects model, 6 studies (n=1,860) • 24% (95% CI 19 to 30), I^2=75.6% **Pooled midterm survival rate (3- to 5-year)** Meta-analysis random effects model, 4 studies (n=742) • 18% (95% CI 11 to 27), I^2=77.3%	**Pooled rate of leg ischaemia** Meta-analysis random effects model, 11 studies (n=945) • 14% (95% CI 10 to 20), I^2=74.8% **Pooled rate of reoperation for bleeding** Meta-analysis random effects model, 10 studies (n=1,268) • 50% (95% CI 32 to 68), I^2=96.6% **Pooled rate of renal failure** Meta-analysis random effects model, 12 studies (n=1,279) • 57% (95% CI 47 to 66), I^2=87.1% **Pooled rate of neurological complications**

First author, date	Efficacy outcomes	Safety outcomes
		Meta-analysis random effects model, 12 studies (n=1,341) • 16% (95% CI 13 to 20), I^2=60.5% **Pooled rate of systemic infection** Meta-analysis random effects model, 9 studies (n=598) • 31% (95% CI 22 to 41), I^2=78.9%
Kowalewski 2020	**Pooled survival to hospital discharge** Meta-analysis random effects model, 53 studies (n=4,367) • 35.3% (95% CI 32.5 to 38.2) **Pooled rate of bridge to HTx** • 3.5% (95% CI 1.8 to 6.6) **Pooled rate of bridge to short or long term VAD** • 4.3% (95% CI 2.8 to 6.5) **Successful weaning from ECMO** • 55.3% (95% CI 31.4 to 100%)	**Pooled limb complications** Meta-analysis random effects model, 30 studies (n=2,766) • 13.0% (95% CI 32.5 to 38.2) **Pooled rate of reoperations for bleeding** Meta-analysis random effects model, 33 studies (n=2,832) • 41.2% (95% CI 35.6 to 47.1) **Pooled neurological complications** Meta-analysis random effects model, 33 studies (n=2,730) • 14.1% (95% CI 11.8 to 16.8) • Included 7.9% brain deaths: n=88 **Pooled rate of sepsis** Meta-analysis random effects model, 29 studies (n=1,860)

First author, date	Efficacy outcomes	Safety outcomes
		• 20.7% (95% CI 17.0 to 24.9) **Pooled rate of acute kidney injury** Meta-analysis random effects model, 34 studies (n=3,199) • 47.3% (95% CI 41.5 to 53.1)
Alba, 2021	**Pooled short-term mortality (30 day and in-hospital)** • Overall: 61% (95% CI 59 to 63) 306 studies n=29,289 • ECPR OHCA: 76% (95% CI 69 to 82), I^2=94%, 41 studies n=2,974 • ECPR IHCA: 64% (95% CI 59 to 69), I^2=81%, 46 studies n=2,987 • Post AMI: 60% (95% CI 59 to 64), I I^2=87%, 80 studies n=7,774 • **Postcardiotomy: 59% (95% CI 56 to 63**), I^2=**87%, 64 studies n=8,231** • AHF: 53% (95% CI 46 to 59), I^2=89%, 33 studies n=3,567 • Post-HTx: 35% (95% CI 29 to 42), I^2=64%, 25 studies n=771 • Myocarditis: 40% (95% CI 33 to 46), I^2=65%, 13 studies n=906 • PE: 52% (95% CI 38 to 66), I^2=75%, 10 studies n=221	**No safety outcomes were reported**

First author, date	Efficacy outcomes	Safety outcomes
	Probability of HTx Meta-analysis • Post AMI: 2.8%, 95% CI 0.8 to 5.5, 19 studies • **Postcardiotomy: 0.4%, 95% CI 0.0 to 1.1, 34 studies** • Post-HTx: 0.0%, 95% CI 0.0 to 0.5, 5 studies • AHF: 13.1%, 95% CI 5.5 to 23.7, 16 studies • Myocarditis: 4.5%, 95% CI 0.3 to 11.7, 5 studies • PE: 0.0%, 95% CI 0.0 to 22.8, 1 study **Probability of VAD** Meta-analysis • Post AMI: 9.0%, 95% CI 4.2 to 15.1, 22 studies • **Postcardiotomy: 0.8%, 95% CI 0.2 to 1.8, 35 studies** • Post-HTx: 2.4%, 95% CI 0.0 to 6.8, 5 studies • AHF: 29.0%, 95% CI 17.3 to 42.1, 17 studies • Myocarditis: 2.3%, 95% CI 0.2 to 5.6, 5 studies • PE: 0.0%, 95% CI 0.0 to 22.8, 1 study	
Chen, 2017	**In-hospital mortality** • ECMO for PCS: 61.7% (701/1,137) • Non-ECMO (without PCS): 6.8% (385/5,685) OR 22.34 (95% CI 19.06 to 26.18), p<0.001	**Re-exploration for bleeding** • ECMO for PCS: 11.3% (129/1,137) • Non-ECMO (without PCS): 2.5% (141/5,685) OR 5.04 (95% CI 3.93 to 6.45), p<0.001

First author, date	Efficacy outcomes	Safety outcomes
	1-year survival (Kaplan-Meier estimate) • ECMO for PCS: 24.1% (95% CI 21.6 to 26.6) • Non-ECMO (without PCS): 83.4% (95% CI 82.4 to 84.4) Log rank test p<0.001 **5-year survival (Kaplan-Meier estimate)** • ECMO for PCS: 17.7% (95% CI 14.7 to 20.7) • Non-ECMO (without PCS): 66.0% (95% CI 64.3 to 67.6) **10-year survival (Kaplan-Meier estimate)** • ECMO for PCS: 9.7% (95% CI 4.0 to 15.5) • Non-ECMO (without PCS): 50.2% (95% CI 46.7 to 53.7)	**Massive blood transfusion (PRBC >8 Units)** • ECMO for PCS: 79.1% (899/1,137) • Non-ECMO (without PCS): 15.3% (870/5,685) OR 21.25 (95% CI 18.09 to 24.96), p<0.001 **New onset ischaemic stroke** • ECMO for PCS: 3.2% (36/1,137) • Non-ECMO (without PCS): 3.5% (201/5,685) OR 0.89 (95% CI 0.62 to 1.28), p=0.534 **New onset haemorrhagic stroke** • ECMO for PCS: 1.1% (12/1,137) • Non-ECMO (without PCS): 0.4% (23/5,685) OR 2.63 (95% CI 1.30 to 5.29), p=0.007 **Acute renal failure and need for haemodialysis** • ECMO for PCS: 32.9% (374/1,137) • Non-ECMO (without PCS): 7.4% (418/5,685) OR 6.26 (95% CI 5.34 to 7.35), p<0.001 **Postoperative infection** • ECMO for PCS: 13.2% (150/1,137) • Non-ECMO (without PCS): 4.5% (256/5,685) OR 3.23 (95% CI 2.61 to 4.00), p<0.001 **Fasciotomy or amputation**

First author, date	Efficacy outcomes	Safety outcomes
		• ECMO for PCS: 2.3% (26/1,137) • Non-ECMO (without PCS): 0.8% (47/5,685) OR 2.81 (95% CI 1.73 to 4.56), p<0.001
Kowalewski 2021	**Successful weaning from ECMO** • 56.4% (4,051/7,185) **Survival to hospital discharge** • Overall: 41.7% (2,997/7,185) **Mortality by primary surgery type** • CABG: 65.4% • Vascular aortic: 69.6% • Heart transplant: 46.0%	**Limb complications: 6.3% (456/7,185)** • Ischaemia 4.3% (312) • Limb compartment syndrome 1.5% (106) • Fasciotomy 2.0% (143) • Amputation 0.6% (43) **Haematological complications: 42.5% (3,052/7,185)** • Disseminated intravascular coagulation: 2.8% (200) • Haemolysis: 4.0% (290) • Surgical site bleed: 26.4% (1,897) • Cannulation site bleed: 15.7% (1,130) • Mediastinal cannulation bleeding: 1.4% (98) • Cardiac tamponade: 7.6% (547) • GI bleeding: 4.1% (298) **Neurological complications: 9.1% (654/7,185)** • Diffuse ischaemia confirmed by US/CT/MRI: 0.1% (7) • Haemorrhage confirmed by US/CT/MRI: 1.7% (122) • Infarction confirmed by US/CT/MRI: 4.5% (326)

First author, date	Efficacy outcomes	Safety outcomes
		• Intra/extra parenchymal haemorrhage confirmed by US/CT/MRI: 0.3% (19) • Intraventricular haemorrhage confirmed by US/CT/MRI: 0.1% (7) • Neurosurgical intervention performed: 0.0% (1) • Seizures confirmed by EEG: 0.4% (32) • Seizures clinically determined: 1.1% (78) • Brain death: 2.5% (18) **Sepsis: 12.1% 871/7,185** • Culture proven infection: 10.7% (771) **Kidney failure: 48.9% 3,510/7,185** • Serum creatinine 1.5 to 3: 22.1% (1,591) • Serum creatinine >3: 10% (715) • Continuous renal replacement therapy: 36.1% (2,593) **Cardiovascular complications: 54.2% 3,894/7,185** • Cardiac arrhythmia: 15.9% (1,141) • CPR required >3 times: 2.9% (206) • Hypotension requiring vasodilators: 3.1% (222) • Inotropes on ECMO: 44.5% (3,196) **Metabolic complications: 26.9% 1,934/7,185**

First author, date	Efficacy outcomes	Safety outcomes
		• Glucose <40: 1.4% (104) • Glucose >240: 10.5% (758) • Hyperbilirubinemia: 13.1% (941) • pH <7.2: 8.6% (620) • pH >7.6: 2.9% (208) **Pulmonary complications: 3.8% 271/7,185** • Pneumothorax: 1.3% (91) • Pulmonary haemorrhage: 2.6% (187)

Loungani, 2021	**Overall survival to discharge**
	• 40% (290/723)
	  ○ Survival without need for permanent cardiac support (n=235)
	  ○ Survival with HTx (n=7)
	  ○ Survival with LVAD (n=48)
	
	Survival to discharge by aetiology
	• **Postcardiotomy: 36.0%**
	• HTx/PGD: 57.6%
	• MI: 39.3%
	• Cardiomyopathy: 40.7%
	• Other cardiogenic shock: 42.9%
	• Non-cardiogenic shock: 36.6%
		Death during ECMO or hospitalisation by aetiology
		• **Postcardiotomy: 64.0% (142)**
		• HTx/PGD: 42.4% (25)
		• MI: 60.7% (74)
		• Cardiomyopathy: 59.3% (112)
		• Other cardiogenic shock: 27.1% (28)
		• Non-cardiogenic shock: 63.4% (52)
		
		Complications on ECMO (n=723)
		• Infection: 21.3% (154)
		• Acute renal dysfunction: 35.5% (257)
		• Major bleeding: 36.1% (261)
		• Clinically significant coagulopathy: 14.2% (103)
		• Disseminated intravascular coagulopathy: 2.2 (16)
		• Deep venous thrombosis: 2.6% (19)

First author, date	Efficacy outcomes	Safety outcomes
		• Pulmonary embolism: 0.4% (3) • Haemothorax:3.5% (25) • Pneumothorax: 3.0% (22) • Diffuse cerebral oedema/hypoxic encephalopathy: 3.9% (28) • Intracranial haemorrhage/haemorrhagic stroke: 2.4% (17) • Ischaemic stroke/embolisation: 2.4% (17) • Seizures: 0.4% (3) • Limb ischaemia: 12.2% (88) • Fasciotomy: 3.5% (25) • Peripheral wound: 1.7% (12) • Hyperperfusion: 0.4% (3) • Air embolism: 0.1% (1) • Cannula dislodgement: 0.8% (6) • Oxygenator failure: 1.1% (8) • Pump malfunction: 0.8% (6) • Thrombosis: 1.1% (8) • Tubing rupture: 0.1% (1)
Danial, 2023	**In-hospital survival** • **Postcardiotomy excluding PGF: 34.6%** • PGF: 73.3% • Drug overdose: 58.6% • Cardiomyopathy: 53.2%	**Complications (entire cohort) n=1,253** • Site infection: 19% (240) • Limb ischaemia: 9% (118) • Limb amputation: 0.9% (11) • Vascular cannulation adverse event: 3% (34)

First author, date	Efficacy outcomes	Safety outcomes
	• Arrhythmic storm: 51.6% • Massive PE: 46.8% • Sepsis induced cardiogenic shock: 44.4% • Fulminant myocarditis: 37.9% • AMI: 37.3% • Refractory vasoplegia shock: 11.1% • Other/unknown aetiology: 25.7% **5-year survival** • **Postcardiotomy excluding PGF: 33.3%** • PGF: 57.3% • Drug overdose: 54.0% • Arrhythmic storm: 50.0% • Cardiomyopathy: 45.3% • Sepsis induced cardiogenic shock: 42.4% • Massive PE: 38.3% • Fulminant myocarditis: 32.9% • AMI: 31.5% • Refractory vasoplegia shock: 0.0% • Other/unknown aetiology: 22.8%	• Vascular decannulation adverse event: 9% (71) • Sensory-motor deficit: 4% (34) • General bleeding: 25% (316) • Neurological adverse event: 16% (194) • Ischaemic stroke: 7% (81) • Intracranial bleeding: 4% (53) • Brain oedema: 2% (22) • Brain death: 9% (107) • Renal failure requiring haemodialysis: 52% (630) • Hydrostatic pulmonary oedema: 9% (11) **Complications (postcardiotomy) n=297** • Site infection: 13% (37) • Limb ischaemia: 11% (34) • Limb amputation: 0.3% (1) • Vascular cannulation adverse event: 3% (9) • Vascular decannulation adverse event: 9% (16) • Sensory-motor deficit: 3% (5) • General bleeding: 34% (101) • Neurological adverse event: 14% (41) • Ischaemic stroke: 6% (18) • Intracranial bleeding: 4% (13) • Brain oedema: 1% (2) • Brain death: 5% (16)

First author, date	Efficacy outcomes	Safety outcomes
		• Renal failure requiring haemodialysis: 58% (170) • Hydrostatic pulmonary oedema: 6% (17)
Chen, 2020	**Successful weaning off ECMO (n=121)** • 64% (77) **Mortality** • On ECMO: 36% (44) • During hospitalisation: 54% (65) • Within 1 month: 55% (66) • Within 12 months: 59% (71) • Within 24 months: 64% (77) • Within 36 months: 66% (80)	**Continuous renal replacement therapy** • 36% (44) **Limb ischaemia** • 10% (12) **Stroke** • 10% (12) **Anoxic encephalopathy** • 3% (4)

Bonacci, 2020	**Successful ECLS weaning (n=209)**
	• 56.9% (119)
	
	Survival to hospital discharge
	• 42.1% (88)
	
	1-year cumulative survival (Kaplan-Meier)
	• 32.1% (SD: 3.2)
	
	5-year cumulative survival (Kaplan-Meier)
	• 25.2% (SD: 3.01)
		Complications (n=209)
		• Arrhythmia: 62.7% (131)
		  ○ AF: 47% (98)
		  ○ VT: 17% (36)
		  ○ VF: 19.1% (40)
		  ○ Other: 21.5% (45)
		• Re-thoracotomy for bleeding: 36.7% (76)
		• Acute kidney injury: 64.1% (134)
		• Continuous veno-venous haemodialysis: 53.6% (112)
		• Respiratory insufficiency: 23.9% (50)
		• Stroke: 11.4% (24)

First author, date	Efficacy outcomes	Safety outcomes
		• Cerebral bleeding: 25.4% (53) • Cerebral ischaemia: 18.2% (38) • Sepsis: 28.2% (59) • Vasoplegic syndrome: 10.5% (22) • Severe RV dysfunction: 38.3% (80) • Leg ischaemia: 6.5% (11/169) • Leg fasciotomy: 2.4% (4/169) • GI complications: 16.2% (34) • Hepatic failure: 6.2% (13) • Bowel ischaemia: 9% (19) • Pneumonia: 17.7% (37) • ARDS: 17.2% (36)

Procedure technique

Of the 10 studies, none detailed the ECMO device or combination of devices used. VA ECMO was inserted during the initial cardiac surgery in the cases of circulatory instability during or immediately after weaning from CPB in 2 systematic reviews and 1 single centre study ([54%] Biancari 2018, [43%] Kowalewski 2020, Chen 2020). One study noted that the exact timing of ECMO implantation was unavailable, so the study authors presumed that most ECMO implantation occurred after cardiac surgery (Chen 2017). One study stated that ECLS was initiated after an evaluation of cardiac performance by transoesophageal echocardiography (TOE) and intraoperative cardiac catheterisation (Bonacchi 2020). Three studies noted the location of ECMO initiation as either the operating room, intensive care unit, catheterisation laboratory, emergency department, or transferred from other institutions already on ECMO support (Kowalewski 2020, Loungani 2021, Danial 2023).

Peripheral cannulation was preferred and most common strategy for VA ECMO in the 7 studies that detailed cannulation procedure (Biancari 2018, Bonacchi 2020, Chen 2020, Danial 2023, Kowalewski 2020, Kowalewski 2021, Loungani 2021), however 46% of people included in the Kowalewski et al. (2021) registry study were noted to be centrally cannulated. Left ventricular unloading using concomitant IABP was used in 31% (Kowalewski 2021), 62% (Biancari 2018), over 90% (Chen 2020), and 100% of people (Bonacchi 2020). Of the 10 studies, 4 detailed the median length of time on ECMO (Chen 2020, Kowalewski 2020, Kowalewski 2021, Loungani 2021), which ranged from 4 days (Chen 2020) to 6 days (Kowalewski 2021).

Efficacy

Survival

In-hospital survival

Of the 10 key evidence studies, 7 reported the in-hospital survival of people having ECMO postcardiotomy.

In meta-analyses from 3 systematic reviews, pooled in-hospital survival ranged from 34 to 36% (Biancari 2018, Wang 2018, Kowalewski 2020). Meta-regression analysis by Biancari (2018) showed a trend toward lower hospital survival in studies with higher mean age (p=0.064). The pooled analysis of 12 studies showed that hospital survivors (n=387) were significantly younger than people who died after VA ECMO (pooled mean age, 56 versus 64 years; mean difference, -7.223 years, 95% CI -9.777 to - 4.669, I^2=53%, p=0.015)

In the registry study of 7,185 people with refractory PCS, in-hospital survival was 42% (Kowalewski 2021). In the registry study of 723 adults treated with VA ECMO (31% postcardiotomy), the survival in the overall population was 40% and 36% in postcardiotomy patients (Loungani 2021).

In the single centre retrospective study of people treated with VA ECMO for cardiogenic shock, among those with PCS (n=297), in-hospital survival was 35% (Danial 2023). In-hospital survival was 42% in the multicentre retrospective study of 209 adults having ECLS following cardiac surgery (Bonacchi 2020).

1-year survival

Of the 10 key evidence studies, 4 reported the 1-year survival of people having ECMO postcardiotomy.

In the systematic review of 31 studies of people who required VA ECMO following cardiac surgery, the pooled 1-year survival in a meta-analysis was 31%

(95% CI 24.3 to 37.5), I^2=82% (11 studies [n=1,290]; Biancari 2018). In the systematic review of 20 studies of people having ECMO for PCS following cardiac surgery, the pooled 1-year survival in a meta-analysis was 24% (95% CI 19 to 30), I^2=76% (6 studies [n=1,860]; Wang 2018).

The cumulative 1-year survival using Kaplan-Meier estimate was 32% (SD 3.2) in the multicentre retrospective study of 209 adults having ECLS following cardiac surgery (Bonacchi 2020).

In the propensity score-matched study of people admitted for cardiac surgery who had VA ECMO (n=1,137), the cumulative 1-year survival using Kaplan-Meier estimate was 24% (95% CI 21.6 to 26.6) in those who had ECMO for PCS (Chen 2017).

Mid-term survival

Of the 10 key evidence studies, 1 study reported the 3- to 5- year survival and 3 studies reported the 5-year survival of people having ECMO postcardiotomy.

In the systematic review of 20 studies of people with PCS following cardiac surgery, the pooled 3- to 5- year survival in a meta-analysis was 18% (95% CI 11 to 27), I^2=77% (4 studies [n=742]; Wang 2018). In the single centre retrospective study of 1,253 people treated with VA ECMO for cardiogenic shock (297 with PCS), the 5-year survival for people postcardiotomy (excluding PGF) was 33% (Danial 2023). The cumulative 5-year survival using Kaplan-Meier estimate was 25% (SD 3.01) in the multicentre retrospective study of 209 adults having ECLS following cardiac surgery (Bonacchi 2020). Cox regression analysis demonstrated that younger age (less than 35 years) was a strong independent predictor of 5-year survival (HR 0.4, 95% CI: 0.2 to 0.8; p=0.021).

In the propensity score-matched study of people admitted for cardiac surgery who had VA ECMO (n=1,137), the cumulative 5-year survival using Kaplan-Meier

estimate was 18% (95% CI 14.7 to 20.7) (Chen 2017). The authors note that although the risk of all-cause mortality was greater in the group receiving ECMO for PCS than in the group without PCS (non-ECMO) ($p<0.001$) in the first year of follow-up, no difference was observed after the first year of follow-up ($p=0.209$; Chen 2017).

Long-term survival

Of the 10 key evidence studies, 1 reported the 10-year survival of people having ECMO postcardiotomy. In the propensity score-matched study of 6,822 people admitted for cardiac surgery with (n=1,137) or without (n=5,685) VA ECMO, the cumulative 10-year survival using Kaplan-Meier estimate was 10% (95% CI 4.0 to 15.5) in those who had ECMO for PCS following cardiac surgery compared to 50% (95% CI 46.7 to 53.7) in those who did not (Chen 2017). Again, the authors note that although the risk of all-cause mortality was greater in the ECMO for PCS group than in the non-PCS group ($p<0.001$) in the first year of follow-up, no difference was observed after the first year of follow-up ($p=0.209$; Chen 2017).

Successful weaning from ECMO

Of the 10 key evidence studies, 4 reported the proportion of people successfully weaned from ECMO postcardiotomy. In the systematic review of 31 studies of people who required VA ECMO following cardiac surgery, the pooled proportion successfully weaned in a meta-analysis was 60% (95% CI 54.6 to 64.3), $I^2=77\%$ (24 studies [n=2,049]; Biancari 2018). In the systematic review of 54 studies reporting on 4,421 people with refractory PCS, 55% (31 to 100%) of people were successful weaned from ECMO (Kowalewski 2020). In the registry study of 7,185 people with refractory PCS, 56% were successfully weaned, and 64% were successfully weaned in the single centre retrospective study of 121 people undergoing CABG who had ECMO for PCS (Kowalewski 2021, Chen 2020).

Bridged to heart transplant

Of the 10 key evidence studies, 3 reported the proportion of people bridged to heart transplant following ECMO. The pooled rate of heart transplantation post-ECMO from a meta-analysis of 21 studies (n=1,685) was 2% (95% CI 1.0 to 2.8, I^2=50%) in the systematic review of people who required VA ECMO following cardiac surgery (Biancari 2018). Of these heart transplant recipients, 66% (95% CI 48.2 to 84.1, I^2=0%) survived until hospital discharge (Biancari 2018). In the systematic review of 54 studies reporting on 4,421 people with refractory PCS, the pooled rate of heart transplantation was 3.5% (95% CI 1.8 to 6.6) (Kowalewski 2020). The pooled rate of heart transplantation in those with PCS was 0.4% (95% CI 0.0 to 1.1) in a meta-analysis of 34 studies in the systematic review by Alba et al. (2021).

Bridged to long term VAD

Of the 10 key evidence studies, 3 reported the proportion of people bridged to a ventricular assist device (VAD) using ECMO. The pooled rate of VAD implantation post-ECMO from a meta-analysis of 21 studies (n=1,685) was 2% (95% CI 1.3 to 3.4, I^2=57%) in the systematic review of people who required VA ECMO following cardiac surgery (Biancari 2018). Of these VAD recipients, 46% (95% CI 28.0 to 63.1, I^2=43%) survived until hospital discharge (Biancari 2018). In the systematic review of 54 studies reporting on 4,421 people with refractory PCS, the pooled rate of heart transplantation was 4.3% (95% CI 2.8 to 6.5) (Kowalewski 2020). The pooled rate of heart transplantation in those with PCS was 0.8% (95% CI 0.2 to 1.8) in a meta-analysis of 35 studies in the systematic review by Alba et al. (2021).

Mortality

Of the 10 key evidence studies, 5 reported on mortality. In the registry study of 7,185 people with refractory PCS, in-hospital mortality by primary surgery type was 65% for CABG, 70% for vascular aortic surgery and 46% for heart transplant

surgery (Kowalewski 2021). Older age was significantly associated with in-hospital mortality. Of the patients aged over 70 years, 70% did not survive to discharge compared to 55% those younger than 70 years (p<0.001).

In the systematic review of 306 studies of CS of any aetiology, the pooled overall short-term mortality (30-day and in-hospital) for those with PCS was 59% (95% CI 56 to 63, I^2=87%, 64 studies). Univariate meta regression analysis stratified by aetiology also showed an 8% increase in mortality per 10-year increase in cohort's age (Alba 2021).

In the registry study of 723 adults treated with VA ECMO (31% postcardiotomy), 64% postcardiotomy patients died during ECMO or hospitalisation (Loungani 2021). Multivariable regression analysis identified older age as a risk factor for mortality on ECMO (OR 1.26; 95% CI 1.12 to 1.42, p<0.001). Mortality rates while on ECMO support increased from 26% in those aged 35 to 44 years to 54% in those 75 years or older (Loungani 2021).

In the propensity score-matched study of 6,822 people admitted for cardiac surgery with (n=1,137) or without (n=5,685) VA ECMO, in-hospital mortality was 62% in those who had ECMO for PCS following cardiac surgery compared to 7% in those who did not have PCS or ECMO (OR 22.34, 95% CI 19.06 to 26.18, p<0.001; Chen 2017). All-cause mortality was reported in the single centre retrospective study of 121 people undergoing CABG who had ECMO for PCS as 36% for those on ECMO, 54% during hospitalisation, 55% within 1 month, 59% within 12 months, 64% within 24 months, and 66% within 36 months (Chen 2020). Older age was an independent risk factor associated with 36-month mortality (HR 1.06; 95% CI 1.03 to 1.10; p<0.001).

Safety

Bleeding

Of the 10 key evidence studies, 8 reported bleeding adverse events or complications. In the propensity score-matched study of 6,822 people admitted for cardiac surgery with (n=1,137) or without (n=5,685) VA ECMO, re-exploration for bleeding was statistically significantly higher in those on ECMO for PCS (11.3% [129 of 1,137]) compared to those who did not have PCS or ECMO (2.5% [141 of 5,685], OR 5.04, 95% CI 3.93 to 6.45, p<0.001; Chen 2017). Massive blood transfusion (PRBC more than 8 Units) was also statistically significantly higher in those on ECMO for PCS (79% [899 of 1,137]) compared to those who did not have PCS or ECMO (15% [870 of 5,685], OR 21.25, 95% CI 18.09 to 24.96, p<0.001; Chen 2017).

In the systematic review of 31 studies of people who required VA ECMO following cardiac surgery, the pooled rate of reoperation for bleeding was 43% (95% CI 34.2 to 51.5, I^2=93%) in the meta-analysis of 18 studies (n=1,779; Biancari 2018). In the systematic review of 20 studies of people with PCS following cardiac surgery, the pooled rate of reoperation for bleeding was 50% (95% CI 32 to 68, I^2=97%, 10 studies, n=1,268; Wang 2018). The pooled rate of reoperations for bleeding was 41% (95% CI 35.6 to 47.1) in the meta-analysis of 33 studies (n=2,832) from the systematic review of people with refractory PCS (Kowalewski 2020).

In the registry study of people with refractory PCS, haematological complications were reported in 43% of people (3,052 of 7,185), including surgical site bleed 26% (1,897), cannulation site bleed 16% (1,130), mediastinal cannulation bleeding 1% (98), cardiac tamponade 8% (547), GI bleeding 4% (298), and haemolysis 4% (290) (Kowalewski 2021). In the registry study of adults treated with VA ECMO, major bleeding was reported in 36% (261 of 723), clinically significant coagulopathy in 14% (103 of 723), and disseminated intravascular coagulopathy in 2% (16 of 723) of the overall population (Loungani 2021).

In the single centre retrospective study general bleeding was reported for 34% (101 of 297) of people with PCS (Danial 2023). Rates of re-thoracotomy for bleeding were 37% (76 of 209) in the multicentre retrospective study of adults having ECLS following cardiac surgery (Bonacci 2020).

Neurological events

Of the 10 key evidence studies, 8 reported neurological adverse events or complications. The pooled neurological complication rates reported in 3 systematic reviews, were 11% (95% CI 7.8 to 14.8, I^2=79%, 16 studies [n=1,736]; Biancari 2018), 16% (95% CI 13 to 20, I^2=61%, 12 studies [n=1,341]; Wang 2018) and 14% (95% CI 11.8 to 16.8, 33 studies [n=2,730]; Kowalewski 2020).

In the registry study of people with refractory PCS, the rate of neurological complications was 9% (654 of 7,185). This included clinically determined seizures 1% (78), brain death 3% (18), haemorrhage confirmed by US/CT/MRI 2% (122), and infarction confirmed by US/CT/MRI 5% (326; Kowalewski 2021). In the registry study of adults treated with VA ECMO, diffuse cerebral oedema or hypoxic encephalopathy occurred in 4% (28 of 723) of the overall population (Loungani 2021).

In the single centre retrospective study of people with PCS, rates of neurological adverse events were 14% (41 of 297). This included sensory-motor deficit 3% (5), intracranial bleeding 4% (13), brain oedema 1% (2) and brain death 5% (16) (Danial 2023). Rates of anoxic encephalopathy were 3% (4 of 121) in the single centre retrospective study of people undergoing CABG who had ECMO for PCS (Chen 2020). Rates of cerebral bleeding were 25% (53 of 209) and cerebral ischaemia were 18% (38 of 209) in the multicentre retrospective study of adults having ECLS following cardiac surgery (Bonacci 2020).

Limb complications

Of the 10 key evidence studies, 9 reported limb adverse events or complications. The pooled limb complication rates reported in 3 systematic reviews, were 11% (95% CI 8.0 to 13.5, I^2=70%, 16 studies [n=1,909]; Biancari 2018), 14% (95% CI 10 to 20, I^2=75%, 11 studies [n=945]; Wang 2018) and 13% (95% CI 32.5 to 38.2, 30 studies [n=2,766]; Kowalewski 2020).

In the registry study of people with refractory PCS, rates of limb complications were 6% (456 of 7,185), including ischaemia 4% (312) and limb compartment syndrome 2% (106) (Kowalewski 2021). In the registry study of adults treated with VA ECMO 12% (88 of 723) of the overall population were reported with limb ischaemia (Loungani 2021).

In the single centre retrospective study of people with PCS, rates of limb ischaemia were 11% (34 of 297; Danial 2023). This was 10% (12 of 121) in the single centre retrospective study of people undergoing CABG who had ECMO for PCS (Chen 2020), and 7% (11 of 169) in the multicentre retrospective study of adults having ECLS following cardiac surgery (Bonacci 2020).

Rates of limb fasciotomy were 2% (143 of 7,185) in the registry study of people with refractory PCS, and 4% (25 of 723) in the overall population in the registry study of adults treated with VA ECMO (Loungani 2021), and 3% (4 of 169) in the single centre retrospective study of people undergoing CABG who had PCS (Bonacci 2020).

In the propensity score-matched study of 6,822 people admitted for cardiac surgery with or without VA ECMO, statistically significantly more people were reported with limb fasciotomy or amputation on ECMO for PCS 2% (26 of 1,137), than those not on ECMO without PCS 1% (47 of 5,685), OR 2.81 (95% CI 1.73 to 4.56, p<0.001; Chen 2017). The pooled rate of lower limb amputation was 1% (95% CI 0.0 to 2.3, I^2=0% in a meta-analysis of 5 studies (n=330) in the systematic review of people who required VA ECMO following cardiac surgery

(Biancari 2018), and the registry study of people with refractory PCS by Kowalewski et al. (2021) also reported amputation rates of 1% (43 of 7,185).

Infection and sepsis

Of the 10 key evidence studies, 8 reported infection or sepsis events or complications. In the propensity score-matched study of 6,822 people admitted for cardiac surgery with or without VA ECMO, significantly more people were reported with post-operative infection on ECMO for PCS 13% (150 of 1,137), than those not on ECMO without PCS 5% (256 of 5,685), OR 3.23 (95% CI 2.61 to 4.00, p<0.001; Chen 2017). In the systematic review of people who required VA ECMO following cardiac surgery, the rate of deep sternal wound infection or mediastinitis was 15% (95% CI 4.0 to 25.4, I^2=92%) in a meta-analysis of 4 studies (n=490; Biancari 2018). Pooled systemic infection rates were 31% (95% CI 22 to 41, I^2=79%) in the systematic review of people with PCS following cardiac surgery (9 studies [n=598]; Wang 2018). In the registry study of adults treated with VA ECMO (31% postcardiotomy), infection rates were 21% (154 of 723) (Loungani 2021). Site infection occurred in 13% (37 of 297) of people with PCS in the French single centre retrospective study (Danial, 2023).

In the systematic review of people with refractory PCS, pooled rates of sepsis were 21% (95% CI 17.0 to 24.9) in a meta-analysis of 29 studies (n=1,860; Kowalewski 2020). Rates of sepsis were reported as 12% (871 of 7,185) in the registry study of people with refractory PCS (Kowalewski 2021), and 28% (59 of 209) in the single centre study of adults having ECLS following cardiac surgery (Bonacci 2020).

Renal complications

Of the 10 key evidence studies, 9 reported renal adverse events or complications. In the propensity score-matched study of 6,822 people admitted for cardiac surgery with or without VA ECMO, statistically significantly more

people were reported with acute renal failure and need for haemodialysis on ECMO for PCS 33% (374 of 1,137), than those not on ECMO 7% (418 of 5,685), OR 6.26 (95% CI 5.34 to 7.35, p<0.001; Chen 2017).

The pooled rates of RRT, renal failure, or acute kidney injury were reported in 3 systematic reviews. Rates were 47% (95% CI 38.9 to 55.2, I^2=92%, 19 studies [n=1,979]; Biancari 2018), 57% (95% CI 47 to 66, I^2=87%, 12 studies [n=1,279]; Wang 2018) and 47% (95% CI 41.5 to 53.1, 34 studies [n=3,199]; Kowalewski 2020), respectively.

In the registry study of people with refractory PCS, rates of kidney failure were 49% (3,510 of 7,185), and rates of RRT were 36% (2,593 of 7,185; Kowalewski 2021). Acute renal dysfunction was reported as 36% (257 of 723) in the registry study of adults treated with VA ECMO (31% postcardiotomy) (Loungani 2021).

Renal failure requiring haemodialysis was reported in 58% (170 of 297), and RRT 36% (44 of 121) in the single centre retrospective studies of people with PCS in France (Danial 2023) and China (Chen 2020), respectively. Acute kidney injury occurred at rate of 64% (134 of 209), and continuous veno-venous haemodialysis 54% (112 of 209) in the multicentre retrospective study of adults having ECLS following cardiac surgery, (Bonacchi 2020).

Stroke

Of the 10 key evidence studies, 4 reported stroke events. In the propensity score-matched study of 6,822 people admitted for cardiac surgery with or without VA ECMO, rates of new onset ischaemic stroke were 3% (36 of 1,137) for those on ECMO for PCS, compared to 4% (201 of 5,685) in those not on ECMO (OR 0.89, 95% CI 0.62 to 1.28, p=0.534; Chen 2017). Rates of new onset haemorrhagic stroke for those on ECMO for PCS were 1% (12 of 1,137), compared to less than 1% (23 of 5,685) in those not on ECMO without PCS (OR 2.63, 95% CI 1.30 to 5.29, p=0.007; Chen 2017).

Intracranial haemorrhage or haemorrhagic stroke and ischaemic stroke or embolisation were both reported as 3% (17 of 723) in the registry study of adults treated with VA ECMO (31% postcardiotomy) (Loungani 2021).

Ischaemic stroke was reported in 6% (18 of 297), and stroke 10% (12 of 121) in the single centre retrospective studies of people with PCS in France (Danial 2023) and China (Chen 2020), respectively. Stroke occurred at rate of 11% (24 of 209) in the multicentre retrospective study of adults having ECLS following cardiac surgery, (Bonacchi 2020).

Cardiovascular complications

Of the 10 key evidence studies, 2 reported cardiovascular adverse events or complications. In one registry study, cardiovascular complications occurred in 54% (3,894 of 7,185) of people with refractory PCS (Kowalewski 2021). These included cardiac arrhythmia 16% (1,141), CPR required more than 3 times 3% (206), hypotension requiring vasodilators 3% (222), and inotropes on ECMO 45% (3,196) (Kowalewski 2021). In the multicentre retrospective study of 209 adults having ECLS following cardiac surgery, cardiovascular events included arrhythmia 63% (131), vasoplegic syndrome 11% (22), and severe RV dysfunction 38% (80) (Bonacci 2020).

Metabolic complications

Of the 10 key evidence studies, 1 registry study reported metabolic adverse events or complications in 27% (1,934 of 7,185) of people with refractory PCS. These included glucose levels below 40 (1%, n=104), glucose levels greater than 240 (11%, n=758), hyperbilirubinemia (13%, n=941), pH lower than 7.2 (9%, n=620), and pH higher than 7.6 (3%, n=208) (Kowalewski 2021).

Pulmonary complications

Of the 10 key evidence studies, 4 reported pulmonary adverse events or complications. In one registry study, pulmonary complications occurred in 4%

(271 of 7,185) of people with refractory PCS, including pneumothorax 1% (91), and pulmonary haemorrhage 3% (187) (Kowalewski 2021). In other registry study of 723 adults treated with VA ECMO (31% postcardiotomy), complications included pulmonary embolism less than 1% (3), haemothorax 4% (25), and pneumothorax 3% (22) (Loungani 2021). Hydrostatic pulmonary oedema was reported in 6% (17 of 297) of people with PCS, in the single centre retrospective study done in France (Danial 2023). Pulmonary complications reported in the multicentre retrospective study of 209 adults having ECLS following cardiac surgery included respiratory insufficiency 24% (50), pneumonia 18% (37), and ARDS 17% (36) (Bonacci 2020).

GI complications

Of the 10 key evidence studies, 1 multicentre retrospective study reported GI complications in 16% (34 of 209) of people having ECLS following cardiac surgery. It also reported bowel ischaemia in 9% (19 of 209) (Bonacchi 2020).

Hepatic complications

Of the 10 key evidence studies, 1 multicentre retrospective study reported hepatic complications in 6% (13 of 209) of people having ECLS following cardiac surgery (Bonacchi 2020).

Technical complications

Of the 10 key evidence studies, 2 reported technical adverse events or complications. In 1 registry study of adults treated with VA ECMO (31% postcardiotomy), oxygenator failure rates were 1% (8 of 723), and air embolism, cannula dislodgement, pump malfunction and tubing rupture were reported in less than 1% of the overall population (Loungani 2021). In the single centre retrospective study of 297 people with PCS, vascular cannulation and decannulation adverse event rates were 3% (9) and 9% (16), respectively (Danial 2023).

Anecdotal and theoretical adverse events

Expert advice was sought from consultants who have been nominated or ratified by their professional society or royal college. They were asked if they knew of any other adverse events for this procedure that they had heard about (anecdotal), which were not reported in the literature. They were also asked if they thought there were other adverse events that might possibly occur, even if they had never happened (theoretical).

They listed the following anecdotal and theoretical adverse events:

- Left ventricle overloading
- Deep vein thrombosis
- Arteriovenous fistula
- Pseudoaneurysm
- Harlequin syndrome
- Haemolysis
- Intra-cerebral haemorrhage
- Major pulmonary bleed
- Failure to cannulate during cardiac arrest
- Malposition of the cannula
- Device clotting
- Differential oxygenation
- Lower body hyperoaxemia/hypocapnia
- Air entrapment
- Embolism
- Oxygenator failure
- Consumption coagulopathy
- Acquired Von Willebrand syndrome
- Systemic inflammatory response syndrome (SIRS)

- Multi-organ failure including kidney, liver, and pancreas.

Sixteen professional expert questionnaires were submitted. Find full details of what the professional experts said about the procedure in the specialist advice questionnaires for this procedure.

Validity and generalisability

- Most studies included in the key evidence had a large number of participants from a variety of countries, although no UK-specific studies were included.
- Due to the nature of the procedure, randomised controlled trials in the postcardiotomy population are not possible. There was therefore a lack of comparative studies included in the key evidence. Chen et al. (2017) was the only comparative study. This study compares those who had ECMO for PCS following cardiac surgery, to a propensity matched sample with the same cardiac surgery who did not have PCS or ECMO. This comparison is a clinically lower risk group compared to those who had ECMO.
- Some studies did not include definitions of PCS or qualifying clinical reasons for requiring ECMO postcardiotomy.
- The studies included people with a mix of primary surgery types and no studies were identified that stratified outcomes by primary surgery type.
- Many studies lacked pre-, intra-, and postoperative information including differences between institutions in terms of patient selection, volume and expertise, treatment strategy as well as availability of ventricular assist devices and heart transplantation, which may impact outcomes.
- Follow-up for most studies was short, reporting key efficacy outcomes at hospital discharge. Four studies had a 5-year follow-up period, and 1 study had a 10-year follow up period.

Related NICE guidance

Interventional procedures

Extracorporeal membrane oxygenation (ECMO) for acute heart failure in adults (2014) NICE interventional procedures guidance [IPG 482]. (Recommendation: special arrangements).

NICE guidelines

Acute heart failure: diagnosis and management (2014 updated 2021) NICE guideline CG187 - At an early stage, the specialist should have a discussion with a centre providing mechanical circulatory support about: people with potentially reversible severe acute heart failure or people who are potential candidates for transplantation.

Professional societies

- The Intensive Care Society
- Society for Cardiothoracic Surgery in Great Britain & Ireland
- Royal College of Anaesthetists
- Royal College of Surgeons
- Faculty of Intensive Care Medicine
- British Society for Heart Failure
- NHS Blood and Transplant
- British cardiovascular society
- European Extracorporeal Life Support Organisation

Company engagement

NICE asked companies who manufacture a device potentially relevant to this procedure for information on it. NICE received 2 completed submissions. These

were considered by the interventional procedures technical team and any relevant points have been taken into consideration when preparing this overview.

References

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3. Kowalewski M, Raffa GM, Zielinski K et al. (2020) The impact of Centre's heart transplant status and volume on in-hospital outcomes following extracorporeal membrane oxygenation for refractory post-cardiotomy cardiogenic shock: A meta-analysis. BMC Cardiovascular Disorders 20(1): 10
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5. Chen S-W, Tsai F-C, Lin Y-S et al. (2017) Long-term outcomes of extracorporeal membrane oxygenation support for postcardiotomy shock. The Journal of Thoracic and Cardiovascular Surgery 154(2): 469-477e2
6. Kowalewski M, Zielinski K, Brodie D et al. (2021) Venoarterial extracorporeal membrane oxygenation for postcardiotomy shock-analysis of the Extracorporeal Life Support Organization Registry. Critical Care Medicine 49(7): 1107-1117
7. Loungani RS, Fudim M, Ranney D et al. (2021) Contemporary use of venoarterial extracorporeal membrane oxygenation: insights from the multicenter RESCUE registry. Journal of Cardiac Failure 27(3): 327-337
8. Danial P, Olivier M-E, Brechot N et al. (2023) Association between shock etiology and 5-year outcomes after venoarterial extracorporeal membrane oxygenation. Journal of the American College of Cardiology 81(9): 897-909
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Appendix A: Methods and literature search strategy

Methods and literature search strategy

NICE has identified studies and reviews relevant to extracorporeal membrane oxygenation (ECMO) for acute heart failure in adults from the medical literature.

Search strategy design and peer review

This search report is informed by the Preferred Reporting Items for Systematic reviews and Meta-Analyses literature search extension (PRISMA-S).

A NICE information specialist ran the literature searches on 18th September 2024. See the search strategy history for the full search strategy for each database. Relevant published studies identified during consultation or resolution that are published after this date may also be considered for inclusion.

The principal search strategy was developed in MEDLINE ALL (Ovid interface). It was adapted for use in each of the databases listed in table 4a, taking into account the database's size, search functionality and subject coverage. The MEDLINE ALL strategy was quality assured by a NICE senior information specialist. All translated search strategies were peer reviewed to ensure their accuracy. The quality assurance and peer review procedures were adapted from the Peer Review of Electronic Search Strategies (PRESS) 2015 evidence-based checklist.

Review management

The search results were managed in EPPI-Reviewer version 5 (EPPI-R5). Duplicates were removed in EPPI-R5 using a 2-step process. First, automated deduplication was done using a high-value algorithm. Second, manual deduplication was used to assess low-probability matches. All decisions about inclusion, exclusion and deduplication were recorded and stored.

Limits and restrictions

The CENTRAL database search removed trial registry records and conference material. The Embase search excluded conference material. We excluded the following publication types in MEDLINE: letter or historical article or comment or editorial or news or case reports. We excluded letters and editorial from the Embase search. English language limits were applied to the search when possible in the database.

The search was limited from March 2013 to September 2024. The date limit was included to update searches undertaken for an earlier version of this guidance.

The limit to remove animal studies in the searches is standard NICE practice, which has been adapted from Dickersin K, Scherer R, Lefebvre C (1994) Systematic Reviews: Identifying relevant studies for systematic reviews. BMJ 309(6964): 1286.

Main search

Table 4a Main search results

Database	Date searched	Database platform	Database segment or version	Number of results downloaded
Cochrane Central Register of Controlled Trials (CENTRAL)	18/08/24	Wiley	Issue 8 of 12, August 2024	410
Cochrane Database of Systematic Reviews (CDSR)	20/08/24	Wiley	Issue 9 of 12, September 2024	13
Embase	20/08/24	Ovid	1974 to 2024 September 17	2101
INAHTA International HTA Database	18/09/24	https://database.inahta.org/	-	24
MEDLINE ALL	18/09/24	Ovid	1946 to Sept 17, 2024	1454

[MEDLINE ALL] search strategy

1 , Heart Failure/th , 29,868

2 , Acute disease/th , 1,194

3 , 1 and 2 , 11

4 , *Cardiomyopathies/th , 1,150

5 , *Shock cardiogenic/th , 2,135

6 , Myocardial Stunning/th [Therapy] , 155

7 , Myocarditis/th [Therapy] , 1,294

8 , *Myocardial infarction/ , 138,977

9 , Out-of-Hospital Cardiac Arrest/th [Therapy] , 5,734

10 , ((acute* or server*) adj (heart* or cardiac* or myocard* or cardio* or ventric*) adj (failur* or decompensation* or insufficient* or dysfunct* or stand* or still* or fault* or shock*)).ti,ab. , 9,513

11 , Myocardit*.ti,ab. , 21,440

12 , ((Postpartum* or post-parttum* or peripartum* or peri-partum*) adj cardiomyopath*).ti,ab. , 1,697

13 , PPCM.ti,ab. , 671

14 , (myocard* adj (stun* or hibernat* or infract*)).ti,ab. , 2,258

15 , Primary Graft Dysfunction/th [Therapy] , 99

16 , (primary* adj graft* adj dysfunct*).ti,ab. , 1,392

17 , or/3-16 , 182,062

18 , *Cardiopulmonary Resuscitation/mt [Methods] , 4,116

19 , *Extracorporeal Membrane Oxygenation/ , 13,895

20 , ECMO.ti. , 3,217

21 , *Extracorporeal Circulation/mt [Methods] , 1,090

22 , (extracorp* adj circulat*).ti,ab. , 8,596

23 , (extracorp* adj ((cardiopulmon* adj resuscitat*) or CPR)).ti,ab. , 1,229

24 , ECPR.ti. , 154

25 , (Biomedicus adj pump*).ti,ab. , 45

26 , (Maquet* adj rotaflow*).ti,ab. , 12

27 , (jostra adj (pump* or rotaflow*)).ti,ab. , 5

28 , (levitronix adj (centrimag* or pump* or system* or oxygen*)).ti,ab. , 54

29 , (Medos adj (Hilite* or oxygen*)).ti,ab. , 22

30 , left ventricle assist device.ti,ab. , 106

31 , or/18-30 , 28,477

32 , 17 and 31 , 2,725

33 , animals/ not human/ , 5,225,551

34 , 32 not 33 , 2,680

35 , limit 34 to english language , 2,503

36 , limit 35 to ed=20130331-20240930 , 2,028

37 , limit 36 to (letter or historical article or comment or editorial or news or case reports) , 574

38 , 36 not 37 , 1,454

[Embase] search strategy

1 , heart failure/th [Therapy] , 15,752

2 , acute disease/th [Therapy] , 2,395

3 , 1 and 2 , 10

4 , *cardiomyopathy/th [Therapy] , 1,144

5 , *cardiogenic shock/th [Therapy] , 2,129

6 , stunned heart muscle/th [Therapy] , 53

7 , myocarditis/th [Therapy] , 864

8 , *heart infarction/ , 110,365

9 , primary graft dysfunction/th [Therapy] , 94

10 , "out of hospital cardiac arrest"/th [Therapy] , 3,862

11 , ((acute* or server*) adj (heart* or cardiac* or myocard* or cardio* or ventric*) adj (failur* or decompensation* or insufficient* or dysfunct* or stand* or still* or fault* or shock*)).ti,ab. , 17,537

12 , Myocardit*.ti,ab. , 31,093

13 , ((Postpartum* or post-parttum* or peripartum* or peri-partum*) adj cardiomyopath*).ti,ab. , 2,835

14 , PPCM.tw. , 1,261

15 , (myocard* adj (stun* or hibernat* or infract*)).ti,ab. , 3,555

16 , (primary* adj graft* adj dysfunct*).tw. , 3,009

17 , or/3-16 , 173,201

18 , *resuscitation/ , 60,473

19 , *extracorporeal oxygenation/ , 16,545

20 , ECMO.ti. , 7,837

21 , *extracorporeal circulation/ , 9,094

22 , (extracorp* adj circulat*).ti,ab. , 9,683

23 , (extracorp* adj ((cardiopulmon* adj resuscitat*) or CPR)).ti,ab. , 1,851

24 , ECPR.ti. , 352

25 , (Biomedicus adj pump*).ti,ab. , 50

26 , (Maquet* adj rotaflow*).ti,ab. , 31

27 , (jostra adj (pump* or rotaflow*)).ti,ab. , 16

28 , (levitronix adj (centrimag* or pump* or system* or oxygen*)).ti,ab. , 150

29 , (Medos adj (Hilite* or oxygen*)).ti,ab. , 44

30 , left ventricle assist device.ti,ab. , 217

31 , or/18-30 , 96,434

32 , 17 and 31 , 5,350

33 , Nonhuman/ not Human/ , 5,532,522

34 , 32 not 33 , 5,275

35 , limit 34 to letter/ or (letter or editorial).pt. , 2,165,352

36 , 34 not 35 , 4,904

37 , limit 36 to dc=20130331-20240930 , 3,599

38 , limit 37 to english language , 3,481

39 , (conference abstract* or conference review or conference paper or conference proceeding).db,pt,su. , 6,020,541

40 , 38 not 39 , 2,101

Cochrane Library (CDSR) search strategy

#1 MeSH descriptor: [Heart Failure] explode all trees and with qualifier(s): [therapy - TH] 2591

#2 MeSH descriptor: [Acute Disease] explode all trees and with qualifier(s): [therapy - TH] 118

#3 #1 and #2 0

#4 MeSH descriptor: [Cardiomyopathies] explode all trees and with qualifier(s): [therapy - TH] 248

#5 MeSH descriptor: [Shock, Cardiogenic] explode all trees and with qualifier(s): [therapy - TH] 177

#6 MeSH descriptor: [Myocardial Stunning] explode all trees and with qualifier(s): [therapy - TH] 3

#7 MeSH descriptor: [Myocarditis] explode all trees and with qualifier(s): [therapy - TH] 13

#8 MeSH descriptor: [Myocardial Infarction] explode all trees and with qualifier(s): [therapy - TH] 3337

#9 MeSH descriptor: [Primary Graft Dysfunction] explode all trees and with qualifier(s): [therapy - TH] 3

#10 MeSH descriptor: [Out-of-Hospital Cardiac Arrest] explode all trees and with qualifier(s): [therapy - TH] 539

#11 ((acute* or server*) near/1 (heart* or cardiac* or myocard* or cardio* or ventric*) near/1 (failur* or decompensation* or insufficient* or dysfunct* or stand* or still* or fault* or shock*)) 2663

#12 Myocardit* 1421

#13 (Postpartum* or post-partum* or peripartum* or peri-partum*) near/1 cardiomyopath* 47

#14 PPCM 39

#15 (myocard* near/1 (stun* or hibernat* or infract*)) 342

#16 (primary* near/1 graft* near dysfunct*) 146

#17 #3 or #4 or #5 or #6 or #7 or #8 or #9 or #10 or #11 or #12 or #13 or #14 or #15 or #168646

#18 MeSH descriptor: [Cardiopulmonary Resuscitation] this term only 1688

#19 MeSH descriptor: [Extracorporeal Membrane Oxygenation] this term only 361

#20 ECMO 1101

#21 MeSH descriptor: [Extracorporeal Circulation] this term only and with qualifier(s): [methods - MT]120

#22 (extracorp* near/1 circulat*) 1423

#23 (extracorp* near/1 ((cardiopulmon* near resuscitat*) or CPR)) 71

#24 ECPR 112

#25 (Biomedicus near/1 pump*) 3

#26 (Maquet* rotaflow*) 3

#27 jostra near/1 (pump* or rotaflow*) 1

#28 (levitronix near/1 (centrimag* or pump* or system* or oxygen*)) 0

#29 Medos near/1 (Hilite* or oxygen*) 0

#30 left ventricle assist device 219

#31 #18 or #19 or #20 or #21 or #22 or #23 or #24 or #25 or #26 or #27 or #28 or #29 or #304577

#32 #17 AND #31 494

#33 "conference":pt or (clinicaltrials or trialsearch):so 777352

#34 #32 NOT #33 with Cochrane Library publication date Between Mar 2013 and Sep 2024, in Cochrane Reviews 13

[Cochrane Library CENTRAL)] search strategy

#1 MeSH descriptor: [Heart Failure] explode all trees and with qualifier(s): [therapy - TH] 2591

#2 MeSH descriptor: [Acute Disease] explode all trees and with qualifier(s): [therapy - TH] 118

#3 #1 and #2 0

#4 MeSH descriptor: [Cardiomyopathies] explode all trees and with qualifier(s): [therapy - TH] 248

#5 MeSH descriptor: [Shock, Cardiogenic] explode all trees and with qualifier(s): [therapy - TH] 177

#6 MeSH descriptor: [Myocardial Stunning] explode all trees and with qualifier(s): [therapy - TH] 3

#7 MeSH descriptor: [Myocarditis] explode all trees and with qualifier(s): [therapy - TH] 13

#8 MeSH descriptor: [Myocardial Infarction] explode all trees and with qualifier(s): [therapy - TH] 3337

#9 MeSH descriptor: [Primary Graft Dysfunction] explode all trees and with qualifier(s): [therapy - TH] 3

#10 MeSH descriptor: [Out-of-Hospital Cardiac Arrest] explode all trees and with qualifier(s): [therapy - TH] 539

#11 ((acute* or server*) near/1 (heart* or cardiac* or myocard* or cardio* or ventric*) near/1 (failur* or decompensation* or insufficient* or dysfunct* or stand* or still* or fault* or shock*)) 2663

#12 Myocardit* 1421

#13 (Postpartum* or post-partum* or peripartum* or peri-partum*) near/1 cardiomyopath* 47

#14 PPCM 39

#15 (myocard* near/1 (stun* or hibernat* or infract*)) 342

#16 (primary* near/1 graft* near dysfunct*) 146

#17 #3 or #4 or #5 or #6 or #7 or #8 or #9 or #10 or #11 or #12 or #13 or #14 or #15 or #168646

#18 MeSH descriptor: [Cardiopulmonary Resuscitation] this term only 1688

#19 MeSH descriptor: [Extracorporeal Membrane Oxygenation] this term only 361

#20 ECMO 1101

#21 MeSH descriptor: [Extracorporeal Circulation] this term only and with qualifier(s): [methods - MT] 120

#22 (extracorp* near/1 circulat*) 1423

#23 (extracorp* near/1 ((cardiopulmon* near resuscitat*) or CPR)) 71

#24 ECPR 112

#25 (Biomedicus near/1 pump*) 3

#26 (Maquet* rotaflow*) 3

#27 jostra near/1 (pump* or rotaflow*) 1

#28 (levitronix near/1 (centrimag* or pump* or system* or oxygen*)) 0

#29 Medos near/1 (Hilite* or oxygen*) 0

#30 left ventricle assist device 219

#31 #18 or #19 or #20 or #21 or #22 or #23 or #24 or #25 or #26 or #27 or #28 or #29 or #304577

#32 #17 AND #31 494

#33 "conference":pt or (clinicaltrials or trialsearch):so 777352

#34 #32 NOT #33 with Cochrane Library publication date Between Mar 2013 and Sep 2024, in Trials 410

[INAHTA HTA Database] search strategy

1 , "Heart Failure"[mh] , 252

2 , "Acute Disease"[mh] , 46

3 , #2 AND #1 , 2

4 , "Cardiomyopathies"[mh] , 21

5 , "Shock, Cardiogenic"[mh] , 11

6 , "Myocardial Stunning"[mh] , 1

7 , "Myocarditis"[mh] , 1

8 , "Myocardial Infarction"[mh] , 123

9 , "Out-of-Hospital Cardiac Arrest"[mh] , 10

10 , ((acute* or server*) and (heart* or cardiac* or myocard* or cardio* or ventric*) and (failur* or decompensation* or insufficient* or dysfunct* or stand* or still* or fault* or shock*)). , 149

11 , Myocardit* , 5

12 , ((Postpartum* or post-parttum* or peripartum* or peri-partum*) AND cardiomyopath*) , 1

13 , PPCM , 0

14 , (myocard* and (stun* or hibernat* or infract*)) , 2

15 , "Primary Graft Dysfunction"[mh] , 0

16 , (primary* AND graft* AND dysfunct*). , 3

17 , #16 OR #15 OR #14 OR #13 OR #12 OR #11 OR #10 OR #9 OR #8 OR #7 OR #6 OR #5 OR #4 OR #3 , 291

18 , "Cardiopulmonary Resuscitation"[mh] , 23

19 , "Extracorporeal Membrane Oxygenation"[mh] , 29

20 , ECMO , 31

21 , "Extracorporeal Circulation"[mh] , 9

22 , (extracorp* AND circulat*). , 13

23 , (extracorp* AND ((cardiopulmon* AND resuscitat*) or CPR)) , 8

24 , ECPR , 4

25 , (Biomedicus AND pump*). , 0

26 , Maquet* and rotaflow*) , 0

27 , (jostra and (pump* or rotaflow*)). , 0

28 , (levitronix AND (centrimag* or pump* or system* or oxygen*)). , 0

29 , (Medos AND (Hilite* or oxygen*)). , 0

30 , left ventricle assist device , 3

31 , #30 OR #29 OR #28 OR #27 OR #26 OR #25 OR #24 OR #23 OR #22 OR #21 OR #20 OR #19 OR #18 , 74

32 , #31 AND #17 , 24

Inclusion criteria

The following inclusion criteria were applied to the abstracts identified by the literature search.

- Publication type: clinical studies were included with emphasis on identifying good quality studies. Abstracts were excluded if they did not report clinical outcomes. Reviews, editorials, and laboratory or animal studies, were also excluded and so were conference abstracts, because of the difficulty of appraising study methodology, unless they reported specific adverse events not available in the published literature.
- People with postcardiotomy heart failure.
- Intervention or test: VA ECMO.
- Outcome: articles were retrieved if the abstract contained information relevant to the safety, efficacy, or both.

If selection criteria could not be determined from the abstracts the full paper was retrieved.

Potentially relevant studies not included in the main evidence summary are listed in Appendix B: Other relevant studies.

Find out more about how NICE selects the evidence for the committee.

Appendix B: Other relevant studies

Other potentially relevant studies that were not included in the main evidence summary (tables 2 and 3) are listed in table 5 below.

Case studies and observational studies with fewer than 100 people were excluded unless they included outcomes that were not frequently reported.

Table 5 additional studies identified

Study	Number of people and follow up	Direction of conclusions	Reason study was not included in main evidence summary
Carroll BJ, Shah RV, Murthy V et al. (2015) Clinical features and outcomes in adults with cardiogenic shock supported by extracorporeal membrane oxygenation. The American Journal of Cardiology 116(10): 1624-30	Single centre retrospective study, US n=123 (26 postcardiotomy [21%]) Follow-up: In-hospital	Overall, 69 people (56%) were weaned from ECMO, with 48 patients (39%) surviving to discharge. People with postcardiotomy shock had the poorest overall survival after ECMO.	Included in Kowalewski (2020) SLR.
Distelmaier K, Wiedemann D, Binder C et al. (2018) Duration of extracorporeal membrane oxygenation support and survival in cardiovascular surgery patients. Journal of Thoracic and Cardiovascular Surgery 155(6): 2471-2476	Single centre retrospective study, Austria n=354 Follow-up: median 45 months (IQR: 20 to 81 months)	Through a median follow-up period of 45 months, 245 people (69%) died. An association between increased duration of ECMO support and mortality was observed in people who survived ECMO support with a crude hazard ratio of 1.96 (95% CI 1.40 to 2.74; p<0.001) for 2 year mortality compared with the third tertile and the second tertile of ECMO	Included in Kowalewski (2020) SLR.

		duration.	
Djordjevic I, Eghbalzadeh K, Sabashnikov A et al. (2020) Central vs peripheral venoarterial ECMO in postcardiotomy cardiogenic shock. Journal of Cardiac Surgery 35(5): 1037-1042	Single centre retrospective study, Germany n=156 Follow-up: 30 days	30-day mortality was comparable with nearly 70% in both cohorts (cECMO 39 [70%] vs pECMO 69 [69%]; p=0.93). ECMO complications occurred significantly more frequently in people treated with cECMO (cECMO 44 [79%] vs pECMO 54 [54%]; p<0.01).	Outcomes not reported as overall population, but by subgroup: central or peripheral VA ECMO.
Flecher E, Anselmi A, Corbineau H et al. (2014) Current aspects of extracorporeal membrane oxygenation in a tertiary referral centre: determinants of survival at follow-up. European journal of cardio-thoracic surgery : official journal of the European Association for Cardio-thoracic Surgery 46(4): 665-671	Single centre retrospective study, France n=325 (postcardiotomy 29%) Follow-up: mean 84 days (SD: 86)	Overall in the VA group, weaning rates were 59%, survival after 30 days was 44% and survival at the end of the follow-up was 41%.	More recent studies with outcomes split by aetiologies were included.
Fux T, Holm M, Corbascio M et al. (2018) Venoarterial extracorporeal membrane oxygenation for postcardiotomy shock: Risk factors for mortality. The Journal of Thoracic and Cardiovascular Surgery 156(5): 1894-1902e3	Single centre retrospective study, Sweden n=105 Follow-up: 90 days	The 90-day overall mortality was 57%, and in-hospital mortality was 56%. Forty-seven percent of patients died on venoarterial extracorporeal membrane oxygenation, 51% of patients were successfully weaned, 1% of patients were bridged to heart transplantation, and 1%of patients were bridged to left ventricular assist device.	Included in Alba (2021) SLR.
Khorsandi M, Dougherty	Systematic	Meta-analysis for	More recent

S, Bouamra O et al. (2017) Extra-corporeal membrane oxygenation for refractory cardiogenic shock after adult cardiac surgery: a systematic review and meta-analysis. Journal of cardiothoracic surgery 12(1): 55	review and meta-analysis n=1,926 24 studies Follow-up: In-hospital	overall survival rate to hospital discharge of 31% (95% CI 0.29 to 0.34, p<0.01, I^2=60%).	systematic reviews and meta-analyses included.
Kowalewski M, Raffa G, Zielinski K et al. (2020) Baseline surgical status and short-term mortality after extracorporeal membrane oxygenation for post-cardiotomy shock: a meta-analysis. Perfusion 35(3): 246-254	Systematic review and meta-analysis n=2,235 22 studies Follow-up: In-hospital, 30 day	Overall in-hospital or 30-day mortality event rate was 67% (95% CI 63 to 70%). There were no differences in in-hospital or 30-day mortality with respect to baseline surgical status in the subgroup analysis (test for subgroup differences; p=0.406).	Studies with more relevant outcomes were included.
Mariani S, van Bussel BCT, Ravaux JM et al. (2023) Variables associated with in-hospital and postdischarge outcomes after postcardiotomy extracorporeal membrane oxygenation: Netherlands Heart Registration Cohort. Journal of Thoracic and Cardiovascular Surgery 165(3): 1127-1137e14	Retrospective Netherlands Heart Registry study n=406 Follow-up: In-hospital, 1 year	In-hospital mortality was 52%, with death occurring in a median of 5 days (IQR 2 to 14 days) after surgery. Hospital survivors (n=196) experienced considerable rates of pulmonary infections, respiratory failure, arrhythmias, and deep sternal wound infections during a hospitalisation of median 29 days (IQR 17 to 51 days).	Larger registry studies from broader regions included.
Melehy A, Ning Y, Kurlansky P et al. (2022) Bleeding and thrombotic events during extracorporeal membrane oxygenation for postcardiotomy shock. The Annals of Thoracic Surgery	Single centre retrospective study, USA n=141 Follow-up: In-hospital	Of the 152 patients who received ECMO for postcardiotomy shock, 33 (23%) had 40 thrombotic events and 64 (45%) had 86 bleeding events.	Studies with more relevant outcomes were included.

113(1): 131-137			
Mihu MR, El Banayosy AM, Harper MD et al. (2024) Comparing outcomes of post-cardiotomy cardiogenic shock patients: on-site cannulation vs. retrieval for V-A ECMO support. Journal of Clinical Medicine 13(11): 3265	Single centre retrospective study, USA n=121 Follow-up: In-hospital	The overall mortality rate was 52%. Of the patients who died (n=63), 50 experienced on-ECMO mortalities, and 13 had post-weaning mortalities. The ECLS weaning rate was 55% (n=34) in the retrieved group and 63% (n=37) in the on-site group (p=0.38).	Outcomes not reported as overall population, but by subgroup: cannulation on or off site.
Papadopoulos N, Marinos S, El-Sayed Ahmad A et al. (2015) Risk factors associated with adverse outcome following extracorporeal life support: Analysis from 360 consecutive patients. Perfusion 30(4): 284-290	Single centre retrospective study, Germany n=360 Follow-up: In-hospital, 5 years	ECLS weaning was successful in 58% and 30% could be discharged from hospital. The main cause of death was sepsis (69%). Overall, major cerebrovascular events occurred in 12% (bleeding 3%, embolic 9%), limb ischaemia in 13%, GI complications in 16% and RRT in 61%. Kaplan Meier estimates for long-term survival were 26% at one year and 22% at 5 years.	Included in Kowalewski (2020), Biancari (2018), Alba (2021) SLRs.
Provaznik Z, Philipp A, Zeman F et al. (2021) Extracorporeal life support in postcardiotomy cardiogenic shock: a view on scenario, outcome, and risk factors in 261 patients. The Thoracic and Cardiovascular Surgeon 69(3): 271-278	Single centre retrospective study, Germany n=261 Follow-up: median 3.2 years	Overall mortality on ECLS was 39%. Overall follow-up survival was 24%.	Larger studies with longer follow-up included.
Sahli SD, Kaserer A, Braun J et al. (2022) Predictors associated with mortality of	Single centre retrospective study,	In-hospital mortality significantly varied between ECLS indications: 71%	Larger studies split by cardiogenic shock

extracorporeal life support therapy for acute heart failure: single-center experience with 679 patients. Journal of Thoracic Disease 14(6): 1960-1971	Switzerland n=679 (postcardiotomy n=215) Follow-up: In-hospital	(152/215) for postcardiotomy, 68% (108/159) for cardiopulmonary resuscitation, 47% (110/234) for refractory cardiogenic shock, and 10% (7/71) for lung transplantation and expansive thoracic surgery (p<0.001).	aetiology were included.
Shao C, Wang L, Yang F et al. (2022) Quality of life and mid-term survival in patients receiving extracorporeal membrane oxygenation after cardiac surgery. ASAIO Journal 68(3): 349-355	Single centre retrospective study, China n=102 Follow-up: 5 years	The SF-36 scores in general health and vitality were significantly lower among the ECMO survivors (p<0.05). After discharge, ECMO versus non-ECMO survival (93% versus 82%; p=0.013).	Studies with more relevant outcomes were included.
Xie H, Yang F, Hou D et al. (2020) Risk factors of in-hospital mortality in adult postcardiotomy cardiogenic shock patients successfully weaned from venoarterial extracorporeal membrane oxygenation. Perfusion 35(5): 417-426	Single centre retrospective study, China n=363 Follow-up: In-hospital	In total, 212 (58%) of 363 postcardiotomy cardiogenic shock patients were successfully weaned from venoarterial extracorporeal membrane oxygenation.	Studies with more relevant outcomes and larger studies with longer follow-up were included.
Zhigalov K, Sa MPBO, Safonov D et al. (2020) Clinical outcomes of venoarterial extracorporeal life support in 462 patients: Single-center experience. Artificial Organs 44(6): 620-627	Single centre retrospective study, Germany n=462 (postcardiotomy n=357) Follow-up: In-hospital	Overall, the in-hospital survival rate was 26%. There was no statistically significant difference between the groups: 26% for PCS and 25% for non-PCS, respectively. Weaning from VA-ECLS was possible in 44% for PCS and in 30% for non-PCS (p=0.004).	Larger studies split by CS aetiology were included.