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ORIGINAL ARTICLE

Continuous positive airway pressure to prevent reintubation in patients recovering from cardiac surgery

A multicentre randomised clinical trial

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BACKGROUND Pulmonary complications, including atelectasis and reintubation, are common after cardiac surgery and are associated with increased morbidity and mortality. Postoperative continuous positive airway pressure (CPAP) may reduce these risks, but its effectiveness remains uncertain.

OBJECTIVES To assess whether CPAP reduces the need for reintubation in hypoxaemic patients after cardiac surgery, and to evaluate its effect on other postoperative pulmonary complications.

DESIGN Multicentre, open-label, randomised clinical trial. The study was prematurely terminated due to funding constraints, leading to an underpowered sample.

SETTING Ten university-affiliated hospitals across Italy.

PATIENTS Adults undergoing cardiac surgery with cardiopulmonary bypass who developed a P_aO_2/FiO_2 ratio 200 or less within 1 h of extubation. Exclusion criteria included severe COPD, previous mechanical ventilation and lack of consent.

MAIN OUTCOME MEASURES The primary endpoint was reintubation within 28 days of surgery. Secondary endpoints included atelectasis, pneumonia, sepsis, mortality and oxygenation.

RESULTS The incidence of reintubation was 10.8% (95% confidence interval [CI], 6.52 to 15.15) in the control group and 8.3% (95% CI, 4.51 to 12.16) in the treatment group ($P = 0.3908$). In contrast, the occurrence of atelectasis was significantly higher in the control group at 24.1% (95% CI, 18.20 to 30.07) compared with 14.2% (95% CI, 9.38 to 19.05) in the treatment group ($P = 0.0110$). At 48 h, the incidence of reintubation was significantly lower in the CPAP group 2.94% (95% CI, 0.60 to 5.28) compared with the control group, 7.39% (95% CI, 3.76 to 11.02), $P = 0.0425$. No significant differences in pneumonia, sepsis or mortality were observed. CPAP significantly improved oxygenation ($P < 0.0001$).

CONCLUSION CPAP did not significantly reduce 28-day reintubation rates compared with oxygen therapy via Venturi mask. However, CPAP was associated with a significant reduction in atelectasis and early reintubation at 48 h. Further research is warranted to confirm these findings and compare CPAP with other noninvasive support strategies.

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KEY POINTS

- Pulmonary atelectasis is one of the major contributors to severe postoperative hypoxaemia in surgical patients.
- CPAP significantly reduces the occurrence of atelectasis compared with spontaneous breathing with Venturi mask.
- CPAP did not significantly lower the 28-day re-intubation rate compared with spontaneous breathing with a Venturi mask; however, a significant reduction of re-intubation rate was observed at 48 h from surgical intervention.

Introduction

Pulmonary atelectasis is a major contributor to severe postoperative hypoxaemia in surgical patients and frequently requires admission to an intensive care unit (ICU) for mechanical ventilation.[1] In cardiac surgery, postoperative pulmonary atelectasis has been linked to a fourfold increase in mortality, along with extended ICU and hospital stays.[2] Although the application of positive end-expiratory pressure (PEEP) can help re-expand the atelectatic areas during invasive mechanical ventilation,[3] persistent atelectasis following extubation may disrupt pulmonary gas exchange, heighten the risk of reintubation and complicate recovery.[1,4,5]

Continuous positive airway pressure (CPAP) is a breathing mode in which a patient breathes spontaneously through a pressurised circuit against a threshold resistor that maintains preset positive airway pressure during both inspiration and expiration. CPAP can prevent alveolar collapse, increase functional residual capacity and oxygenation, and reduce both breathing workload and cardiac preload.[6] A previous meta-analysis of randomised clinical trials suggested that CPAP decreased the risk of atelectasis and supported its clinical use in patients recovering from abdominal[7,8] and cardiac[9] surgery. A more recent network meta-analysis of studies including patients undergoing extra-thoracic and thoracic surgery,[10] and cardiac surgery[11] found that, compared to conventional oxygen therapy, CPAP did not reduce the risk of reintubation for post-extubation respiratory failure. However, owing to the limited quality of current evidence, questions remain regarding the efficacy and safety of CPAP.[12]

This randomised clinical trial aimed to evaluate whether applying CPAP in patients recovering from cardiac surgery and who developed severe hypoxaemia after extubation could reduce reintubation rates by expanding lung areas of postoperative atelectasis.

Methods

This multicentre, open-label, randomised clinical trial was conducted in 10 Italian hospitals ('Città della Salute e della Scienza' university hospital, Turin; 'Santa Croce e Carle' hospital, Cuneo, 'Papa Giovanni XXIII' hospital, Bergamo, 'Sant'Orsola' university hospital, Bologna; 'Niguarda' and 'Monzino'' hospitals, Milan; 'Umberto I' and 'Gemelli' university hospitals, Rome; 'Policlinico' and 'Santa Maria' hospitals, Bari) and was supported by Agenzia Italiana del Farmaco (AIFA; FARM12MNXK).

Ethics

The study was approved by all Institutional Ethics Committees. Informed consent was obtained before randomisation, and study procedures were in accordance with the Declaration of Helsinki.[13]

Population

All patients undergoing cardiac surgery with cardiopulmonary bypass (CPB) were eligible. After extubation in the ICU, patients underwent a 1 h screening test breathing oxygen through a Venturi mask at an inspiratory fraction of 0.5. Patients were eligible for inclusion in the study if they developed an arterial oxygen tension/inspiratory oxygen fraction ratio (P/F) of 200 or less. Exclusion criteria included patients under 18 years of age, preoperative left ventricular ejection fraction less than 25%, need for mechanical ventilation (invasive or noninvasive) before surgery, severe COPD requiring oxygen therapy with an FEV_1 less than 50%, use of veno-venous or arterio-venous extracorporeal membrane oxygenation, heart and lung transplants, lack of consent.

Study procedure

Patients were randomly assigned to receive either 6 h of oxygen therapy through a Venturi mask with an inspiratory O_2 fraction adjusted to maintain SpO_2>95% (*control*) or CPAP at 10 cmH_2O delivered via helmet, or face mask with the inspiratory oxygen fraction adjusted to maintain SpO_2>95% (*treatment*). After the 6 h period, all patients underwent a 15 min screening test, breathing oxygen through a Venturi mask set to an inspiratory O_2 fraction of 0.5. Patients recommenced their assigned treatment if their P/F ratio was 200 or less, and treatment was discontinued if their P/F ratio exceeded 200.

Concealed randomisation was centrally managed through a dedicated website using a computer-generated random sequence stratified by the centre. The block sizes were four and six, each containing an equal number of treatments, with the treatment order within each block in random permutations.

The primary endpoint was the proportion of patients who were reintubated within 28 days of randomisation. Reintubation was performed if any of the following predefined events occurred: (1) respiratory failure defined as the presence of at least two of the following criteria: respiratory acidosis (pH <7.35 or P_aCO_2 >45 mmHg); arterial saturation of O_2 less than 90% or P_aO_2 less than 60 mmHg

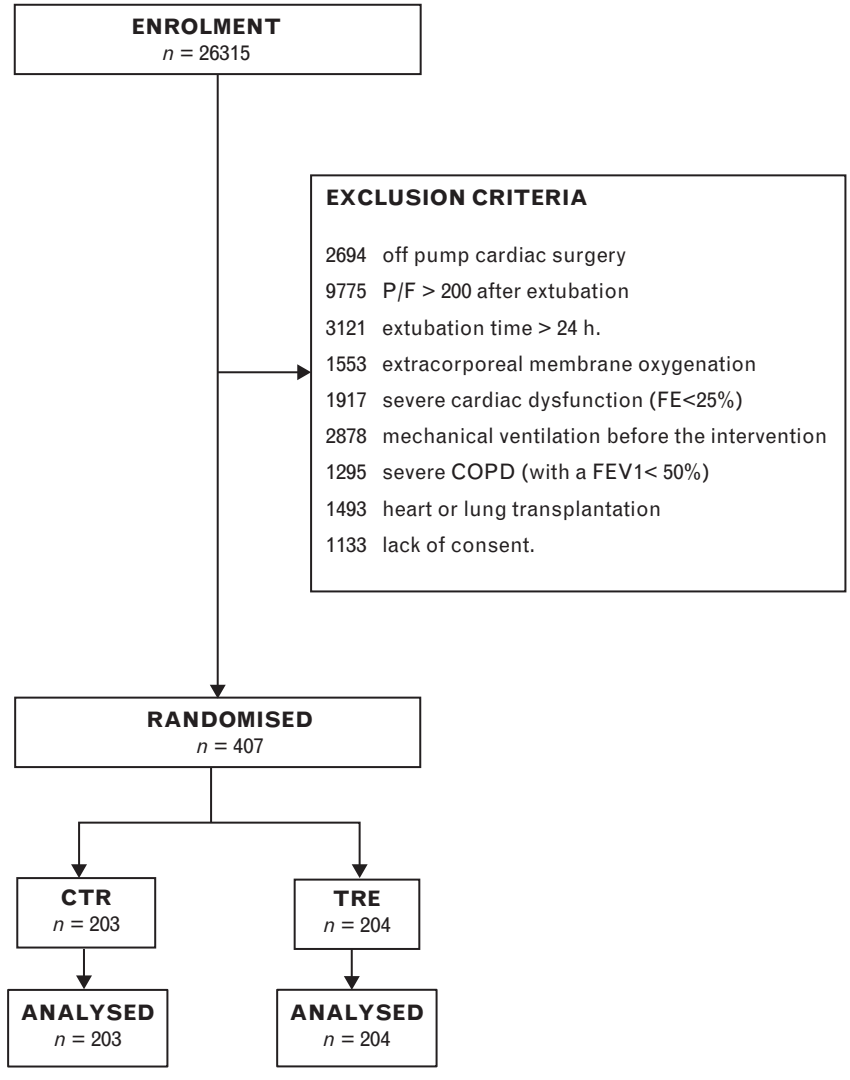
with an inspired oxygen fraction greater than 50%; respiratory rate more than 35 breaths per minute; decreased consciousness, agitation; diaphoresis; clinical signs suggestive of respiratory muscle fatigue and/or increased work of breathing, such as the use of respiratory accessory muscles, paradoxical motion of the abdomen, or retraction of the intercostal spaces; (2) respiratory or cardiac arrest; (3) loss of consciousness; (4) psychomotor agitation inadequately controlled by sedation; (6) massive aspiration; (7) persistent inability to remove secretions and (8) severe haemodynamic instability.[14]

The secondary endpoints included the proportion of patients who developed atelectasis, pneumonia, sepsis and death within 28 days of randomisation. We also evaluated the incidence and relative risk of reintubation and the occurrence of postoperative atelectasis in the control and treatment groups within 48 h of randomisation. Atelectasis was evaluated on postoperative chest radiographs by the attending clinician and evidence of one atelectatic area in at least one quadrant was classified as positive. Pneumonia was assessed using the Clinical Pulmonary Infection Score.[15] We also assessed ICU and hospital lengths of stay.

Statistical analysis

The reintubation rate in the control group was estimated to be 10%. To observe a reduction from 10% to 5% in the treatment group, the study was designed to enrol a total of 480 patients. An interim analysis to evaluate the efficacy of the treatment was planned at the enrolment of the 50% of the sample size. The O'Brien–Fleming method was used to control the inflation of the type I error.[16]

Fig. 1 Consort flow diagram.



COPD, chronic obstructive pulmonary disease; CTR, control; EF, ejection fraction; TRE, treatment.

Analyses were performed using SAS™ version 9.4 for Windows (SAS Institute Inc., Cary, NC, USA). Data were analysed according to the intention-to-treat principle. Participants who withdrew their consent were excluded from the study. Continuous variables are expressed as mean ± SD or median [IQR], and categorical variables are expressed as a percentage of the raw number.

Comparisons between groups were made using student's *t*-test or Wilcoxon–Mann–Whitney test for continuous variables, and the χ^2 or Fisher exact test for categorical variables. To analyse the time course of the *P*/*F* ratio profiles in the different patient groups, we used a generalised linear model.

For primary and secondary endpoints, we calculated the odds ratio (OR) and the 95% confidence interval (95% CI). Furthermore, the effect size of the treatment on the primary endpoint was evaluated using Cox proportional hazards model and estimating the hazard ratio (HR) and its 95% CI. The Kaplan–Meier method, along with the log-rank test, was performed.

Results

The study was terminated before reaching the planned interim analysis (407 instead of 480 patients) due to cessation of funding. We determined that the power to detect the differences between group proportions, as initially specified in the study plan, had decreased by 48%.

From May 2013 to July 2024, 26 315 patients were evaluated for eligibility, and 407 patients matched the inclusion and exclusion criteria and were randomised (203 in the control group and 204 in the treatment group) (Fig. 1).

Clinical variables before randomisation are shown in Table 1. The protocol was applied for a median [IQR] time of 12 [6 to 18] hours and 9 [6 to 12] hours in the Venturi mask and CPAP groups, respectively ($P = 0.1663$). Figure 2 shows the progression of the *P*/*F* ratio during the first 9 h of treatment, starting from the time when entry criteria were met. Oxygenation was significantly improved in the treatment group compared with that in the control group ($P < 0.0001$).

The time-to-event analysis of reintubation and atelectasis at 28 days are shown in Fig. 3. The incidence of reintubation was 10.8% (95% CI, 6.52 to 15.15) in the control group and 8.3% (95% CI, 4.51 to 12.16) in the treatment group ($P = 0.3908$). The occurrence of atelectasis was significantly higher in the control group at 24.1% (95% CI, 18.20 to 30.07) compared with 14.2% (95% CI, 9.38 to 19.05) in the treatment group ($P = 0.0110$). The relative risk in the treatment group was 0.7689 (95% CI, 0.4210 to 1.4044) for reintubation and 0.5889 (95% CI, 0.3885 to 0.8928) for atelectasis. The incidence of pneumonia, sepsis, death and ICU and hospital length of stay did not differ between the control and treatment arms (Table 2). It should be noted that incidence of

Table 1 Baseline characteristics and prerandomisation data of the patients

	CTR ($n = 203$)	TRE ($n = 204$)
Age (years)	70 ± 10	69 ± 9
Female	71 (35.0)	76 (37.3)
BMI (kg m^{-2})	28 [25 to 31]	27 [25 to 31]
NYHA class III-IV or unstable angina or AMI	49 (24.1)	64 (31.8)
EF (%)	55.8 ± 9.4	55.0 ± 9.4
Previous cardiac surgery	21 (10.3)	13 (6.4)
Dialysis	5 (2.46)	0 (0)
Preoperative creatinine (mg dl^{-1})	2.0 ± 8.4	1.7 ± 8.9
P/*F* (mmHg)	335 ± 134	319 ± 103
P_aO_2 (mmHg)	116 ± 81	107 ± 76
P_aCO_2 (mmHg)	38 ± 6	39 ± 5
Arterial pH	7.43 ± 0.05	7.42 ± 0.05
HCO_3 (mEq l^{-1})	26.4 ± 18.0	26.6 ± 16.9
Lactate (mmol l^{-1})	1.06 ± 0.41	1.13 ± 0.59
ACEF score	1.23 [1.08 to 1.43]	1.23 [1.09 to 1.38]
EURO score	4 [2 to 7]	4 [2 to 6]
Type of surgery		
CABG	48 (23.6)	56 (28.5)
Valve	99 (48.7)	83 (40.7)
CABG ∗ valve	33 (16.3)	32 (15.7)
Aortic surgery	20 (10.0)	26 (12.8)
Unknow	3 (1.5)	7 (3.4)
Surgical urgency		
Elective	180 (88.7)	173 (84.8)
Emergency	3 (1.5)	8 (3.9)
Unknown	20 (9.9)	23 (11.3)
Surgical approach		
Sternotomy	162 (79.8)	165 (80.9)
Mini-thoracotomy	21 (10.3)	15 (7.3)
Unknown	20 (9.9)	24 (11.8)
Intervention duration (min)	305 [270 to 360]	300 [265 to 360]
Cardiopulmonary bypass duration (min)	119 [91 to 149]	120.5 [91 to 150]
Cross clamping duration (min)	82 [62 to 115]	84 [65 to 109]
Intra-operative Hct (%)	27.8 ± 5.5	29.5 ± 20.5
Intra-operative Hb (g dl^{-1})	9.1 ± 1.9	10.0 ± 8.6
Intra-operative temperature (°C)	31.9 ± 3.3	32.0 ± 2.7
Diuresis (ml)	757 ± 624	809 ± 664
Transfusion RPC (ml)	258 ± 375	230 ± 391
Transfusion FFP	20 (9.9)	15 (7.4)
Transfusion FFP (ml)	490.6 ± 222.7	683.4 ± 473.4
Hypotension (MAP <65 mmHg)	26 (12.8)	16 (7.9)
Severe arrhythmia/cardiac arrest		
Severe arrhythmia or cardiac arrest	8 (3.9)	3 (1.5)
Arrhythmia absent	192 (94.6)	195 (95.6)
Unknown	3 (1.5)	6 (2.9)
ABG at extubation		
pH	7.39 ± 0.05	7.38 ± 0.05
P_aO_2 (mmHg)	82.6 ± 12.5	82.8 ± 12.6
P/*F* (mmHg)	165 ± 25	165 ± 26
Lactate (mmol l^{-1})	2.14 ± 2.79	2.06 ± 1.50
P_aCO_2 (mmHg)	41.2 ± 5.8	41.3 ± 6.2
HCO_3 (mEq l^{-1})	24.5 ± 2.8	24.4 ± 3.0
Chest X-ray		
Atelectasis – yes	31 (15.3)	25 (12.3)
Atelectasis – no	169 (83.3)	179 (87.8)
Unknown	3 (1.5)	0 (0)
Oedema – yes	16 (8.0)	18 (8.8)
Oedema – no	184 (90.6)	186 (91.2)
Unknown	3 (0.4)	0 (0)
Infiltrate		
No infiltrate	193 (96.1)	200 (98.0)
Diffuse (or patchy) infiltrate	1 (0.5)	1 (0.5)
Localised infiltrate	6 (2.9)	3 (1.5)
Unknown	3 (1.5)	0 (0)

Table 1 (*continued*)

	CTR ($n = 203$)	TRE ($n = 204$)
Haemodynamic parameters		
HR (bpm)	83 ± 14	82 ± 14
MAP (mmHg)	78.7 ± 10.8	79.5 ± 11.9
EF (%)	54.6 ± 12.2	54.8 ± 9.1
CVP (mmHg)	8.56 ± 3.86	8.28 ± 3.51
Swan–Ganz catheter	31 (15.5)	28 (13.7)
Haemodynamic support		
Dopamine	32 (16)	42 (21)
Norepinephrine	31 (15.5)*	16 (7.8)
Enoximon	5 (2.5)	3 (1.5)
Dobutamine	41 (20.5)	36 (17.6)
Epinephrine	18 (9)	17 (8)
Levosimendan	3 (1.5)	6 (2.9)
IABP	1 (0.5)	2 (1.0)

Data are presented as mean ± SD, median [IQR], number (%). ABG, arterial blood gas; ACEFscore, age, creatinine, ejection fraction; AGB, arterial blood gasses; BMI, body mass index; bpm, beats per minute; CABG, coronary artery bypass grafting; CVP, central venous pressure; EF, ejection fraction; EuroSCORE, European System for Cardiac Operative Risk Evaluation; FFP, fresh frozen plasma; Hb, haemoglobin; Hct, haematocrit; HR, heart rate; IABP, intra-aortic balloon pump; MAP, mean arterial pressure; *P/F*, partial pressure of arterial oxygen divided by the decimal fraction of inspired oxygen – expressed as a number, P_aCO_2, partial pressure of arterial carbon dioxide; RPC, red packed cell.
* $P < 0.05$.

reintubation at 48 h was 7.39% (95% CI, 3.76 to 11.02) in the control group and 2.94% (95% CI, 0.60 to 5.28) in the treatment group ($P = 0.0425$); the relative risk in the treatment group was 0.9542 (95% CI, 0.9116 to 0.9987).

Discussion

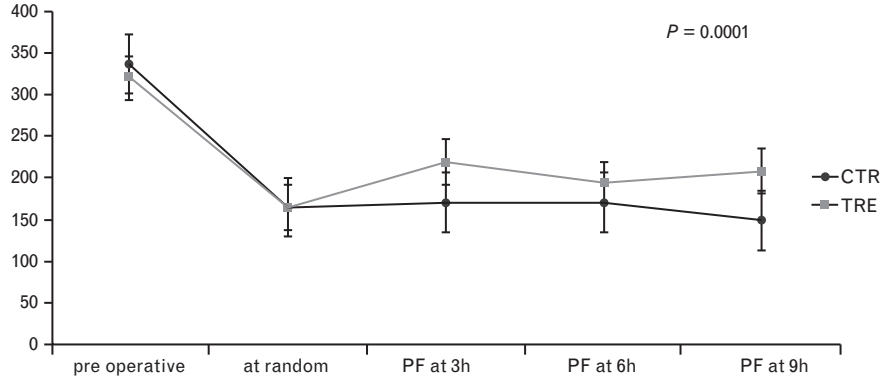
The results of the present study suggest that although CPAP significantly reduced the incidence of atelectasis compared with oxygen therapy, it did not significantly lower the 28-day reintubation rate in patients with severe hypoxaemia (*P/F* ratio ≤200) following extubation after cardiac surgery compared with those using a Venturi mask with spontaneous breathing. Daily analysis showed a significantly lower reintubation rate at 48 h in the CPAP-treated group, which is consistent with the incidence of atelectasis detected mostly within the first 48 h after surgery.

CPAP is a respiratory support mode in which patients breathe spontaneously through a pressurised circuit with a threshold resistor, maintaining a constant positive airway pressure during both inspiration and expiration, thereby preventing alveolar collapse and improving oxygenation.[6] In a randomised controlled study, Squadrone *et al.* evaluated the addition of CPAP to standard oxygen therapy in 209 patients with acute hypoxaemia after major elective abdominal surgery. The use of CPAP significantly reduced the need for endotracheal intubation and lowered the rates of pneumonia, infection and sepsis compared with oxygen therapy alone. The CPAP group also showed a tendency toward shorter ICU stays, with no reported deaths, whereas three deaths occurred in the oxygen-only group.[17] Zarbock *et al.*[18] conducted a prospective randomised clinical trial that included 500 patients and showed that administration of prophylactic nasal CPAP applied after extubation for elective cardiac surgery either in the operating room (early) or in the ICU (late) led to improved arterial oxygenation, a decrease in pneumonia, a reduced reintubation rate and ICU readmissions.

Although the results and the conclusions of previous meta-analyses have supported the use of CPAP in patients recovering from abdominal[7,8] and cardiac[9] surgery, recent network meta-analyses have examined the efficacy of CPAP in broader surgical populations, including those undergoing both extra-thoracic and thoracic procedures[10] as well as cardiac surgery.[11] These studies suggest that, compared with standard oxygen therapy, CPAP does not significantly reduce the risk of reintubation for postextubation respiratory failure and concluded that despite the potential of CPAP to prevent atelectasis, current evidence remains inconclusive on its efficacy and safety in reducing reintubation rates.

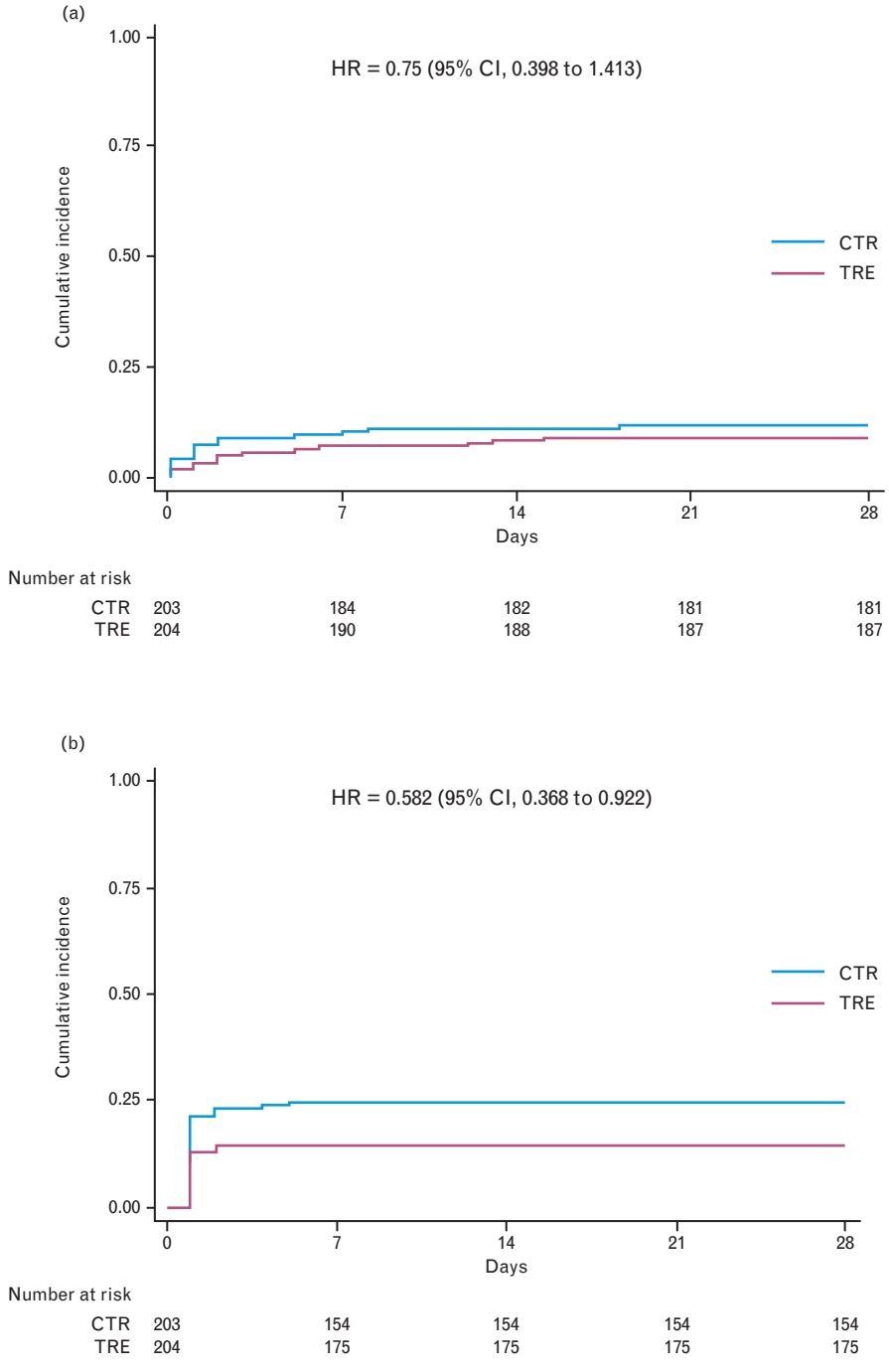
Although the results of the present study seem to confirm the lack of efficacy of CPAP in preventing reintubation in cardiac surgery patients who developed severe hypoxemia (*P/F* ratio ≤ 200) following extubation, it should be

Fig. 2 Arterial to inspiratory O_2 ratio (*P/F*) trend over the first 9 h of the protocol, stratified by study arm.



Squares indicate median values; bars represent the interquartile range [IQR] of the *P/F* ratio during this period.

Fig. 3 Time-to-event analysis of reintubation (panel a) and atelectasis (panel b) over 28 days.



The blue curve shows the cumulative incidence in the control group (CRT), while the red curve depicts the cumulative incidence in the treatment group (TRE).

noted that Beverly *et al.*[19] found that unplanned reintubation occurred more frequently on the second day after surgery. This finding may be related to the fact that persistent atelectasis after extubation can impair gas exchange, thereby increasing the risk for early reintubation. In our study, we observed that most reintubations in both groups occurred within the first week; most cases of atelectasis were recorded within the first 48 h; the incidence of reintubation was significantly higher among patients with atelectasis and the occurrence of atelectasis was significantly reduced in the group treated with CPAP for the first 24 h through the end of follow-up. These observations may explain the finding that the reintubation rate at 48 h was 7.39% (95% CI, 3.76 to 11.02) in the

Table 2 Primary and secondary endpoints

	CTR ($n = 203$)	TRE ($n = 204$)	OR (95% CI) TRE vs. CTR	*P* value
Primary endpoint				
Incidence of 28-day reintubation	22 (10.8)	17 (8.3)	0.748 (0.385 to 1.454)	0.39
Incidence of 48-h reintubation	15 (7.4)	6 (2.9)	0.380 (0.144 to 0.999)	0.04
Secondary endpoint				
Incidence of 28-day atelectasis	49 (24.1)	29 (14.2)	0.521 (0.313 to 0.865)	0.01
Incidence of 48-h atelectasis	47 (23.2)	29 (14.2)	0.550 (0.330 to 0.917)	0.02
Incidence of 28-day pneumonia	1 (0.5)	1 (0.5)	0.995 (0.062 to 16.018)	1.0
Incidence of 28-day sepsis	1 (0.5)	3 (1.5)	3.015 (0.311 to 29.221)	0.34
28-day mortality	2 (0.99)	2 (0.98)	1.064 (0.148 to 7.643)	1.0

Data are *n* (%) and odds ratio (95% CI).

control group compared with 2.94% (95% CI, 0.60 to 5.28) in the treatment group ($P = 0.0425$), supporting the idea that reintubation related to atelectasis tends to occur early and may, therefore, be more effectively prevented by CPAP. However, CPAP may not protect against reintubation because of factors unrelated to atelectasis.

Although the study design and standardised protocol for reintubation represent notable strengths of the present investigation, its limitations continue to affect the interpretation of data. Firstly, enrolment slowed down after the initial years, extending the duration of the trial. Conducting the study over a 10-year span introduced the potential for changes in surgical techniques, intervention durations, cardiopulmonary bypass maintenance and standard postoperative care. Moreover, the SARS-CoV-2 outbreak temporarily halted enrolment from March 2020 to March 2022. Despite resuming efforts, the target sample size required to demonstrate CPAP treatment efficacy was not achieved, reducing the statistical power of the results. The consort diagram highlights the high number of patients excluded during enrolment. Under these circumstances, the early termination of the study reduced its capacity to produce definitive and statistically robust conclusions about the primary outcome. As a result, the study may have been underpowered, increasing the risk of a type II error where a potentially effective CPAP intervention could be mistakenly deemed ineffective. Moreover, this study confirms that funding is a major problem that consistently hinders research in anaesthesia and critical care. The lack of stable and sufficient funding may force researchers to face significant obstacles, such as the inability to recruit a sufficient number of participants, acquire the necessary devices/tools or retain staff involved in the study. Secondly, a recent systematic review of noninvasive respiratory support in cardiac surgery patients demonstrated a prophylactic benefit in preventing postoperative pulmonary complications, such as atelectasis, pneumonia, acute respiratory distress syndrome and pulmonary aspiration, using noninvasive respiratory support methods other than CPAP.[11] This review analysed studies using high-flow nasal cannula (HFNC), CPAP and noninvasive ventilation (NIV) and concluded that only prophylactic NIV significantly reduced postoperative pulmonary complications compared with standard treatment: relative risk (RR) 0.67 (95% CI, 0.49 to 0.93); absolute risk reduction (ARR) 7.6 (95% CI, 1.6 to 11.8)%; low certainty. It also reduced the incidence of atelectasis: RR 0.65 (95% CI, 0.45 to 0.93); ARR 19.3 (95% CI, 3.9 to 30.4)%; moderate certainty. However, NIV was not associated with a reduced reintubation rate: RR 0.82 (95% CI, 0.29 to 2.34); low certainty. Over the 10-year study period, the increasing use of HFNO and NIV as alternatives to CPAP may have impacted clinical equipoise and influenced the treatment approaches.

Thirdly, chest X ray as evaluated by the attending physician, probably underestimates atelectasis compared with CT scans. However, it may be difficult to justify a postoperative CT scan for all patients recovering from cardiac surgery. More recently, lung ultrasound has been shown to be highly accurate in the bedside diagnosis of atelectasis, but we did not consider it at the time of the beginning of the trial.

In conclusion, our findings suggest that in patients with severe hypoxemia following extubation after cardiac surgery, CPAP did not significantly lower the 28-day reintubation rate compared with spontaneous breathing with a Venturi mask. However, CPAP was associated with a significantly lower incidence of atelectasis, and reintubation rate at 48 h was reduced in the CPAP group. Given these results, the efficacy and safety of CPAP in preventing reintubation in postcardiac surgery patients remains uncertain. Future studies should evaluate CPAP in comparison with other oxygen delivery methods such as HFNO and NIV.

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Conflicts of interest: none.

Presentation: none.

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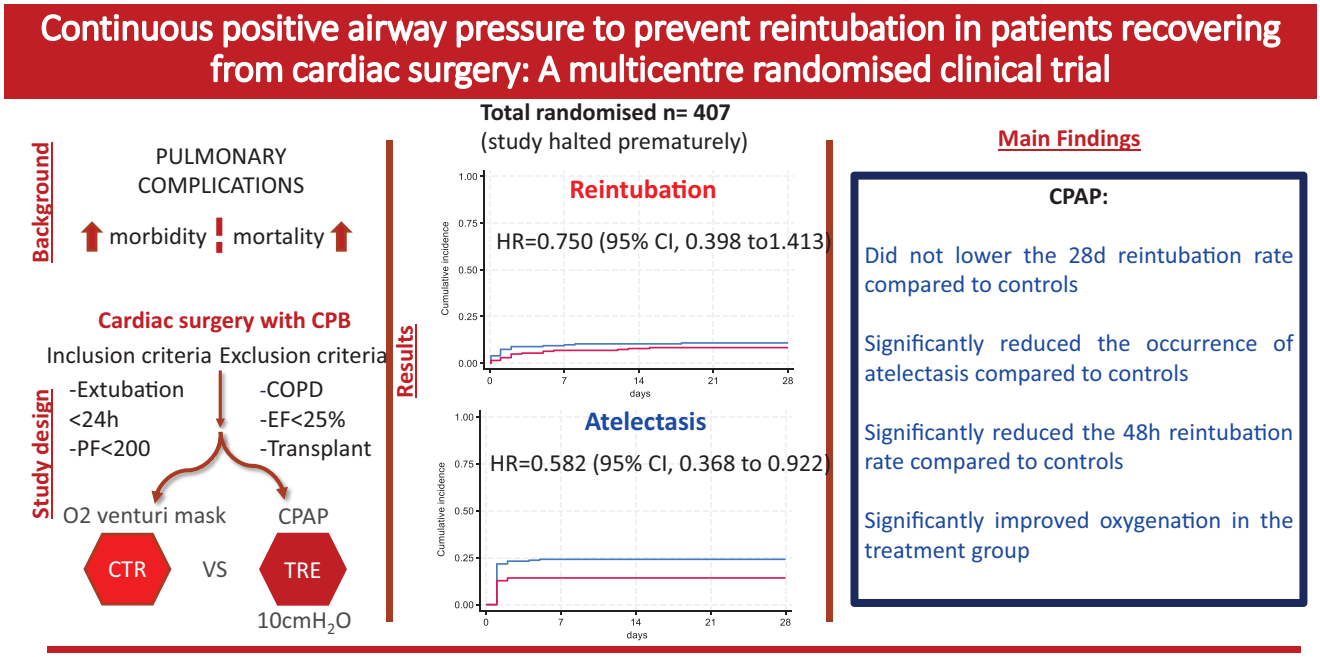
VISUAL ABSTRACT



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