# Expiratory Positive Airway Pressure in Postoperative Cardiac Hemodynamics

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## Abstract

**Background:** **Expiratory positive airway pressure (EPAP) is used in after cardiac surgeries. However, its hemodynamic effects have not been clearly studied.**

**Objective:** **To evaluate the hemodynamic changes caused by EPAP in patients after cardiac surgery monitored by Swan-Ganz.**

**Methods:** **Patients at the first or second cardiac surgery postoperative period hemodynamically stable with a Swan-Ganz catheter were included in the study. They were assessed at rest and after using 10 cm$H_2O$ EPAP at random. The variables studied were: oxygen saturation, heart rate and respiratory rate, mean artery pressures and pulmonary artery mean pressures (MAP and PAMP), central venous pressure (CVP) and pulmonary capillary wedge pressure (PAOP), cardiac output and index, and systemic and pulmonary vascular resistances. Patients were divided into subgroups (with ejection fraction ≤ 50% or > 50%) and data were compared by t test and ANOVA.**

**Results:** **Twenty-eight patients were studied (22 men, aged 68 ± 11 years). Comparing the period of rest *versus* EPAP, the changes observed were: PAOP (11.9 ± 3.8 to 17.1 ± 4.9 mmHg, $p < 0.001$), PVC (8.7 ± 4.1 to 10.9 ± 4.3 mmHg, $p = 0.014$), PAMP (21.5 ± 4.2 to 26.5 ± 5.8 mmHg, $p < 0.001$), MAP (76 ± 10 for 80 ± 10 mmHg, $p = 0.035$). The other variables showed no significant differences.**

**Conclusion:** **EPAP was well tolerated by patients and the hemodynamic changes found showed an increase in pressure measurements of right and left ventricular filling, as well as mean arterial pressure. (Arq Bras Cardiol 2010; 95(5): 594-599)**

**Keywords:** **Positive pressure respiration; hypertension; cardiac output; facial masks; thoracic surgery.**

## Introduction

The post-operative periods for major surgeries such as cardiac surgeries, usually occur with hemodynamic complications[1] and respiratory complications such as atelectasis, respiratory infection and bronchopneumonias[2]. Although controversial, respiratory therapy may be recommended in these circumstamces[3].

Among physiotherapeutic techniques, the use of expiratory positive airway pressure (EPAP), has been used to move secretions and prevent atelectasis[4]. Aware of ventilatory[5] and hemodynamic changes of positive pressure during invasive mechanical ventilation (IMV)[6,7] and non-invasive ventilation (NIV)[8,9], raises the possibility that EPAP may have hemodynamic effects, but these have not yet been studied. Moreover, it is known that the increase in expiratory resistance caused by EPAP may have consequences such as increased respiratory effort[10], which could be detrimental for patients recovering from heart surgery (RHS).

Most studies in physiotherapy investigating hemodynamic and metabolic effects use various combinations of techniques, but it is not possible to attribute specific results to a technique in particular[3]. Because these effects in relation to the use of EPAP have not been clearly studied, although their use is frequent in patients in intensive care units (ICU) and RHS, this study aims to evaluate the hemodynamic effects of EPAP in a group of stable patients RHS.

## Methods

The study comes from a randomized cross-over trial.

### Population and sample

This study was conducted between January 2004 and February 2006 in the Intensive Care Unit of *Hospital São Francisco da Santa Casa de Misericórdia de Porto Alegre* (ISCMPA).

Patients with pulmonary artery catheterization who were able to understand verbal commands and who ventilated spontaneously with or without contribution of $O_2$ by nasal cannula were included in the study. The study was conducted

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in the first or second day after surgery, during which the patient is allowed to remain with the pulmonary artery catheter, as needed. Radiological control was performed on patients to confirm the correct placement of the catheter (zone 3 of West).

Intubated patients with severe lung disease, hemodynamically unstable were excluded from the study (mean arterial pressure < 70 mmHg and > 100 mmHg systolic blood pressure < 100 mmHg, cardiac index < 2.2 l/min/m² using vasoactive drugs: dopamine > 5 micrograms/kg/min; dobutamine > 5 micrograms/kg/min and norepinephrine at any dose.)

The procedures started as the patient met the requirements of hemodynamic stability, and after signing an informed consent. The study was approved by the Ethics and Research Committee of ISCMPA.

### Variables under study

The variables under study were: peripheral oxygen saturation ($SpO_2$), heart rate (HR), respiratory rate (RR), mean arterial pressure (MAP), central venous pressure (CVP), pulmonary capillary wedge pressure (PCWP), pulmonary artery mean pressure (PAMP), cardiac output (CO), cardiac index (CI), systolic volume index (SVI), systemic vascular resistance index (SVRI) and pulmonary vascular resistance index (PVRI). The CO was measured through the thermodilution technique.

The instruments needed for the research were: a silicone face mask Newmed (Vital Signs/USA) and a valve Spring Loaded Newmed (Vital Signs/USA); pulmonary artery catheter brands Baxter or Arrow (Edwards Life Sciences/USA); multiparameter monitor (Hewlett-Packard/USA).

### Data collection

Patients were evaluated at three different times: at baseline, rest time and intervention time.

Initially the pulmonary artery catheter was connected to the monitor by a trained nurse. After stabilization of parameters patient baseline values were recorded (at baseline).

Then, patients were randomized into two groups to start the procedure. In group 1, all measurements were performed first at rest (resting time) and then with the application of EPAP (intervention time); in group 2, measurements were performed first with the application of the mask (intervention time) and after five to ten minutes, the time needed to return to baseline, the resting time. We chose this method of randomization in order to try to lessen the influence of the "time" factor in relation to results obtained.

At the time of the intervention, the mask was placed on the patient's face, who stood for five minutes breathing against an expiratory resistance of 10 $cmH_2O$. Patients were verbally encouraged to breathe normally during the application of the technique to standardize respiratory pattern. After the procedure, patients were encouraged to cough and expectorate.

We recorded the arithmetic mean of three values of the variables studied during the performance of the procedures.

Subsequently, data were analyzed in subgroups of patients with normal ejection fraction (EF) (> 50%) and patients with reduced EF (≤ 50%).

The criteria for stopping the protocol were: signs of respiratory distress, drop in $SpO_2$ (< 90%), elevated RF (> 30 ivpm), increased HR (> 130 bpm), change in MAP (< 70 or > 100 mmHg) and agitation.

### Statistical analysis

Categorical variables were described by absolute frequency and relative frequency percentage. Quantitative variables were described by mean and standard deviation.

Groups 1 and 2 were compared by cross-over analysis to assess potential effects of time and interaction. The moments of rest and intervention were compared by Student t test for paired samples. The subgroups with EF > 50% and EF ≤ 50% were compared by ANOVA and t test for paired samples and independent samples. Results are presented as mean and standard deviation. A significance level of 5% was considered.

## Results

We selected 31 patients RHS for this study. Three patients did not complete the collection, two for feeling anguish due to the use of a mask and one for not understanding the commands. There were no other complications during the procedures in other patients. Out of the 28 patients who completed the collection, 22 were males.

The comparison between groups 1 and 2 showed no effects of time and interaction in the assessment of hemodynamic variables, showing that the performance time did not interfere with measurements.

Clinical characteristics of patients are shown in Table 1.

Table 1 - **General characteristics of patients**

| Characteristics | |
|---|---|
| Age (years) | 68.2 ± 11.29 |
| Sex M/F | 22 (78.6%) / 6 (21.4%) |
| Surgery | |
| CABG | 17 (60.7%) |
| Valve replacement | 6 (21.4%) |
| Valve replacement/CABG | 4 (14.3%) |
| Valve replacement/aneurysmectomy | 1 (3.6%) |
| Previous diseases | |
| Unstable angina | 4 (22.2%) |
| Stable angina | 14 (77.8%) |
| Hypertension | 12 (42.9%) |
| Diabetes mellitus | 8 (28.6%) |
| Smoking | |
| Current smokers | 3 (10.7%) |
| Previous smokers | 17 (60.7%) |
| Non-smokers | 8 (28.6%) |
| EF ≤ 50% | 9 (36%) |

*The data presented in mean ± standard deviation or n (%); CABG - coronary artery bypass grafting; FE - ejection fraction.*

Baseline $SpO_2$ (96 ± 3%), FR (19 ± 17 ivpm), HR (92 ± 17 bpm), MAP (75 ± 10 mmHg), PVC (9 ± 4 mmHg) demonstrated the clinical and hemodynamic stability of patients before the procedure.

The comparison between the intervention time and resting time can be seen in Table 2. We observed a statistically significant difference between groups, with an increase in the variables: MAP, CVP, PCWP and PAMP. $SpO_2$ values were maintained, though.

Similarly, subgroups EF > 50% and EF ≤ 50% showed an increase of PCWP and PAMP (Table 3). Patients with lower ejection fraction had high PAMP and PVRI, but these had similar responses to the application of EPAP.

## Discussion

The most important results of this study showed that the EPAP of 10 $cmH_2O$ was well clinically tolerated with $SpO_2$ maintenance, and caused an increase in MBP, CVP, PCWP and PAMP variables. Comparing the subgroups FE > 50% and EF ≤ 50%, a similar behavior was observed and there was an increase in PCWP and PAMP. However, although there are statistically significant differences for these variables, this does not translate into clinical relevance when considering the values together.

Respiratory therapy is an integral part of the teams in intensive care units in developed countries[3] and it has been reported in patients RHS[11]. Although some studies have questioned its effectiveness[12], in recent years, some studies have reported the role of physiotherapy in reducing hospitalization time, shifting secretions[13-15], preventing and solving atelectasis, improving gas exchanges[5] and improving inspiratory muscle strength[11].

Positive expiratory pressure in the airways is among the techniques mostly used by physiotherapy. Despite an increased respiratory muscle workload resulting from the use of EPAP[10], it presents good results in the reversal of atelectasis, removal of secretions[15] and recovery of muscle strength in patients RHS[11,16] as well as significant improvements in FEV1 and FVC after one month of hospital discharge[16]. However, a recent study did not report differences in the evolution of RHS as to pulmonary function, radiological findings and length of hospital stay when compared with physical therapy *versus* conventional therapy with EPAP[17].

**Table 2 - Evaluation of cardiorespiratory variables**

| | Rest | Intervention | p |
|---|---|---|---|
| $SpO_2$ (%) | 95.5 ± 3.1 | 96 ± 2.6 | 0.154 |
| HR (bpm) | 89.2 ± 17.1 | 88.5 ± 16.1 | 0.503 |
| RR (ivpm) | 19 ± 1.5 | 21 ± 4.1 | 0.069 |
| PCWP (mmHg) | 11.8 ± 3.7 | 17 ± 4.9 | < 0.001 |
| MAP (mmHg) | 75.5 ± 9.5 | 80.3 ± 9.5 | 0.035 |
| CVP (mmHg) | 8.7 ± 4.0 | 10.9 ± 4.3 | 0.014 |
| PAMP (mmHg) | 21.5 ± 4.2 | 26.4 ± 5.8 | < 0.001 |
| CO (l/min) | 5.4 ± 1.6 | 5.4 ± 1.5 | 0.756 |
| CI (l/min/m²) | 2.9 ± 0.8 | 2.93 ± 0.7 | 0.773 |
| SVI (ml/bat/m²) | 34.6 ± 10.6 | 34.1 ± 9.9 | 0.559 |
| SVRI (mmHg/l/min) | 1,927 ± 631 | 1,993 ± 562 | 0.541 |
| PVRI (mmHg/l/min) | 273 ± 79 | 252 ± 86 | 0.450 |

*The data is presented in media±standard deviation; $SpO_2$ - peripheral oxygen saturation periods; HR - heart rate; RR - respiratory rate; PCWP - pulmonary capillary wedge pressure; MAP - mean arterial pressure; CVP - central venous pressure; PAMP - pulmonary artery mean pressure; CO - cardiac output; CI - cardiac index; SVI - systolic volume index; SVRI - systemic vascular resistance index; PVRI - pulmonary vascular resistance index.*

**Table 3 - Assessment of cardiorespiratory variables in subgroups**

| | EF ≤ 50% | | | EF > 50% | | |
|---|---|---|---|---|---|---|
| | Rest | Intervention | p | Rest | Intervention | p |
| $SpO_2$ (%) | 94.5 ± 3.9 | 95.5 ± 3.2 | 0.172 | 96.0 ± 2.8 | 96.4 ± 2.4 | 0.45 |
| HR (bpm) | 91.4 ± 18.2 | 93.4 ± 17.7 | 0.050 | 88.2 ± 17.1 | 88.2 ± 15.2 | 0.187 |
| RR (ivpm) | 19.2 ± 2.1 | 23.0 ± 6.8 | 0.220 | 19.0 ± 1.4 | 19.9 ± 1.1 | 0.045 |
| PCWP (mmHg) | 12.8 ± 5.0 | 17.8 ± 4.7 | < 0.001 | 11.5 ± 3.1 | 16.7 ± 5.1 | < 0.001 |
| MAP (mmHg) | 69.5 ± 8.2 | 72.5 ± 5.0 | 0.279 | 79.0 ± 9.0 | 84.9 ± 8.7 | 0.080 |
| CVP (mmHg) | 8.0 ± 5.5 | 11.8 ± 6.2 | 0.022 | 9.1 ± 3.5 | 10.4 ± 3.3 | 0.211 |
| PAMP (mmHg) | 24.3 ± 4.3* | 28.7 ± 5.2 | 0.007 | 20.3 ± 4.0* | 25.4 ± 6.0 | < 0.001 |
| CO (l/min) | 5.5 ± 1.7 | 5.6 ± 1.8 | 0.075 | 5.5 ± 1.8 | 5.4 ± 1.5 | 0.620 |
| CI (l/min/m²) | 2.8 ± 0.9 | 3.0 ± 0.9 | 0.095 | 3.0 ± 0.9 | 2.9 ± 0.7 | 0.593 |
| SVI (ml/beats/m²) | 32.7 ± 9.2 | 32.6 ± 8.8 | 0.947 | 35.8 ± 11.9 | 35.0 ± 11.1 | 0.575 |
| SVRI (mmHg/l/min) | 1,862 ± 583 | 1,711 ± 389 | 0.234 | 1,964 ± 699 | 2,153 ± 605 | 0.207 |
| PVRI (mmHg/l/min) | 340 ± 58* | 284 ± 98 | 0.494 | 234 ± 62* | 233 ± 79 | 0.930 |

*The data are presented in mean ± standard deviation; EF - ejection fraction; $SpO_2$ - peripheral oxygen saturation; HR - heart rate; RR - respiratory rate; PCWP - pulmonary capillary wedge pressure; MAP - mean arterial pressure; CVP - central venous pressure; PAMP - pulmonary artery mean pressure; CO - cardiac output; CI - cardiac index; SVI - systolic volume index; SVRI - systemic vascular resistance Index; PVRI - pulmonary vascular resistance index. * p<0.05 comparing groups at rest.*

As all these studies using positive pressure evaluated predominantly respiratory variables, the use of EPAP in this study was based on the beneficial clinical effects reported above. However, our study appears to be the first one with the purpose of researching the hemodynamic responses of EPAP, as it was performed in a stable population RHS.

The use of positive pressure in cardiac patients is part of the therapies employed mainly in the form of non-invasive mechanical ventilation (NIMV). The NIMV significantly reduces the need for reintubation[9,18] and the the need for tracheostomy[19] in patients with respiratory failure, improving oxygenation[9] and reducing respiratory work[20].

The effects of continuous positive airway pressure on cardiac performance can be translated as a reduction in preload by reducing venous return and reduction in afterload by reducing left ventricular transmural pressure and may be considered a gold standard in the treatment of acute pulmonary edema[21]. The ability of continuous positive airway pressure to recruit collapsed alveolar units, explains the reduction of the shunt, thereby improving respiratory mechanics, oxygenation and reducing the overload on the cadiovascular system[22-24]. Some studies have shown beneficial effects of using continuous positive airway pressure (CPAP)[18,25] with improved levels of $PaO_2$ and decrease in RR in patients with respiratory failure[26]. In cardiac patients there was initial suggestions of poor results with two levels of positive airway pressure (BIPAP)[27], which was not confirmed later[28]. Patients with acute pulmonary edema of cardiogenic origin benefited from BIPAP with pressure levels lower than the conventional ones, suggesting a minor effect on preload and a lower risk of hypotension[29].

Considering the effects of positive pressure through the NIMV, the use of EPAP could show benefit in RHS. In our study, the use of EPAP resulted in a mild increase of MAP, the PAMP and right and left ventricular filling pressures. These increases are probably due to direct transmission of increased intrathoracic pressures.

It is important to consider, however, that some studies using positive end expiratory pressure (PEEP) during invasive mechanical ventilation (IMV) in RHS showed some disadvantages. The prophylactic use of PEEP with levels of 10 $cmH_2O$ was safe, although it has not reduced chest drainage output[30]. In a study comparing the use of three levels of PEEP (0, 5 and 10 $cmH_2O$) in RHS in patients with EF $\geq$ 45%, there were no statistical differences between groups, which led us to conclude that low levels of PEEP have no advantage over zero level of PEEP in improving gas exchange in patients RHS[31]. The effects of PEEP on respiratory mechanics and hemodynamics of patients after cardiac surgery resulted in reduced airway resistance and respiratory elastance, which may reflect an improved respiratory mechanics[6]. However, due to possibility of hemodynamic instability, PEEP should be carefully applied in RHS. In an experimental study, ventilation with increased levels of PEEP did not change right ventricular function, but it impaired left ventricular function[7].

Such studies emphasize the importance of controlling the levels of positive pressure while avoiding very high levels. The levels we used, 10 $cmH_2O$ of EPAP, did not cause harmful haemodynamic effects on this group of patients.

The limitations of this study include the small number of patients and the inclusion of RHS patients only, hemodynamically stable patients and those patients without significant respiratory disease associated. These patients presented a variation of basic pathologies, which may present different hemodynamic effects as well as heterogeneous responses to the therapy under study. Although some had EF $\leq$ 50%, few had significant myocardial dysfunction (only four with EF $\leq$ 30%). Furthermore, the level of EPAP used was relatively low, although within the range commonly used in physical therapy practice. Larger studies with other types of patients and other pressure values may show different results. However, our results are valid for the group of patients studied.

In short, the use of the positive pressure in the form of EPAP as a physiotherapy technique was safe and well tolerated, with no deleterious effects. Importantly, despite increases in right and left filling pressures and in arterial pressure, there was no hemodynamic or respiratory deterioration and there was maintenance of $SpO_2$. Similar results were observed by dividing the patients according to normal or reduced ejection fraction.

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**Potential Conflict of Interest**

No potential conflict of interest relevant to this article was reported.

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**Study Association**

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