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Effect of ventilation on systemic blood flow evaluated by echodopplercardiography

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Abstract

Systemic blood flow (Q) was measured by echodopplercardiography in 5 normal young adult males during apnea, eupnea and tachypnea. Measurements were made in a recumbent posture at 3-min intervals. Tachypnea was attained by doubling the respiratory frequency at eupnea at a constant tidal volume. An open glottis was maintained during apnea at the resting respiratory level. The Q values were positively correlated with the respiratory frequency, decreasing from eupnea to apnea and increasing from eupnea to tachypnea ($P<0.05$). These data demonstrate that echodopplercardiography, a better qualified tool for this purpose, confirms the positive and progressive effects of ventilation on systemic blood flow, as suggested by previous studies based on diverse technical approaches.

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Key words
- Ventilation and circulation
- Apnea and systemic blood flow
- Tachypnea and systemic blood flow
- Cardiac output

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The objective of the present study was to analyze the effect of varying rates of breathing on systemic blood flow as measured by echodopplercardiography. An increase in systemic blood flow (Q) by ventilation has been suggested or documented by different methods for measuring cardiac output (1-10). The echodopplercardiographic method to measure Q has not yet been employed. This method has interesting qualifications for this purpose: it does not interfere with breathing or the ventilatory airways, as the Fick principle and the foreign gas methods do, it is not limited in time by blood pulmonary recirculation, as the foreign gas methods are, it is not an invasive method, as the Fick and the dilution methods are, it is more reliable than the transthoracic electrical impedance method, and it can be utilized during apnea, when the Fick and the foreign gas methods cannot.

Five normal resting adult males, ranging in age from 24 to 37 years (mean, 31.8), 167 to 185 cm in height (mean, 176.8) and 72 to 86 kg in weight (mean, 78.6), were studied in a recumbent posture at eupnea, tachypnea and apnea. Tidal volume was kept constant from eupnea to tachypnea. Apnea was held for 30 s at functional residual levels with an open glottis. Ventilation was monitored with a respiration monitoring system (No. 120-0162-0001, Echo Ultrasound, Reedsville, PA). Systemic blood flow was measured by bidimensional echodopplercardiographic

(HP - Sonos 1000, Hewlett Packard, Andover, MS) determination of the diameters of the left ventricle outflow, allowing the calculation of the cross-sectional area of the aortic annulus, and the beat-by-beat integration of the blood flow velocity profile at this level.

Table 1 - Measurement of ventilatory and circulatory parameters by echodopplercardiography.

Data are reported as means ± SEM for 5 normal young adult male volunteers. RF, Respiratory frequency; HR, heart rate; SV, stroke volume; Q, systemic blood flow.

Ventilation state	RF (mpm)	HR (bpm)	SV (ml)	Q (l/min)
Apnea	0	61.8 ± 4.5	76.1 ± 1.3	4.64 ± 0.17
Eupnea	13.4 ± 1.6	64.0 ± 4.9	81.5 ± 4.7	5.15 ± 0.15
Tachypnea	24.0 ± 3.6	70.6 ± 5.3	81.6 ± 4.3	5.67 ± 0.14

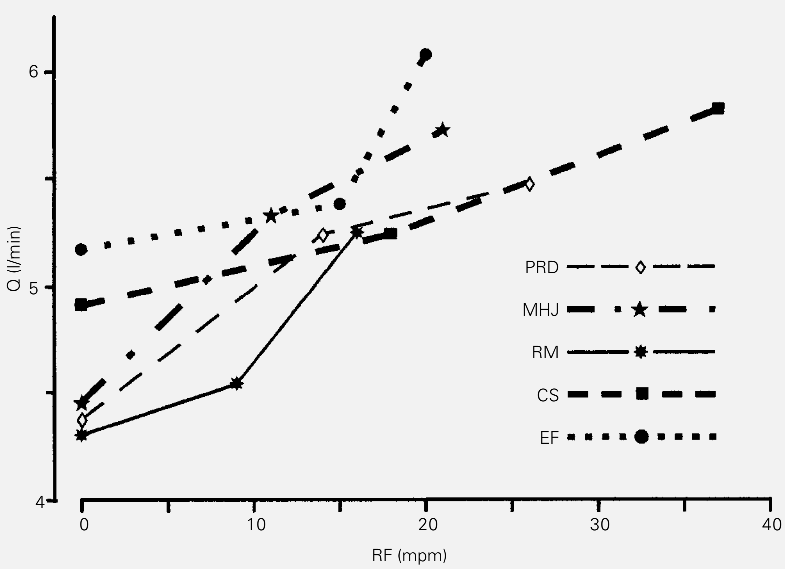

Figure 1 - Changes of systemic blood flow (Q) with respiratory frequency (RF) at apnea, eupnea and tachypnea measured by echodopplercardiography. Each line drawing corresponds to one subject.

The multiplication of the aortic cross-sectional area by the integrated flow led to the beat-by-beat ventricular stroke volume. The mean stroke volume of 10 successive heart beats was then multiplied by the mean heart rate during this period to produce cardiac output (systemic blood flow) (11). An electrocardiographic tracing was recorded during each run. A 3-min interval was allowed between runs.

Considering the non-invasive, routine diagnostic techniques used in the study, no restriction was raised to it by the Hospital Ethics Committee. Oral informed consent was obtained from each subject.

For the whole series, the respiratory frequency (RF) was 13.4 ± 1.6 mpm (mean ± SEM) at eupnea and 24.0 ± 3.6 mpm at tachypnea. Heart rate (HR) was 61.8 ± 4.5 bpm at apnea, 64.0 ± 4.9 at eupnea and 70.6 ± 5.3 at tachypnea. Stroke volume was 76.1 ± 1.3 ml at apnea, 81.5 ± 4.7 at eupnea and 81.6 ± 4.3 at tachypnea. Systemic blood flow (cardiac output; Q) was 4.64 ± 0.17 l/min at apnea, 5.15 ± 0.15 at eupnea and 5.67 ± 0.14 at tachypnea (Table 1).

Figure 1 shows a positive correlation between systemic blood flow and respiratory frequency. When RF was reduced from eupnea to apnea, Q was reduced by 10%. By doubling RF from eupnea to tachypnea, Q was increased by a similar magnitude. The positive correlation between ventilation and systemic blood flow, as shown in the present study by echodopplercardiography, is in agreement with previous studies (5-10) in which other methods for the determination of cardiac output were used, including the only other study which considered changes from eupnea to apnea (9).

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