A Comparison between High Frequency Positive Pressure Ventilation and Intermittent Positive Pressure Ventilation during Closed Mitral Valvotomy

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Citation

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Abstract

Background: Patients with tight mitral stenosis usually suffer low cardiac output symptoms and elevated pulmonary vascular resistance. They may be candidates for the use of high frequency positive pressure ventilation (HFPPV). We aimed to compare HFPPV with intermittent positive pressure ventilation (IPPV) in patients subjected to closed mitral valvotomy (CMV).

Methods: Twenty-four patients subjected to closed mitral valvotomy were randomly allocated to ventilation with IPPV or HFPPV. The minute volume in the IPPV group was given as a tidal volume of 10 ml/kg and a respiratory rate of 14 breaths/min, while in the HFPPV it was given as a tidal volume of 3 ml/kg and a respiratory rate of 60 breaths/min. Heart rate, arterial blood pressure, right atrial pressure (RAP), O2 saturation (SpO2), end-tidal CO2 (PeCO2), arterial CO2 tension (PaCO2) and arterial O2 tension (PaO2) were recorded during the procedure. In addition, interferences to correct hypoxaemia were recorded. Dead space fraction was calculated.

Results: RAP decreased significantly during surgery in HFPPV group when compared to IPPV group. Interferences with manual ventilation to correct hypoxaemia were less frequent in HFPPV group compared to IPPV group. In each group dead space fraction increased significantly during surgery when compared to the baseline values. Surgeon's complaint was more frequent in IPPV group.

Conclusion: The use of HFPPV during closed mitral valvotomy provides a safe alternative to the conventional IPPV with possible better right side unloading, less hypoxic episodes and better surgical conditions.

INTRODUCTION

Tight mitral stenosis is one of the most prevalent valve disorders in Egypt. Closed mitral valvotomy (CMV) is the technique of choice for treatment of rheumatic mitral stenosis ([1,2]). Percutaneous mitral balloon valvoplasty (PMBV) may be the preferred approach when surgical intervention is contraindicated.

Low cardiac output and high pulmonary vascular resistance (PVR) are the consequences of mitral valve stenosis ([3]). Therefore, patients with mitral stenosis usually suffer limited exercise tolerance ([4]). During CMV, the critical period of dilatation of the valve with the surgeon's right index finger and Tubbs dilator is usually associated with profound decrease in the cardiac output (CO) and sometimes hypoxaemia.

The mode of ventilation during this period may have additional effects. High frequency positive pressure ventilation (HFPPV) was reported to have more favourable effects on cardiac output, pulmonary vascular resistance and oxygen transport compared to conventional intermittent positive pressure ventilation ([5]). The use of HFPPV may be advantageous during the period of valvotomy in respects of haemodynamics, oxygenation and easiness of surgical access.

To test this hypothesis, patients subjected to CMV were randomly allocated to ventilation with either IPPV or HFPPV. Haemodynamics, oxygenation, ventilation and easiness of surgical access were considered the outcome

measures.

PATIENTS AND METHODS

This randomised comparative study was approved by the Hospital Ethics Committee and informed written consents were obtained from all patients. Twenty-four patients suffering from tight mitral stenosis and subjected to CMV were enrolled. Patients with mitral regurgitation, atrial thrombi or rapid atrial fibrillation were excluded from the study. Redo cases were also excluded from the study.

Preoperative evaluation included history, clinical examination, ECG, chest X-ray, laboratory tests and echocardiography. Patients received oral diazepam 5 mg the night and morning of the operation. At the operative suite, patients received midazolam 2–4 mg and fentanyl 50–70 µg intravenously.

Monitoring included ECG, pulse oximetry and side-stream capnography. An arterial cannula was inserted in the brachial artery of the non-dominant limb for blood pressure monitoring and blood gas analysis. The right internal jugular vein was cannulated for right atrial pressure (RAP) monitoring. Pressure zeroing was done while the patient was supine and adjusted after the lateral decubitus position.

Anaesthesia was induced with fentanyl 150–200 µg, vecuronium 0.12 mg/kg, and a sleeping dose thiopentone, followed by orotracheal intubation. Anaesthesia was maintained with isoflurane 1–1.2% in a nitrous oxide/oxygen mixture (FiO2= 0.4). According to a closed envelop randomisation, the lungs were ventilated with either IPPV or HFPPV delivered by Ohmeda™ 7000 ventilator.

In the IPPV group, the ventilator setting was adjusted at fixed minute volume to yield a tidal volume of 10 ml/kg, respiratory rate 14 breaths/min and I:E ratio 1:2. In the HFPPV group a similar minute volume was used to yield a tidal volume of 3 ml/kg, respiratory rate 60 breaths/min and I:E ratio1:2. After closure of the chest, IPPV was used in both groups. If hypoxaemia (SpO2 = 90%) occurred for more than thirty seconds, the lungs were ventilated with 100% O2. If hypoxaemia continued, manual ventilation with 100% O2 was used temporarily. During episodes of hypoxaemia arterial blood gas analysis was done. A 20% decrease in systolic blood pressure necessitated stopping isoflurane until normal blood pressure was resumed.

Heart rate, mean arterial blood pressure, RAP, O2 saturation (SpO2), end-tidal CO2 (PeCO2), arterial CO2 tension (PaCO2) and arterial O2 tension (PaO2) were recorded before induction, 15 minutes after induction, before valvotomy, 10 min after valvotomy and at the end of surgery. In addition, the occurrence of hypoxaemia and manual ventilation was recorded. Dead space was calculated from Enghoff modification of Bhor equation ($_6$).

$$VD = VT (1 – PeCO2 / PaCO2)$$

Where VD is dead space and VT is tidal volume. As the tidal volumes in both groups are not comparable, we expressed the dead space as a fraction of the tidal volume and not the absolute values.

$$VD\ fraction = 1 – PeCO2 / PaCO2$$

All patients were extubated at the end of surgery. In the recovery room, monitoring of vital signs and physiological parameters was extended.

STATISTICAL ANALYSIS

Statistical analysis was carried out with Student's t-test, repeated measures ANOVA with post hoc Newman-Keul's test, or Fisher's exact test, as appropriate. A P value less than 0.05 was considered statistically significant.

RESULTS

The closed envelop randomisation ensured equal number of 12 cases in each group. Age, body weight, height and gender were comparable between both IPPV and HFPPV groups (Table 1).

The changes in heart rate and mean arterial blood pressure were comparable between both groups. Right atrial pressure was significantly lower in the HFPPV group compared to the IPPV group ($P < 0.05$) before and after valvotomy (Table 2).

Both groups were parallel with no significant between-group differences with respect to PeCO2, PaCO2 and dead space fraction (Table 3). However, within-group differences occurred in the dead space during surgery, where a significant increase in the dead space occurred in each group before and after valvotomy and at the end of the surgical intervention ($P < 0.05$).

Hypoxaemia requiring oxygenation with 100% oxygen then manual ventilation was significantly more frequent in the IPPV group than the HFPPV group ($P < 0.05$). During all surgeries, 5 complaints about uneasy surgical approach were recorded in the IPPV group compared to 1 complaint in the HFPPV group (Table 4).

Figure 1

Table 1: Characteristics of patients subjected to intermittent positive pressure ventilation (IPPV) or high frequency positive pressure ventilation (HFPPV). Data are means (SD) or ratio.

	IPPV (n = 12)	HFPPV (n = 12)
Age (year)	26.8 (8.5)	25.3 (9.0)
Body weight (kg)	61.7 (9.0)	63.6 (8.8)
Height (cm)	161.9 (12.5)	163.0 (11.8)
Gender (male/female)	5/7	6/6

Figure 2

Table 2: Heart rate (HR), mean arterial blood pressure (MBP) and right atrial pressure (RAP) during mitral valvotomy under intermittent positive pressure ventilation (IPPV) or high frequency positive pressure ventilation (HFPPV). Values are means (SD).

	HR (beats/min)		MBP (mm Hg)		RAP (mm Hg)	
	IPPV (n = 12)	HFPPV (n = 12)	IPPV (n = 12)	HFPPV (n = 12)	IPPV (n = 12)	HFPPV (n = 12)
Baseline	84 (11)	91 (13)	81 (9)	79 (8)	7 (1.5)	8 (1.3)
Post-induction	73 (9)	74 (4)	71 (8)	73 (6)	6 (1.5)	6 (1.5)
Pre-valvotomy	81 (8)	75 (8)	84 (6)	72 (11)	13 (2.0)	7 (2.0)*
Post-valvotomy	90 (15)	84 (9)	84 (9)	82 (10)	13 (2.0)	8 (1.6)*
End of surgery	89 (9)	88 (6)	81 (9)	84 (9)	10 (1.7)	9 (1.6)
Recovery	85 (10)	90 (10)	85 (8)	86 (7)	9 (1.4)	8 (1.3)

*Significantly different (P < 0.05) compared to the other group.

Figure 3

Table 3: End tidal CO2 tension (PeCO2), arterial CO2 tension (PaCO2) and dead space fraction during mitral valvotomy under intermittent positive pressure ventilation (IPPV) or high frequency positive pressure ventilation (HFPPV). Values are means (SD).

	$PeCO_2$ (mm Hg)		$PaCO_2$ (mm Hg)		Dead space (%)	
	IPPV (n = 12)	HFPPV (n = 12)	IPPV (n = 12)	HFPPV (n = 12)	IPPV (n = 12)	HFPPV (n = 12)
Baseline	32 (3)	33 (4)	37 (3)	36 (4)	14 (1)	11 (2)
Post-induction	31 (4)	29 (4)	35 (4)	35 (3)	12 (3)	17 (4)
Pre-valvotomy	29 (4)	22 (3)	42 (4)	34 (4)	31 (3)*	35 (5)*
Post-valvotomy	30 (3)	22 (3)	43 (4)	34 (3)	30 (3)*	31 (5)*
End of surgery	28 (3)	26 (4)	36 (4)	32 (4)	23 (3)*	22 (4)*
Recovery	33 (4)	32 (4)	38 (3)	35 (4)	14 (2)	9 (2)

Baseline and recovery values were obtained during mask oxygenation.

*Significantly different (P < 0.05) compared to their baseline values.

Figure 4

Table 4: Intraoperative incidents during mitral valvotomy under intermittent positive pressure ventilation (IPPV) or high frequency positive pressure ventilation (HFPPV). Values are median (range) or number (%) of patients.

	IPPV (n = 12)	HFPPV (n = 12)	P value
Median highest $PaCO_2$ (mm Hg)*	41 (28–55)	43 (30–56)	NS
Median lowest PaO_2 (mmHg)	79 (58–169)	91 (69–180)	NS
Patients with SpO_2 = 90%	6 (50%)	1 (8%)	< 0.01
Patients who needed 100% O_2	6 (50%)	1 (8%)	< 0.01
Patients who needed manual ventilation	5 (41%)	0 (0%)	< 0.01
Surgeon's complaint	5 (41%)	1 (8%)	< 0.05

*Values were obtained during lowest SpO2. NS = not significant.

DISCUSSION

The results of this study revealed that HFPPV can be safely used as an alternative to IPPV during mitral valvotomy with the advantage of less episodic desaturation and lower RAP implying a better right heart unloading.

Since the introduction of HFPPV into clinical practice in 1971, a number of methods of high frequency ventilation (HFV) have been evaluated during general anaesthesia and intensive care practice ([7]).

HFV was applied during coronary artery bypass grafting ([8]), oesophagectomy ([9]), adult airway procedures ([10]) and neonatal intensive respiratory therapy ([11]). Conventional anaesthesia ventilators were found to provide HFV efficiently ([5,12]).

In our study, Ohmeda™ 7000 anaesthesia ventilator provided reasonable ventilation and oxygenation with either conventional IPPV or HFPPV as depicted from CO2 elimination, O2 saturation and O2 tension. However, interventions to correct hypoxia by 100% O2 with or without manual ventilation were more frequent during IPPV.

In this study, the changes in RAP were considered to reflect right ventricular loading and unloading. Although, central venous pressure may not correlate well with right ventricular functions ([13]), the associated tricuspid regurgitation with tight mitral stenosis ([14]) allows right ventricular changes to

be readily transmitted to the right atrium. During HFPPV, RAP significantly decreased at pre- and post-valvotomy periods when compared to IPPV. This may reflect adequate right ventricular unloading due to decreased pulmonary vascular resistance ([11], [15]). It may also be explained by the decreased transmural right ventricular pressure during HFV ([16]). In agreement with the later explanation, Jardin et al. ([17], [18]) observed an increase in right ventricular diastolic volume (increased preload) in mechanically ventilated patients attributable to lung inflation and increased transmural pressure.

The changes in dead space fraction were comparable between both groups. Dead space fraction increased significantly in each group during surgery when compared to baseline values. This increase was attributed to the intrathoracic manipulations during surgery. Calculations of dead space depend mainly on the ratio between end-tidal and arterial CO2 tensions. During mitral commissurotomy, end-tidal CO2 tracing was reported as an unsuitable monitor for adequacy of ventilation ([19]). However, the changes in end-tidal CO2 tracing were parallel in both groups.

The surgeons complained of restricted access in 5 patients in IPPV group. These complaints were announced during manoeuvres to correct hypoxic episodes. Manual ventilation has the advantage of better oxygenation but it may interrupt surgery at times when it is critical for the surgeon to have an uninterrupted view.

In conclusion, the use of HFPPV during closed mitral valvotomy provides a safe alternative to the conventional IPPV with possible advantages of less right side preload, less hypoxic episodes and better surgical field. More experience about the use of this mode of ventilation for adult intrathoracic procedures is warranted before extensive application.

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