Original Article

Right Ventricular End-diastolic Volume Monitoring after Cardiac Surgery

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Introduction: In the postoperative management of cardiac surgery patients, pulmonary capillary wedge pressure (PCWP) and central venous pressure (CVP) are the most commonly used parameters of preload. However, these pressure parameters are easily affected by ventricular compliance, positive end-expiratory pressure and other factors. The aim of this study was to evaluate whether right ventricular end-diastolic volume index (RVEDVI) reflects cardiac output or ventricular preload in patients after cardiac surgery during postoperative management.
Methods: We performed measurements in 31 patients postoperatively in the intensive care unit every 1 or 2 hours using a modified thermodilution catheter.
Results: There were 999 measured hemodynamic data sets and the measurement duration was 47±21 hours (mean ± SD). RVEDVI was 119±32 ml/m^2, cardiac index (CI) was 2.7±0.7 L/min/m^2, and PCWP was 11±4 mmHg. A significant correlation was found between RVEDVI, CVP and CI in 15 of 31 patients, and between PCWP and CI in 4 of 22 patients. In 33% of cases, CVP showed a negative correlation with CI, whereas 7% showed a negative correlation between RVEDVI and CI.
Conclusion: RVEDVI was a significant index during the postoperative management after cardiac surgery. (Ann Thorac Cardiovasc Surg 2004; 10: 167–70)

Key words: right ventricular end-diastolic volume, right ventricular function, cardiac surgery, monitoring

Introduction

Preload is related to the degree to which the myocardial fibers are stretched at the end of diastole and is most accurately described clinically as end-diastolic volume. The relationship between end-diastolic volume and end-diastolic pressure describes the compliance of the ventricle. Ventricular compliance is affected by primary disease states and therapeutic interventions, such as cardiac surgery with or without cardiopulmonary bypass, myocardial infarction, application of positive end-expiratory pressure (PEEP).[1,2] Changes in ventricular compliance make it difficult to assess ventricular preload from measurements of end-diastolic pressure. The main purpose of the present study was to compare commonly used indices of preload, central venous pressure (CVP) and pulmonary capillary wedge pressure (PCWP) versus right ventricular end-diastolic volume index (RVEDVI) in patients after cardiac surgery.

Patients and Methods

This study was performed on 31 patients after cardiac surgery. Twenty-one were males and 10 were females. They ranged in age from 46 to 87 years, with a mean age of 68±11 years. Coronary artery bypass grafting (CABG) was performed in 24 patients; 3-CABG (on pump) in one patient, 2-CABG (off pump) in eight patients and 1-CABG (off pump) in 15 patients. Aortic valve replacement (AVR) was performed in two patients, mitral valve replacement (MVR) in two patients, MVR concomitant

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Received December 8, 2003; accepted for publication January 16, 2004.
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Table 1. Patients characteristics

Age (year)	68±11 (46-87)
Sex (M/F)	21/10
Procedure	31
3-CABG	1
2-OPCAB	8
1-OPCAB	15
AVR	2
MVR	2
MVR+TAP	2
DVR	1
Measurement	
Time (hour)	47±21 (12-97)
Points	32±11 (11-57)

AVR, aortic valve replacement; CABG, coronary artery bypass grafting; DVR, aortic valve and mitral valve replacement; OPCAB, off pump CABG; MVR, mitral valve replacement; TAP, tricuspid annuloplasty.

Table 2. Hemodynamic profile of all patients

RVEDVI (ml/m^2)	119±32
RVEF (%)	28±7
CI (L/min/m^2)	2.7±0.7
SvO_2 (%)	69±8
HR (beats/min)	88±4
CVP (mmHg)	8.8±4
PA systole (mmHg)	30±6
PA diastole (mmHg)	13±5
PCWP (mmHg)	11±4

CI, cardiac index; CVP, central venous pressure; HR, heart rate; PA, pulmonary artery pressure; PCWP, pulmonary capillary wedge pressure; RVEDVI, right ventricular end-diastolic volume index; RVEF, right ventricle ejection fraction; SvO_2, mixed venous oxygen saturation.

with tricuspid annuloplasty (TAP) in two patients and AVR concomitant with MVR in one patient (Table 1). Cardiac output (CO), pulmonary artery pressure, RVEDVI, and right ventricular ejection fraction (RVEF) were determined with a modified pulmonary artery catheter (774HF75, Edwards Lifesciences Corporation, Irvine, CA, USA). CO, RVEDVI, RVEF and mixed venous oxygen saturation (SvO_2) were measured and calculated continuously with an Oximeter/CCO/CEDV monitoring system (Edwards Lifesciences Corporation), PCWP and CVP were obtained from a strip chart recording. These cardiac parameters were measured in the intensive care unit every 1 or 2 hours. In the 31 patients studied, 999 sets of hemodynamic data were analyzed. Univariate regression analysis was performed on all hemodynamic data to determine significant correlations. Data are presented as the mean ± standard deviation (SD). Statistical significance determined using Student's t test and Mann-Whitney U-test were inferred at $p<0.05$ for all comparisons.

Results

None of the 31 patients died or suffered a perioperative myocardial infarction (appearance of a new Q wave). Mean measurement time was 47±21 hours, range from 12 to 97. Mean RVEDVI was 119±32 ml/m^2, RVEF was 28±7%, CVP was 8.8±4 mmHg and PCWP 11±4 mmHg (Table 2). In individual patients, a significant correlation between RVEDVI and CI was found in 15 of 31 patients (48%, r values = –0.46 to 0.87), between CVP and CI also in 15 of 31 patients (48%, r values = –0.76 to 0.77), whereas between PCWP and CI in 4 of 22 patients (18%, r values = 0.39 to 0.90) (Table 3). In a comparison of the hemodynamic profiles of the 15 patients with a good correlation between RVEDVI and CI, and of the 16 patients who demonstrated no correlation between these param-

Table 3. Percentage of patients with good correlation between CI and other cardiac parameters

	% (n)	Correlation | r |		% of negative* (n)	
RVEDVI	48 (15/31)	0.62±0.14 (–0.46-0.87)	**	7 (1)	***
CVP	48 (15/31)	0.55±0.13 (–0.76-0.77)		33 (5)	
PCWP	18 (4/22)	0.64± 0.23 (0.39-0.90)		0 (–)	
PA diastole	26 (8/31)	0.48±0.10 (–0.52-0.61)		25 (2)	

*negative correlation
**p=0.02
***p=0.04
RVEDVI, right ventricular end-diastolic volume index; CVP, central venous pressure; PA, pulmonary pressure; PCWP, pulmonary capillary wedge pressure.

Table 4. Hemodynamic profiles of patients with good and poor correlation between RVEDVI and CI

	Good (n=15)	Poor (n=16)	p value
RVEDVI (ml/m^2)	122±33	118±26	0.42
RVEF (%)	28±8	28±5	0.51
CI (L/min/m^2)	2.8±0.6	2.8±0.5	0.39
SvO_2 (%)	69±5	71±7	0.84
HR (beats/min)	89±13	86±8	0.26
CVP (mmHg)	8.3±3	8.4±3	0.54
PA systole (mmHg)	30±6	29±5	0.29
PA diastole (mmHg)	12±4	13±4	0.51
PCWP (mmHg)	11±3	11±4	0.55

CI, cardiac index; CVP, central venous pressure; HR, heart rate; PA, pulmonary artery pressure; PCWP, pulmonary capillary wedge pressure; RVEDVI, right ventricular end-diastolic volume index; RVEF, right ventricle ejection fraction; SvO_2, mixed venous oxygen saturation.

Table 5. Hemodynamic profiles of patients with positive and negative correlation between CVP and CI

	Good (n=9)	Poor (n=6)	p value
RVEDVI (ml/m^2)	120±26	136±50	0.45
RVEF (%)	29±7	27±8	0.63
CI (L/min/m^2)	2.8±0.5	3.0±1.0	0.54
SvO_2 (%)	70±5	71±10	0.95
HR (beats/min)	88±5	89±12	0.41
CVP (mmHg)	8.5±3	8.7±5	0.96
PA systole (mmHg)	32±6	28±6	0.34
PA diastole (mmHg)	13±4	13±5	0.88
PCWP (mmHg)	11±4	12±6	0.34

CI, cardiac index; CVP, central venous pressure; HR, heart rate; PA, pulmonary artery pressure; PCWP, pulmonary capillary wedge pressure; RVEDVI, right ventricular end-diastolic volume index; RVEF, right ventricle ejection fraction; SvO_2, mixed venous oxygen saturation.

eters, there was no significant difference (Table 4). In five of 15 patients (33%), CVP showed a negative correlation with CI, whereas one patient (7%) showed a negative correlation between RVEDVI and CI (Table 3). A comparison of the hemodynamic profiles of the nine patients with a positive correlation and the six patients with a negative correlation between CVP and CI is presented in Table 5.

Discussion

Although cardiac filling pressures, such as CVP and PCWP, have commonly been used to guide the postoperative management of cardiac surgery, several studies have shown that PCWP may not provide a reliable guide to cardiac preload.[3-6] Assuming the absence of technical difficulties, PCWP provides a reliable estimate of left atrial pressure and left ventricle end-diastolic pressure (LVEDP) under most physiologic conditions.[7] However, because of changes in ventricular compliance, estimates of LVEDP do not provide a reliable index of left ventricular end-diastolic volume (LVEDV), which is a more accurate clinical predictor of cardiac function than LVEDP. Moreover, some factors, such as myocardial ischemia, pulmonary dysfunction, mechanical ventilation and PEEP, are thought to disturb the relationship between PCWP and LVEDV.[1,6,7] This study compared various measures of preload, such as RVEDVI, PCWP and CVP with CI, to determine which parameter best reflects ventricular preload after cardiac surgery.

In nearly half of patients, RVEDVI and CVP showed a good correlation with CI, while less than 20% of patients showed a good correlation between PCWP and CI. This indicates that RVEDVI and CVP are better indicators of cardiac output than PCWP. This result supports that the relation between PWCP and CI is easily affected by factors that are often observed after cardiac surgery such as changes in ventricular compliance, edema of the myocardium, and positive pressure respiratory support. Calvin et al. also reported a poor correlation between PCWP and LVEDV, which relates to cardiac function, in critically ill patients including cardiac illness.[6] However, different from other studies,[1,3,5,8,9] in 16 patients no significant correlation was found in the relationship of both RVEDVI with CI and CVP with CI in our study. We surmised that the causes of the low correlation were changes in the measurement state by cessation of ventilation or changes in pharmacological agents, such as catecholamine and nitroglycerin, which influences the Starling curve. The correlation between them becomes much better by unifying these factors. Moreover, most of the subjects in previous studies were trauma or septic patients who had isolated left ventricular failure. If left ventricular failure had occurred in the patients of those previous studies, the correlation between RVEDVI and CI would not be so different from the result of our study.

Comparing between RVEDVI and CVP, in the group with a good correlation between CVP and CI, a negative correlation was found in 33% of patients, whereas a negative correlation was found in 7% of patients in the group with a good correlation between RVEDVI and CI. In the negative correlation group between CVP and CI, mean values of RVEDVI, RVEF, CI, CVP and PCWP were

136±50 ml/m^2, 27±8%, 3.0±1.0 L/min/m^2, 8.7±5 mmHg and 12±6 mmHg, respectively, which showed no significant difference from those of the positive correlation group. If a marked decline of ventricular function or cardiogenic shock had occurred, this negative correlation between CVP and CI would be explained, but these cardiac data indicate that no cardiac failure or collapse occurred. The reason why CVP showed a negative correlation with CI in some patients is not clear. But it may be explained by the fact that CVP is not a volume measured index but the measured pressure which is affected by respiratory support and pleural pressure.[8)] Packman et al. concluded from the poor correlation between CVP and PCWP in critically ill patients that the usefulness of CVP in the clinical setting is limited.[10)] Some studies also revealed that RVEDV is better than CVP as an index of cardiac preload.[3,8)] CVP does not always reflect cardiac preload and cannot be used to reliably predict preload status. Therefore, if only CVP is measured after cardiac surgery, this negative relation may produce misleading results regarding cardiac preload during postoperative care.

RVEDVI measurement is useful for postoperative management after cardiac surgery, although different from other studies; a good correlation was found in only half of cases. Moreover, there was 7% (one case) of negative correlation between RVEDVI and CI. Therefore, further study of the relation between RVEDVI and CI is needed. In conclusion, RVEDV measurement is a significant clinical indicator during postoperative management of cardiac surgery patients.

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