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Changes in left ventricular function and coronary blood flow velocity during isocapnic hypoxia: A cardiac magnetic resonance imaging study

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Background

Cardiac stress testing is the standard of care for diagnosing ischemic heart disease. Traditional stress testing involves physical or pharmacological stress to induce hyperemia and/or increase myocardial oxygen demand. Physical stress is not possible in 100% of cases however, and pharmacological stress carries rare but serious risk. We asked whether acute isocapnic hypoxia could be utilized as an alternative cardiovascular stress test.

Methods

Eight healthy male volunteers (31 + 4 yrs) were exposed to isocapnic hypoxia using a dynamic end-tidal forcing system. Left ventricular function and coronary artery blood flow velocity were measured by MRI (3T, Siemens). The end-tidal partial pressure of oxygen was maintained at 43 ± 0.3 mmHg, while the end-tidal partial pressure of carbon dioxide was controlled at baseline levels. Left ventricular ejection fraction was assessed using a free-breathing cine sequence (TE/TR = 1.08/46.74 ms; in-plane spatial resolution = 2.5 × 2.5 mm^2; slice thickness = 8 mm). Coronary blood flow velocity was measured in the left anterior descending (LAD), left circumflex (LCX), and left main (LM) coronary arteries using a free-breathing, navigator-gated, Cartesian 2D phase-contrast (PC)-MRI sequence (temporal resolution = 26.4 ms; in-plane spatial resolution = 0.88 × 0.88 mm^2; slice thickness = 7 mm; VENC = 40-80 cm/s in z-direction). Coronary cross-sectional area was assessed in 3 of 8 subjects (all in the left anterior descending coronary artery, LAD), using a 2D balanced steady-state free precession sequence (ECG-triggered and navigator gated; acquisition only in the quiescent phase; in-plane spatial resolution = 0.85 × 0.85 mm^2; slice thickness = 7 mm).

Results

During hypoxia arterial oxyhemoglobin saturation was reduced to 79 ± 1% and heart rate and systolic pressure increased by 47% and 4%, respectively (all $P < 0.05$). Hypoxia increased left ventricular ejection fraction from 66 + 1 to 74 + 1% ($p< 0.01$) and rate pressure product from 7057 + 639 to 10340 + 801 mmHg/beat/min ($P < 0.01$). Mean coronary flow velocity increased significantly in seven of the eight subjects (5 LAD, increasing from 17.9 + 2.1 to 25.6 + 1.2 cm/s; 1 LCX, increasing from 20.1 to 38.8 cm/s; and 1 LM, increasing from 18.6 to 40.0 cm/s). Poor image quality prevented analysis of coronary flow velocity in 1 subject. The change in coronary flow velocity was proportional to the change in myocardial oxygen demand ($P = 0.26$). Coronary cross-sectional area was measured in three subjects and found to remain constant (22.3 + 4.5 vs. 22.4 + 5.3 mm^2, p = ns, baseline vs. hypoxia, respectively).

Conclusions

This is the first MRI study to simultaneously evaluate cardiac function and coronary blood flow in response to acute isocapnic hypoxia using dynamic end-tidal forcing. The results support the use of hypoxia as a unique cardiovascular stress test. Further investigation is required to determine the feasibility and efficacy of its use in targeted patient populations.

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