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ORIGINAL ARTICLE

Impact of Continuous Positive Airway Pressure on Left Ventricular Systolic Loading and Coronary Flow Reserve in Healthy Young Men

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Q6 **Background** Increased augmentation index (AIx) is accompanied by an elevated cardiovascular risk. A reduction of AIx is known for long-term continuous positive airway pressure (CPAP) therapy. We hypothesised that acute preload and left ventricular workload effects AIx and subendocardial viability ratio (SEVR) as a marker of coronary flow reserve.

Q7 **Methods** Increased augmentation index and central blood pressure parameters were measured by radial artery tonometry in 17 healthy men (32/ ± 6 years) at rest and during CPAP ventilation at pressures of 5, 10 mbar and after recovery. In a subset of seven individuals, haemodynamic parameters and autonomic function were additionally examined using combined impedance cardiography and continuous noninvasive blood pressure monitoring.

Q8 **Results** Continuous positive airway pressure reduced heart rate corrected (AIx@75) (-2.8 ± 8.1 [rest] to −10.7 ± 11.3 [5 mbar], $p < 0.01$, to −12.2 ± 10.5% [10 mbar], $p < 0.01$) and systolic time integral as a marker of left ventricular workload (2115 ± 231 [rest] to 1978 ± 290 [5 mbar], p = 0.02 to 1940 ± 218 [10 mbar], $p < 0.01$ to 2013 ± 241 mmHg/s per min [recovery], p = 0.03), while central systolic pressure did not change during CPAP. Total Peripheral Resistance Index increased reaching level of significance at 10 mbar CPAP condition (1701 ± 300 [rest] to 1850 ± 301 dyn*s*m^2/cm^5 [10 mbar], p = 0.04). There was a reversible increase of SEVR under CPAP conditions.

Conclusions Continuous positive airway pressure ventilation acutely reduces AIx, heart rate and left ventricular workload in healthy young men. These effects seem to be mediated by left ventricular filling pressure, workload and reflection wave. Furthermore, we found an increase of subendocardial viability ratio as an indication for a rising coronary flow reserve by CPAP.

Keywords Augmentation index • CPAP • Workload • Cardiovascular physiology • Systolic time integral • Buckberg index

Abbreviations: AIx, Augmentation index; AIx@75, Heart rate (75/min) corrected Augmentation index; CPAP, Continuous positive airway pressure; HRV, Heart rate variability; SEVR, subendocardial viability ratio; TTI, Tension Time Index i.e. systolic pressure time integral , OSAS

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Introduction

Intrathoracic pressure is known to influence left ventricular function depending on pre and afterload, underlying status of the heart, peripheral circulation and lung volume [1]. Application of continuous positive airway pressure (CPAP) acutely decreases left ventricular pre and afterload and increases left ventricular stroke volumes in dilated ventricles [2]. However, because of the high complexity of pulmonary-cardiac interrelationship more detailed physiologic determinants of left ventricular function and central haemodynamics are needed. In this context it should be indicated that less is known about the effects of CPAP on coronary perfusion.

Non-invasive central pulse wave analysis characterises the arterial pressure waveform, which is a composite of the forward pressure wave created by ventricular contraction and a reflected wave [3]. Pulse wave velocity and augmentation index (AIx, ratio between augmentation pressure and pulse pressure) are commonly accepted to represent aspects of aortic stiffness [4,5]. Both are independent predictors of mortality, cardiovascular events and fatal strokes [6–9]. Deduced parameters, e.g. subendocardial viability ratio (SEVR), provide a reliable tool for the assessment of coronary microcirculation and therefore coronary flow reserve [10].

To our knowledge, there is no information on the acute effects of intrathoracic pressure variations on pulse wave velocity, augmentation index and subendocardial viability ratio. We hypothesised that application of CPAP at different pressures influences AIx and SEVR as markers of left ventricular systolic loading and coronary perfusion/flow reserve in a healthy and male study population. Since effects might be modulated by the autonomic nervous system, we measured baroreceptor sensitivity and heart rate variability under different CPAP pressures.

Methods

Study Population

The study population consisted of 17 healthy men (32.0/ $\pm$ 6 years). Procedures were carried out in accordance with the Declaration of Helsinki (2000). The study received approval from the local ethics Committee on Human Research (EK 089/07), and all participants provided informed consent.

Radial Tonometry

For each condition central blood pressure parameters were measured by radial applanation tonometry (SphygmoCor® by AtCor Medical, Australia), in accordance with the recommendations of the expert consensus on arterial stiffness [3]. Via a generalised transfer function, the pressure wave form of the ascending aorta was synthesised. Increased augmentation index, central systolic and diastolic pressure and corresponding time integrals were analysed. Increased augmentation index was analysed in two ways. Augmentation index (P2/P1) was defined as (second systolic peak/first systolic peak) x 100 and not heart rate corrected. Augmentation index @75 was defined as (augmented pressure height/pulse pressure) x 100). Heart rate (75/min) corrected augmentation index (AIx@75) was automatically corrected for heart rate [11,12]. The Buckberg Index or subendocardial viability ratio is a marker of coronary perfusion [10] and defined as the percentage ratio of the diastolic/systolic pressure-time integral. Measurement quality was provided by the SphygmoCor Operator index showed an average result of 93.5 $\pm$ 4.9.

Radial tonometry was recorded after 10 minutes of resting in a supine position, after 10 minutes of applied CPAP ventilation with pressures of 5 and 10 mbar and 10 minutes after withdrawal of CPAP, while still resting (Figure 1) (Recovery).

Continuous Positive Airway Pressure (CPAP)

Continuous positive airway pressure was applied using a nasal mask with pressure of 5 mbar and 10 mbar each. Nasal CPAP application was performed using a standard device reliable at the used pressures and well-established in routine obstructive sleep apnoea syndrome (OSAS) therapy (SOMNOcomfort ® by Weinmann; Hamburg, Germany) and corresponding nasal mask, tubes and filters (Figure 1).

Impedance Cardiographhy

Continuous measurements of beat-to-beat cardiac output, continuous and oscillometric blood pressure and total peripheral resistance index were performed by impedance cardiography (Task force monitor® by CNSystems; Gratz, Austria). Baroreceptor sensitivity and heart rate variability were determined by analysis of continuous blood pressure measurement and standard parameters of heart rate variability as normalised high and low frequency plot and the ratio [13–18].

Statistical Analysis

Data were analysed using Predictive Analytics SoftWare (PASW) software 18.0 (SPSS Inc.). Data were presented as mean $\pm$ SD and $p < 0.05$ was considered significant. To analyse differences due to CPAP conditions repeated

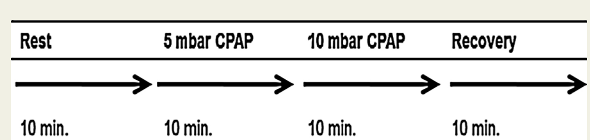

Figure 1 Study protocol. AIx and central blood pressure parameters were measured by radial tonometry at rest, at 5/10 mbar CPAP and after recovery.
Abbreviations: AIx: Augmentation index; CPAP: Continuous positive airway pressure.

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