Original Article

A systematic review and meta-analysis on the curative effects of cardiothoracic surgery for critical patients in the intensive care unit

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Background: The aim of this study was to explore the curative effects of cardiothoracic surgery (CTS) for critical patients in the intensive care unit (ICU) using meta-analysis.

Methods: Literature was searched using the following search terms: "cardiothoracic surgery", "intensive care unit", "critical patients", "post-operation", and "curative effects". Rev Man 5.3 was used for meta-analysis.

Results: A total of 15 randomized controlled trials (RCTs) were included, all of which had a low risk of bias, indicating medium and high quality. At 30 days after CTS, the number of patients with grade III and IV cardiac function was reduced by 76.84%, and the overall heterogeneity test results revealed that Tau^2=0.09, Chi^2=17.08, df=5, I^2=71%, P=0.004<0.01, Z=7.62, RR =0.33, and 95% CI: 0.24 to 0.43. The incidence of adverse reactions was analyzed in 6 RCTs, and mainly manifested as improper anticoagulation thrombosis and bleeding. The overall heterogeneity test results revealed that Chi^2=1.07, df=5, I^2=0%, P=0.96, Z=4.93, OR =0.46, 95% CI: 0.34 to 0.63, and P<0.01. The 30-day mortality rate was analyzed in 8 RCTs. The overall analysis using the fixed effects model revealed that there was a notable difference between the experimental group and the baseline, with Z=10.11, OR =0.12, 95% CI: 0.08 to 0.18, and P<0.01.

Discussion: CTS can reduce the incidence of adverse events and the mortality rate of critical patients in the ICU, demonstrating high safety.

Keywords: Cardiothoracic surgery (CTS); intensive care unit; critical patients; curative effects

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Introduction

There are more than 1.6 million critical patients in the intensive care unit (ICU) undergoing cardiothoracic surgery (CTS) every year (1). After CTS, the most common postoperative complications are alveolar atrophy and thoracic cavity effusion (2), prolonging hospital stay and increasing costs. It is reported that the annual mortality rate of patients who have not undergone CTS is about 6%, and the 5-year mortality rate is as high as 60%. Conservative treatment demonstrates limited efficacy, failing to prolong the survival time (3).

Critical patients in the ICU have declining systemic organ function and poor surgical tolerance. Among them, some patients suffer from chronic diseases, such as coronary heart disease, diabetes, and hypertension, and have engaged in long-term smoking, irregular physical exercise habits,

and have low cardiorespiratory function capacity, increasing the risk of surgery (4). Additionally, during the process of CTS, cardiopulmonary function will further decline due to unavoidable anesthetics, surgical trauma stimulation, postoperative pain, and lung infection, severely damaging the body's immunity and negatively affecting the patient's rapid recovery (5). How to quickly recover from CTS is a challenge for both critical patients in the ICU and their doctors (6).

Cardiopulmonary exercise during the perioperative period enhances the blood supply of the heart and relieves the fatigue of the respiratory muscles so that the patient can inhale sufficient oxygen, further improving the body's tolerance, which is of great significance for the surgical rehabilitation of elderly patients (7). More importantly, postoperative cardiopulmonary exercise can significantly reduce the incidence of complications, and long-term and systematic cardiopulmonary exercise can improve the long-term quality of life of patients (8).

At present, there are an increasing number of patients undergoing CTS, but there are few randomized controlled trials (RCTs) and relevant studies to confirm the safety and effectiveness of CTS (9). The innovation of this study is that by collecting a large number of relevant literatures, concerning postoperative cardiac function classification, five-minute walking distance, echocardiography, adverse reactions, and the mortality rate of critical patients in the ICU undergoing CTS in order to deeply understand the postoperative curative effects and safety of CTS. This study is expected to provide a scientific basis for later clinical diagnosis and treatment. We present the following article in accordance with the PRISMA reporting checklist (available at https://dx.doi.org/10.21037/apm-21-2224).

Methods

Literature review

Chinese and English medical databases were searched from the establishment of the database to October 20, 2020, with "cardiothoracic surgery", "intensive care unit", "critical patients", "post-operation", and "curative effects" used as the search terms.

Literature inclusion and exclusion criteria

The inclusion criteria were as follows: (I) RCTs; (II) literature with critical patients in the ICU undergoing CTS as subjects; and (III) literature containing indexes for evaluation outcomes.

The following studies were excluded: (I) literature with overlapping subjects; (II) literature not relevant to this study; and (III) literature with ambiguous results or missing indexes.

Data extraction

The following data were collated: (I) the title of the research; (II) the first author; (III) the name of the publication; (IV) year of publication; (V) the basic characteristics of the patients including age, gender, and number of cases; (VI) the intervention methods in the experimental group and the control group; and (VII) the evaluation indexes, including postoperative cardiac function, 5-minute walking distance, echocardiography, incidence of adverse reactions, and mortality rate.

Bias risk assessment and quality evaluation

Two researchers conducted a bias risk assessment simultaneously. The risk of bias was evaluated by factoring in the 5 aspects of random allocation method, blinding method, allocation concealment, complete data, and research results.

The Newcastle-Ottawa Scale (NOS) was used to evaluate the quality of the literature according to 3 aspects (*Table 1*), namely patient selection, comparability of the study, and outcome. The score ranged from 0 to 9. Studies with a score of 1 or less were considered low quality (high risk bias), studies with a score of 2–5 were considered medium quality (unclear), and studies with a score of 6–9 were considered high-quality literature (low risk bias).

Statistical analysis

Stata SE13.0 was used for statistical analyses. Relative risk (RR), odds ratio (OR), mean difference (MD), and 95% confidence intervals (CI) were used to assess the postoperative cardiac function, 5-minute walking distance, echocardiography, incidence of adverse reactions, and mortality rate of critical patients in the ICU undergoing CTS. RevMan 5.3 software was used to assess the risk of bias. When $P>0.1$ and $I^2<50\%$, the fixed effects model (FEM) was used. When $P<0.1$ and $I^2>50\%$, the random effects model (REM) was used.

Table 1 The evaluation criteria of the Newcastle-Ottawa Scale (NOS)

Content	Items	Evaluation criteria
Selection of research subjects	The exposure subjects were representative (1 point)	Highlighting the characteristics of the exposure subjects; displaying the characteristics of the exposure subjects to a certain extent; not elaborating on the sources of the exposure subjects
	The selection of non-exposure subjects	The same as that of the exposure subjects; different from that of the exposure subjects; not elaborating on the sources of the non-exposure subjects
	Identification of exposure factors	The history of surgeries; the structural interviews; the case report
Comparability between groups	There was a comparison between the exposure group and the non-exposure group (2 points)	Yes; no
Results obtained	Whether the results were comprehensive (1 point)	The blinding method; the case record; one's own case report; no description
	There was a long follow-up period (1 point)	Yes; no
	Whether there was a long follow-up of the exposure group and the non-exposure group (1 point)	The follow-up was complete; some subjects were missed during the follow-up; not pointing out the number of missed cases; not elaborating on the reason for the missed subjects

Results

Basic information

In this research, 315 literatures were obtained from the database and 309 literatures were obtained from the register. By reading the abstract and title of the articles, 131 literatures were repeatedly published, 109 were unqualified, and 58 were for other reasons, leaving 326 literatures. After reading the full text, 197 articles with repeated subjects were eliminated, leaving 129 articles. Eighty-one review reports were excluded, leaving 48. Thirty-three articles that could not be extracted were excluded, and 15 articles were finally included in the study (*Figure 1*).

Figure 2 shows that 8 articles scored 5–9, 5 scored 2–4, and 2 scored 1 and below.

The 15 studies that met the inclusion criteria involved a total of 1,264 patients older than 18 years old, with sample sizes ranging from 34 to 96. These studies were analyzed for the average age, number of cases, and intervention measures. The general characteristics of the research subjects are shown in *Table 2*.

Risk of bias assessment

Figures 3,*4* are the results of the risk bias evaluation of studies plotted by Rev Man 5.3 software. Of the 15 RCTs, 3 (10-12) had the correct random allocation method and only 2 (13,14) had allocation concealment. All studies adopted the blinding method.

Postoperative cardiac function

Postoperative cardiac function was analyzed in 6 RCTs, with a total of 812 cases involved. At 30 days after CTS, the number of patients with grade III and IV cardiac function was reduced by 76.84%, and the overall heterogeneity test results revealed that Tau^2=0.09, Chi^2=17.08, df=5, I^2=71%, and P=0.004<0.01. The research results by Paaske [2004] had the highest overlap with the combined results at 20.1%, followed by the research results of Arcêncio [2008] (18.4%). Additionally, the horizontal line was on the left side of the invalid vertical line at 95% CI in all 6 studies. The overall analysis using the REM revealed that there was a notable difference between the experimental group and the baseline, with Z=7.62, RR =0.33, and 95% CI: 0.24 to 0.43 (*Figure 5*).

The five-minute walking distance

The five-minute walking distance was analyzed in 4 RCTs, with a total of 546 cases involved. After CTS, the five-minute walking distance increased by 75m, and the overall heterogeneity revealed that Tau^2=557.74, Chi^2, 22.41, df=3, I^2=87%, and P<0.01. Additionally, the horizontal line was on the right side of the invalid vertical line at 95% CI in all 4 studies. The overall analysis using the REM revealed that there was a notable difference between the experimental

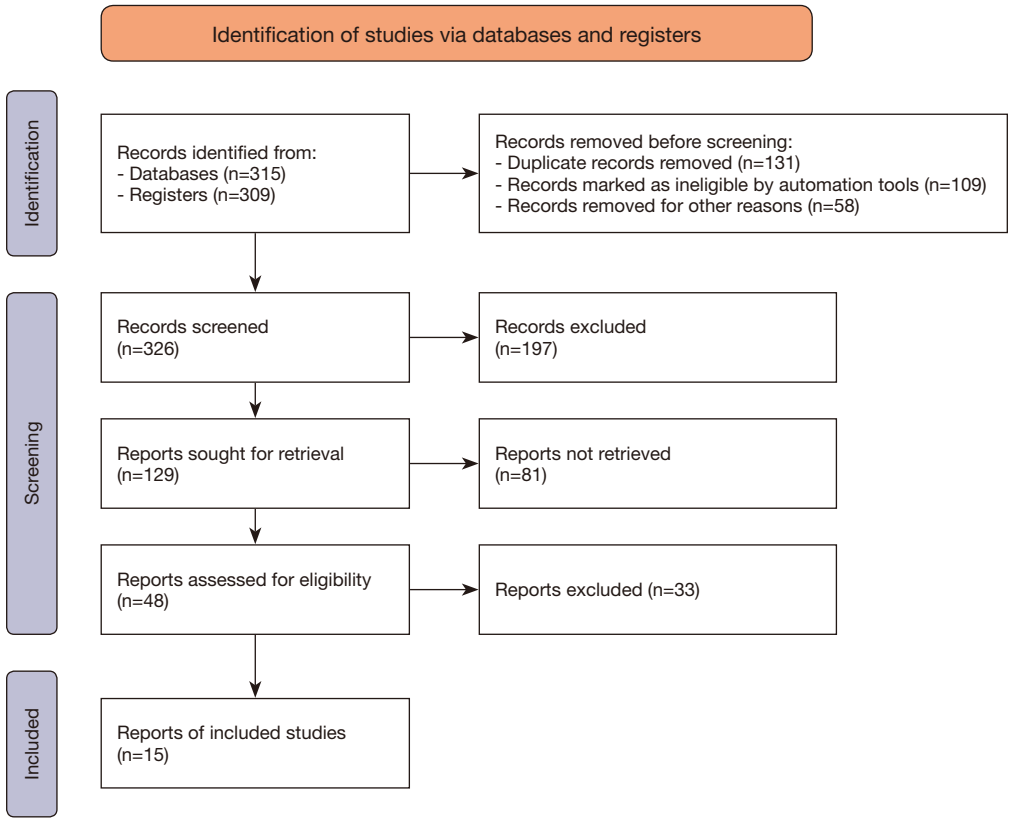


Figure 1 The literature search process.

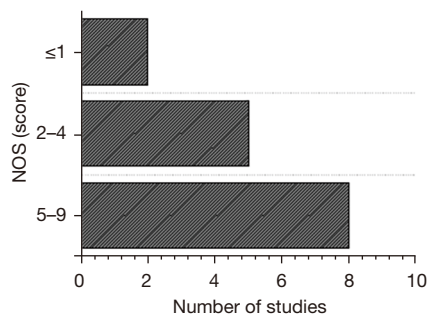


Figure 2 Quality classification results.

group and the baseline, with Z=11.56, MD =147.34, 95% CI: 122.39 to 172.35, and P<0.01 (*Figure 6*).

RevMan 5.3 was used to generate the five-minute walking distance funnel plot (*Figure 7*). It was noted that the circles in some studies were basically symmetrical along the midline, suggesting that the research accuracy was high and there was no bias in the publications.

Echocardiography

Echocardiography was analyzed in 6 RCTs, with a total of 862 cases involved. After CTS, the patients' left ventricular end-diastolic volume was reduced by 45.62 mL from baseline, and the overall heterogeneity test results revealed that Tau^2=237.40, Chi^2=31.14, df=5, I^2=74%, and P<0.01. In 2 studies, the horizontal line was on the left side of the invalid vertical line at 95% CI. The overall analysis using the REM revealed that there was a notable difference between the experimental group and the baseline, with Z=8.58, MD =–59.57, 95% CI: –73.17 to –45.96, and P<0.01 (*Figure 8*).

RevMan 5.3 was used to generate the funnel plot of echocardiography (*Figure 9*). It was noted that the circles in some studies were basically symmetrical along the midline, suggesting that the research accuracy was high, and there was no publication bias.

After CTS, the patients' left ventricular end-diastolic diameter was reduced by 0.45 cm from baseline, and the overall heterogeneity test results revealed that Tau^2=0.05, Chi^2=87.43, df=5, I^2=94%, and P<0.01. The horizontal line

Table 2 The general characteristics of the research subjects

Author	Year	Average age (year)	Number of cases	Cardiothoracic surgery
Ranucci M	2014	36.59±12.49	146	Mitral valve clamp
Mollberg NM	2013	46.29±11.35	130	Mitral valve replacement
Stéphan F	2016	31.53±8.36	134	Multi-center tricuspid valve surgery
Hu A	2017	37.12±15.89	118	Single-center tricuspid valve replacement
Habibi V	2018	32.24±10.67	95	Mitral valve replacement
Arora KS	2015	34.51±12.49	72	Mitral valve replacement
Sade RM	2008	46.59±15.48	72	Mitral valve clamp
Kamarajah SK	2019	36.59±12.49	192	Mitral valve replacement
Hasegawa T	2014	36.54±14.45	116	Mitral valve clamp
Paaske WP	2004	47.53±13.44	134	Multi-center tricuspid valve surgery
Macfie R	2018	44.55±12.49	77	Mitral valve clamp
Arcêncio L	2008	36.59±11.62	184	Single-center tricuspid valve replacement
Okusanya O	2020	46.74±12.41	169	Mitral valve replacement
Vaporciyan AA	2009	41.69±15.47	148	Mitral valve clamp
Via MA	2010	36.58±16.58	171	Mitral valve replacement

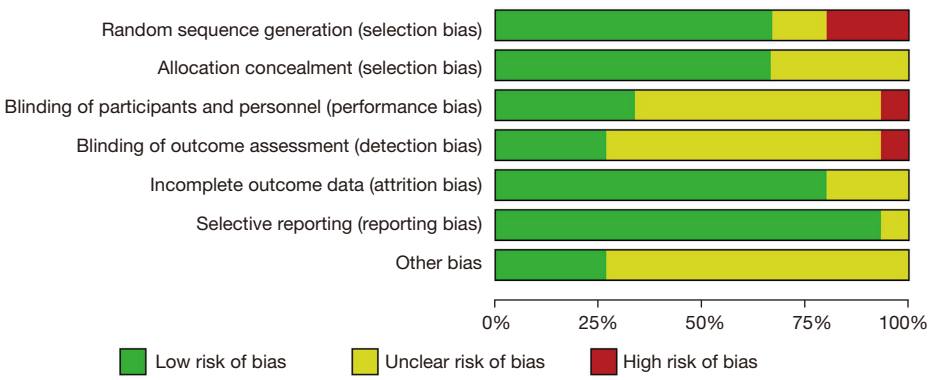


Figure 3 The risk of bias assessment.

was on the left side of the invalid vertical line at 95% CI in 2 studies. The overall analysis using the REM revealed that there was a notable difference between the experimental group and the baseline, with Z=7.37, MD =–0.66, 95% CI: –0.84 to –0.49, and P<0.01 (*Figure 10*).

The incidence of adverse reactions

The incidence of adverse reactions was analyzed in 6 RCTs, mainly manifesting as improper anticoagulation thrombosis and bleeding, with a total of 739 cases involved. The overall heterogeneity test results revealed that Chi^2=1.07, df=5, I^2=0%, and P=0.96. In some studies, the horizontal line crossed the invalid vertical line on the left at 95% CI. The overall analysis using the FEM revealed that there was a notable difference between the experimental group and the baseline, with Z=4.93, OR =0.46, 95% CI: 0.34 to 0.63, and P<0.01 (*Figure 11*).

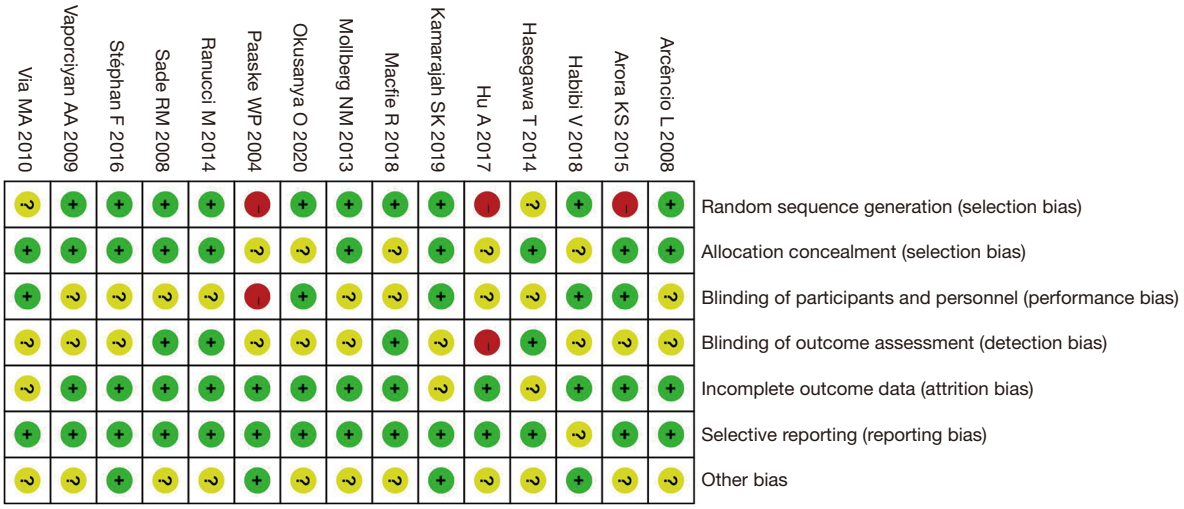


Figure 4 The multiple risk of bias evaluation results.

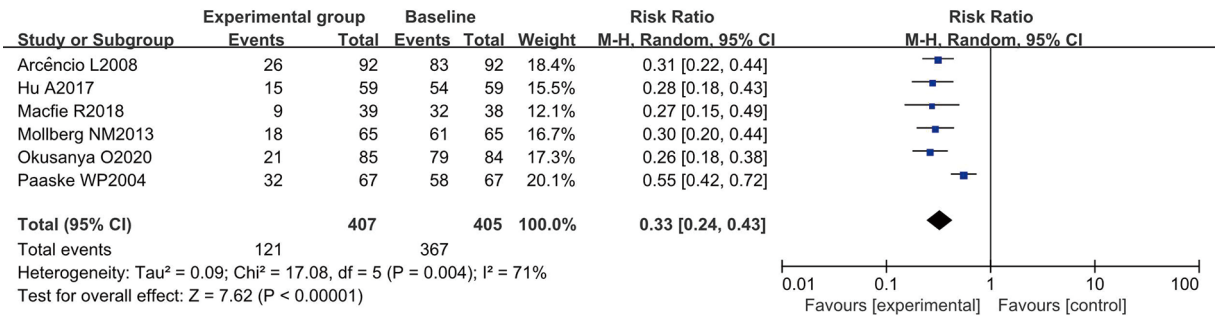


Figure 5 The proportion of patients with grade III and IV cardiac function.

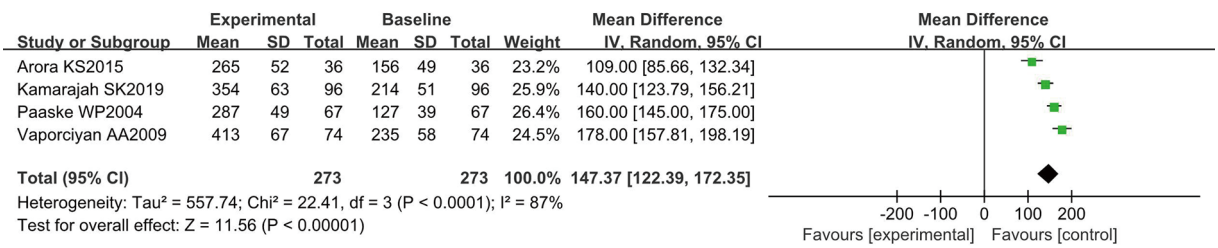


Figure 6 Forest plot for random effects model of five-minute walking distance.

The 30-day mortality rate

The 30-day mortality rate was analyzed in 8 RCTs, with a total of 1,073 cases involved. The horizontal line was on the left side of the invalid vertical line at 95% CI in 8 studies. The overall analysis using the FEM revealed that there was a notable difference between the experimental group and the baseline, with Z=10.11, OR =0.12, 95% CI: 0.08 to 0.18, and P<0.01 (*Figure 12*).

RevMan 5.3 was used to generate a funnel plot of mortality (*Figure 13*). It was noted that the circles in some studies were basically symmetrical along the midline,

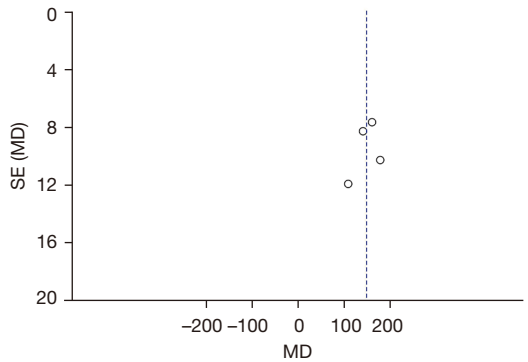


Figure 7 A funnel plot of a five-minute walk.

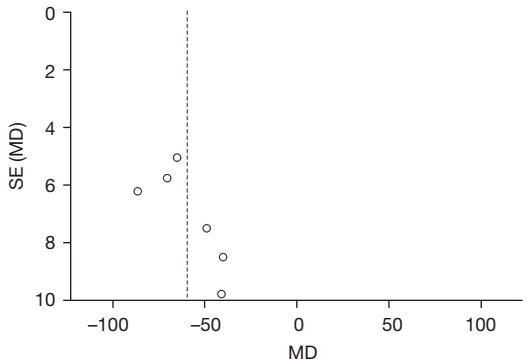
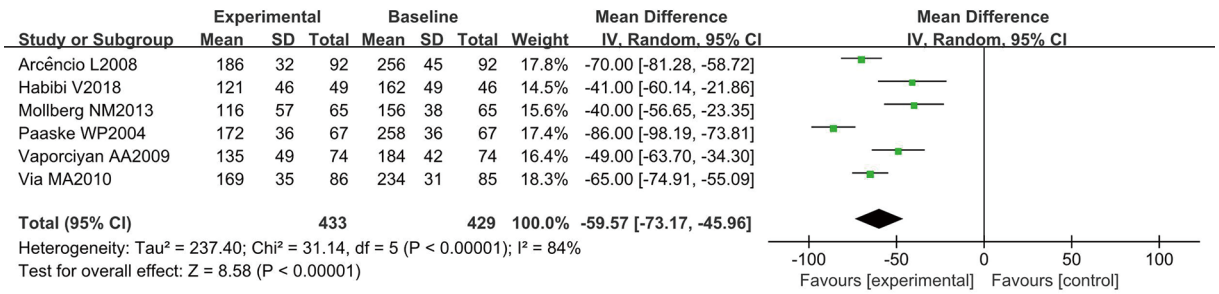


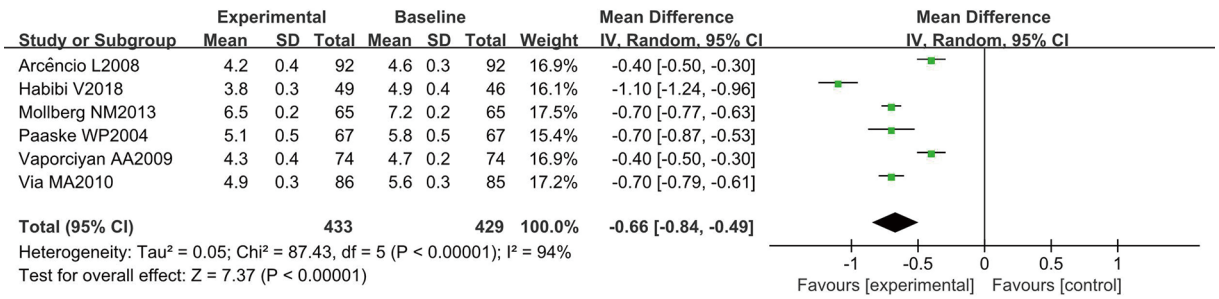
Figure 9 A funnel plot of echocardiography.



Study or Subgroup	Experimental Mean	SD	Total	Baseline Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
Arcêncio L2008	186	32	92	256	45	92	17.8%	-70.00 [-81.28, -58.72]
Habibi V2018	121	46	49	162	49	46	14.5%	-41.00 [-60.14, -21.86]
Mollberg NM2013	116	57	65	156	38	65	15.6%	-40.00 [-56.65, -23.35]
Paaske WP2004	172	36	67	258	36	67	17.4%	-86.00 [-98.19, -73.81]
Vaporciyan AA2009	135	49	74	184	42	74	16.4%	-49.00 [-63.70, -34.30]
Via MA2010	169	35	86	234	31	85	18.3%	-65.00 [-74.91, -55.09]
Total (95% CI)			**433**			**429**	**100.0%**	**-59.57 [-73.17, -45.96]**

Heterogeneity: Tau² = 237.40; Chi² = 31.14, df = 5 (P < 0.00001); I² = 84%
Test for overall effect: Z = 8.58 (P < 0.00001)

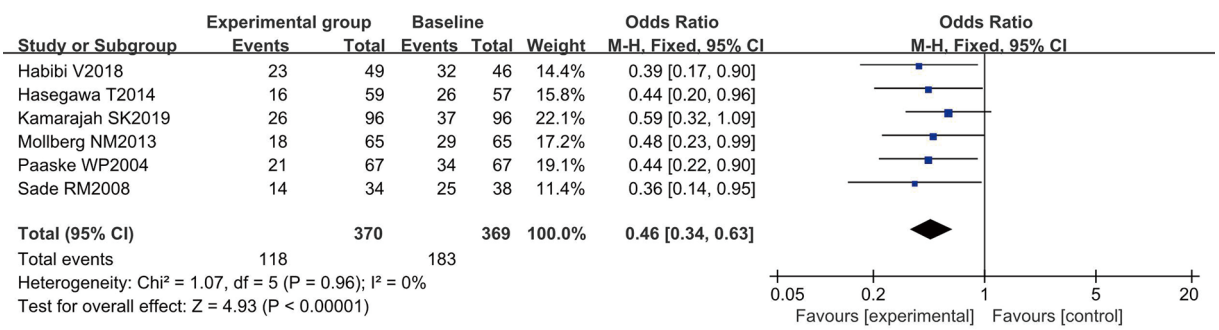
Figure 8 The left ventricular end-diastolic volume.



Study or Subgroup	Experimental Mean	SD	Total	Baseline Mean	SD	Total	Weight	Mean Difference IV, Random, 95% CI
Arcêncio L2008	4.2	0.4	92	4.6	0.3	92	16.9%	-0.40 [-0.50, -0.30]
Habibi V2018	3.8	0.3	49	4.9	0.4	46	16.1%	-1.10 [-1.24, -0.96]
Mollberg NM2013	6.5	0.2	65	7.2	0.2	65	17.5%	-0.70 [-0.77, -0.63]
Paaske WP2004	5.1	0.5	67	5.8	0.5	67	15.4%	-0.70 [-0.87, -0.53]
Vaporciyan AA2009	4.3	0.4	74	4.7	0.2	74	16.9%	-0.40 [-0.50, -0.30]
Via MA2010	4.9	0.3	86	5.6	0.3	85	17.2%	-0.70 [-0.79, -0.61]
Total (95% CI)			**433**			**429**	**100.0%**	**-0.66 [-0.84, -0.49]**

Heterogeneity: Tau² = 0.05; Chi² = 87.43, df = 5 (P < 0.00001); I² = 94%
Test for overall effect: Z = 7.37 (P < 0.00001)

Figure 10 The left ventricular end-diastolic diameter.



Study or Subgroup	Experimental group Events	Total	Baseline Events	Total	Weight	Odds Ratio M-H, Fixed, 95% CI
Habibi V2018	23	49	32	46	14.4%	0.39 [0.17, 0.90]
Hasegawa T2014	16	59	26	57	15.8%	0.44 [0.20, 0.96]
Kamarajah SK2019	26	96	37	96	22.1%	0.59 [0.32, 1.09]
Mollberg NM2013	18	65	29	65	17.2%	0.48 [0.23, 0.99]
Paaske WP2004	21	67	34	67	19.1%	0.44 [0.22, 0.90]
Sade RM2008	14	34	25	38	11.4%	0.36 [0.14, 0.95]
Total (95% CI)		**370**		**369**	**100.0%**	**0.46 [0.34, 0.63]**
Total events	118		183			

Heterogeneity: Chi² = 1.07, df = 5 (P = 0.96); I² = 0%
Test for overall effect: Z = 4.93 (P < 0.00001)

Figure 11 The incidence of adverse reactions.

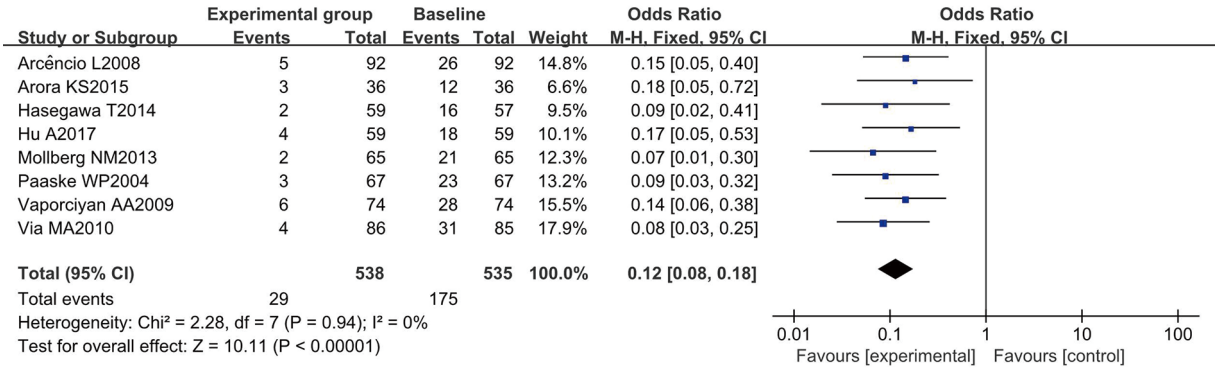


Figure 12 The mortality rate.

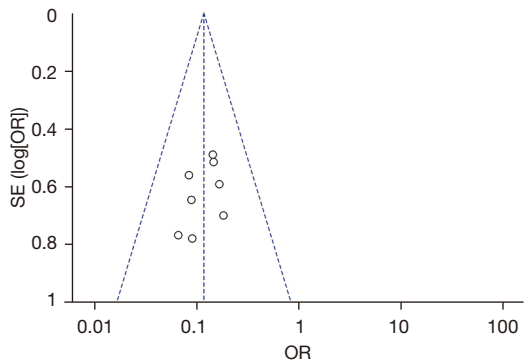


Figure 13 The mortality rate.

indicating that the research accuracy was high, and there was no bias in the publications.

Discussion

In this study, a meta-analysis was performed on the postoperative curative effects of CTS for critical patients in the ICU. The results found that the included literature demonstrated no bias (15).

At 30 days after CTS, the number of patients with grade III and IV cardiac function was reduced by 76.84%, and the overall heterogeneity test results revealed that Tau^2=0.09, Chi^2=17.08, df=5, I^2=71%, and P=0.004<0.01. The overall analysis using the REM revealed that there was a notable difference between the experimental group and the baseline, with Z=7.62, RR =0.33, and 95% CI: 0.24 to 0.43. After CTS, there were 72.46% of critical patients with grade I and II cardiac function, lower than 87.49% reported by Chatterjee *et al.* [2019] (16).

The incidence of adverse reactions was analyzed in 6 RCTs, mainly manifesting as improper anticoagulation thrombosis and bleeding, with a total of 739 cases involved. The overall heterogeneity test results revealed that Chi^2=1.07, df=5, I^2=0%, and P=0.96. The overall analysis using the FEM revealed that there was a notable difference between the experimental group and the baseline, with Z=4.93, OR =0.46, 95% CI: 0.34 to 0.63, and P<0.01, which was aligned with the research results of Shelley *et al.* [2019] (17).

The 30-day mortality rate was analyzed in 8 RCTs. The FEM revealed that there was a notable difference between the experimental group and the baseline, with Z=10.11, OR =0.12, 95% CI: 0.08 to 0.18, and P<0.01. The mortality rate in the study was 5.3%, which was similar to 6.8% reported by Geoffrion *et al.* [2020] (18).

In the study, the 30-day mortality rate was 5.3%, and 29 patients died 30 days after CTS. Adverse reactions included myocardial infarction, acute stroke, respiratory failure, bleeding, atrial fibrillation, infection, renal failure, and bleeding, with an incidence of about 31.89% (19). During the 1-year follow-up, 156 patients died, and the 1-year mortality rate was 28.9%. The mortality rate and quality of life are important indicators to evaluate postoperative clinical efficacy (20). In the study, the different CTS methods had distinct impacts on the patients.

In this study, the included literature was classified based on the selection of subjects, the comparability between groups, and the results obtained using the NOS. There are some limitations of this study. The sample size was small, and the included literature was mostly of medium and high quality with high heterogeneity, and most of them were self-controlled trials. Hence, more clinical RCTs with larger samples sizes are needed.

Conclusions

In this study, 15 publications were retrieved to explore the curative effects of CTS for critical patients in the ICU. The investigation confirmed that CTS can reduce the incidence of adverse events and the mortality rate of critical patients in the ICU, demonstrating high safety.

Acknowledgments

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Footnote

Reporting Checklist: The authors have completed the PRISMA reporting checklist. Available at https://dx.doi.org/10.21037/apm-21-2224

Conflicts of Interest: All authors have completed the ICMJE uniform disclosure form (available at https://dx.doi.org/10.21037/apm-21-2224). The authors have no conflicts of interest to declare.

Ethical Statement: The authors are accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.

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