Detection of viable myocardium: comparison of dobutamine echocardiography and echocardiography after hyperbaric oxygenation

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Veselka J, Mates M, V. Doležal. Detection of viable myocardium: comparison of dobutamine echocardiography and echocardiography after hyperbaric oxygenation. Undersea Hyper Med 1999; 26(1):9–13.—The study concerned the possibility of using echocardiography after hyperbaric oxygenation (HBO2) to detect viable myocardium. Results were compared with dobutamine stress echocardiography (DSE). Seventeen patients with left ventricular dysfunction were enrolled in this study. The regional wall motion of the left ventricle was assessed for every patient and a wall motion score index was calculated. A resting wall motion abnormality was found in 204 segments (75%), of which 119 segments (58%) improved during DSE, and 59 (29%) after HBO2. Of 119 segments with evidence of viability in DSE, HBO2 showed viability in 58 segments. Of 85 segments non-viable in DSE, 84 segments were also non-viable after HBO2. The positive and negative predictive values of HBO2 compared to DSE were 98 and 58%, respectively. Comparing the wall motion score index at rest with the index after DSE 5 and 10 μg · kg⁻¹ · min⁻¹ dobutamine and after HBO2, there was significant improvement (P < 0.005). Differences between DSE 5 μg · kg⁻¹ · min⁻¹ dobutamine and DSE 10 μg · kg⁻¹ · min⁻¹ dobutamine and between HBO2 and DSE 10 μg · kg⁻¹ · min⁻¹ dobutamine were also significant (P < 0.005). There was no significant difference between DSE 5 μg · kg⁻¹ · min⁻¹ and HBO2. Echocardiography after HBO2 is a new method for the detection of viable myocardium. It appears similar in accuracy to DSE 5 μg · kg⁻¹ · min⁻¹, but is inferior to DSE 10 μg · kg⁻¹ · min⁻¹.

myocardial viability, hyperbaric oxygenation, dobutamine stress echocardiography, left ventricular dysfunction

A clinical assessment of reversibility of left ventricular dysfunction in patients after myocardial infarction is particularly important. A number of techniques for detection of hypocontractile but viable myocardium are available (1–3); most techniques often used include dobutamine stress echocardiography (DSE), single photon emission computed tomography (SPECT) imaging, and positron emission tomography (PET). These methods differ in sensitivity, specificity, and predictive values. PET and DSE have a higher positive predictive value (>80%), whereas SPECT yields a higher negative predictive value (90%). Comparing methods used most often in clinical practice, DSE is generally more specific and SPECT is more sensitive (4).

Hyperbaric oxygenation (HBO2) can produce transient hypoxia, even in ischemic, hypoperfused tissue (5,6). Predictably, a transitory increase in tissue oxygen tension in dysfunctional myocardium would be followed by transitory improvement in contraction of viable segments. So far this hypothesis has been proved only by Swift et al. (7). The aim of the present study was to utilize echocardiography after HBO2 to detect viable myocardium and to compare this method with DSE.

METHODS

Patient population: We examined 17 patients (13 men and 4 women, mean age 62 ± 13) with history of myocardial infarction, who had unstable angina pectoris within the last 3 mo. and who satisfied the following criteria: demonstrable wall motion abnormality on routine transthoracic echocardiography (TTE) and a stable cardiac condition at the time of the test. No patient had severe pulmonary emphysema, ear, nose, or throat disease, or severe mental disorder. Informed consent was obtained from each patient before the study.

Dobutamine stress echocardiography: All echocardiograms were performed with a Hewlett Packard Sonos 1000 equipped with a 2.5 MHz transducer. Each patient underwent resting echocardiography and DSE at 5 and 10 μg dobutamine · kg⁻¹ · body weight · min⁻¹. Images were recorded in four standard views: parasternal long axis, parasternal short axis, apical two and four chamber views. Images were recorded on video and digitized on-line in a quad-screen format, which allowed an optimal assessment of the response to dobutamine infusion. The left ventricle was divided into 16 segments, and wall motion at each
stage was assessed using a four-grade scoring system: 1 normal, 2 hypokinesia, 3 akinesia, 4 dyskinesia (8,9). For each patient, a wall motion score index was derived by dividing the sum of scores of individual segments by 16. Heart rate, blood pressure, and one-lead electrocardiograms were monitored throughout the study.

Hyperbaric oxygenation and echocardiography: HBO₂ was performed 2 h after TTE. Before examination, patients were fully informed about the method of HBO₂, and were warned of the necessity of continuous equalizing pressure in the middle ear inside the hyperbaric chamber by repetitive swallowing or Valsalva maneuver. In the three-seat hyperbaric chamber (Vitkovice a.s.) each patient underwent air compression to 2 atm abs for 10 min, then through a facial mask inhaled 100% O₂ for another 90 min. During the air compression the patient was in contact through an intercom and was followed visually. The decompression to normal air pressure started after 90 min and lasted for 15 min, including two 5-min stops at “depth” of 6 and 3 m. Immediately after leaving the hyperbaric chamber, TTE was performed with evaluation of regional wall motion. Echocardiographic images were analyzed off-line by two independent observers. In case of initial disagreement, all discrepancies were resolved by consensus. No complication occurred in any patient.

Statistical analysis: All data are expressed as mean ± standard deviation. The differences between groups were evaluated with paired t tests. P values < 0.05 were considered statistically significant.

RESULTS

Two hundred and seventy-two segments were defined in 17 patients; 68 segments had normal baseline wall motion, the remaining 204 (75% of total) segments were abnormal. Of these 204 segments, 141 (69%) were hypokinetic segments, 57 (28%) akinetic segments, and 6 (3%) segments with dyskinesia at rest.

The number of normal segments increased from 68 to 150 after DSE 10 µg · kg⁻¹ · min⁻¹ and from 68 to 104 after HBO₂. One normal segment became hypokinetic after HBO₂. Of 141 hypokinetic segments, 31 segments normalized wall motion in DSE 5 µg · kg⁻¹ · min⁻¹, 79 segments in DSE 10 µg · kg⁻¹ · min⁻¹, and 33 segments after HBO₂. In the group of akinetic segments, wall motion improved by at least one grade in 20 segments and in 35 segments in DSE 5 and 10 µg · kg⁻¹ · min⁻¹, respectively. Twenty-one akinetic segments improved after HBO₂.

Of the remaining six dyskinetic segments, five improved after DSE 5 or 10 µg · kg⁻¹ · min⁻¹ and after HBO₂. All changes of wall motion for individual segments are described in Fig. 1.

Improvement in wall motion at low doses of dobutamine (10 µg · kg⁻¹ · min⁻¹) occurred in 119 (58%) of 204 dysfunctional segments. HBO₂ evidence of myocardial viability was found in 58 (49%) of the 119 segments that had improved wall motion in dobutamine. Wall motion did not improve with dobutamine stimulation in 85 dysfunctional segments. Of these 85 segments, 84 (99%) were identified as non-viable after HBO₂. Positive and negative predictive values of HBO₂ compared to DSE were 98 and 58%, respectively (Table 1).

Comparing the wall motion score indexes at rest and after DSE 5 and 10 µg · kg⁻¹ · min⁻¹ and after HBO₂, an overall improvement was statistically significant (P < 0.005). Differences between DSE 5 µg · kg⁻¹ · min⁻¹ and DSE 10 µg · kg⁻¹ · min⁻¹, and between DSE 10 µg · kg⁻¹ · min⁻¹ and HBO₂ were also significant (P < 0.005, Table 2).

DISCUSSION

Hyperbaric oxygenation is the breathing of 100% O₂ at higher than normal atmospheric pressure. Decreased size of myocardial infarction after HBO₂ and its possible anti-arrhythmic effects have been described in animal studies (10–12). In a study of 208 patients, Thurston et al. (13) reported a decrease in mortality of high-risk patients with myocardial infarction treated with HBO₂. A reduction of angina and improvement of myocardial function occurred after HBO₂ in patients with chronic coronary artery disease (14,15).

In normal air pressure, the dissolved amount of O₂ is 0.32 ml in 100 ml of plasma, and total O₂ content is 19.82 vol% When breathing pure O₂ at 2 atm abs, the amount of dissolved O₂ increases to 4.44 ml · 100 ml⁻¹ plasma and 23.8 vol% (16) and tissue O₂ tension was increased even an hour after decompression (17). Swift et al. (7) tried to detect viable myocardium by immediate echocardiography after HBO₂, and compared results with SPECT. They reported fixed contraction abnormalities in 42 segments after HBO₂, of which 30 segments showed a fixed defect in SPECT (negative predictive value 71%). Of the 20 segments with improvement of contraction after HBO₂, 18 segments were viable by SPECT (positive predictive value 90%). Swift et al. (7) proposed the term “covert hibernation” to describe myocardium with reversible thallium SPECT defects had no improvement of contractility after HBO₂; these authors also reported that no improvement of motion abnormality was found in patients receiving hyperbaric room air.

Because DSE is considered one of the standard methods to detect viable myocardium (18–22), we decided to compare DSE with echocardiography after HBO₂. Advantages of DSE include low interobserver variability (22,23) and a higher specificity (4).
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DSE 5

Normal

Hypokinesia

Akinesia

Dyskinesia

DSE 10

HBO

FIG. 1—Chart of individual changes of segmental wall motion. DSE 5 = between wall motion at rest and during dobutamine infusion 5 μg·kg⁻¹·min⁻¹; DSE 10 = between wall motion at rest and during dobutamine infusion 10 μg·kg⁻¹·min⁻¹; HBO = between wall motion at rest and after HBO₂.

Table 1: Total of Viable Segment in DSE Compared With Viable Segments Assessed by Hyperbaric Oxygenation

<table>
<thead>
<tr>
<th>DSE Positive</th>
<th>DSE Negative</th>
</tr>
</thead>
<tbody>
<tr>
<td>HBO₂ positive</td>
<td>58</td>
</tr>
<tr>
<td>HBO₂ negative</td>
<td>61</td>
</tr>
</tbody>
</table>

Key: DSE positive = viable in DSE; DSE negative = non-viable in DSE; HBO₂ positive = viable in hyperbaric oxygenation; HBO₂ negative = non-viable in hyperbaric oxygenation.

Although the mechanism of improvement of contractility is different for DSE and HBO₂ (stimulation of beta1 adrenoreceptors vs. increased O₂ delivery to ischemic tissue), the cellular consequences seem similar. These findings in this study show a high specificity of HBO₂ when compared to DSE, and the high specificity of DSE was verified in several previously published reports (18,21,22). Positive and negative predictive values of HBO₂ compared to DSE (10 μg·kg⁻¹·min⁻¹) were 98 and 58%, respectively. The number of segments with improved contractions after HBO₂ was lower than in DSE at 10 μg·kg⁻¹·min⁻¹, but higher than DSE at an infusion rate of 5 μg·kg⁻¹·min⁻¹. Thus HBO₂ echocardiography was statistically equivalent to low dose (5 μg·kg⁻¹·min⁻¹), but inferior to DSE at 10 μg·kg⁻¹·min⁻¹.

The observed sensitivity of DSE for residual myocardial viability after myocardial infarction is 80–90% with an infusion rate 10 μg·kg⁻¹·min⁻¹ of dobutamine and about 70% using 5 μg·kg⁻¹·min⁻¹ (4,18). Thus, indirectly we can presume that sensitivity of HBO₂ for detection of myocardial viability might be about 70%.

We propose that the SPECT “covert hibernation” reported by Swift et al. (7) (i.e., negative HBO₂ with positive SPECT) could be the result of a limited ability of HBO₂ to detect viable myocardium and not truly a different form of hibernation. The reason for this finding could be that DSE and SPECT detect different properties of myocardium: DSE identifies only contractile myocardial reserve whereas SPECT detects all viable myocardium, including some portions that are contractile and others that are dedifferentiated and non-contractile. It is necessary to remember that DSE and HBO₂ provide information about contractile reserve of myocardium, whereas SPECT reflects only perfusion and cell membrane integrity of cardiomyocytes.

Because a rapid improvement in O₂ delivery to myocardium is not always followed by an immediate improvement of contractile function, we do not propose that HBO₂ alone...
could lead to better detection of myocardial viability than DSE, but a combination of HBO\(_2\) and DSE could have an increased accuracy compared to DSE alone. Further studies are necessary to test this hypothesis.

Limitations: First, this study is limited by the small number of patients. Second, there is no information about an effect of myocardial revascularization, either on improvement of left ventricular function or improvement of post-revascularization prognosis of patients with viable myocardium. Some data suggest that patients with viable myocardium who undergo coronary artery bypass have a lower perioperative mortality and morbidity and a greater long-term survival rate than patients with a comparable degree of left ventricular dysfunction and angiographic extent of coronary artery disease who undergo surgery but who preoperatively manifest poor myocardial viability (24). Third, the study did not utilize a different protocol of DSE-biphasic response, that increases specificity to 90% along with a small loss in sensitivity (25).

The last limitation of this method is a necessity of the previous cardiac stabilization of patient’s state before HBO\(_2\), because medical intervention during a stay in a hyperbaric chamber is limited. This disadvantage may be eliminated with large hyperbaric chambers, where medical staff may accompany the patient during HBO\(_2\).

Conclusions: This study indicates that HBO\(_2\) may have some utility in the detection of myocardial viability. Echocardiography following HBO\(_2\) seems similar in accuracy to DSE at an infusion rate of 5 \(\mu\)g \cdot kg\(^{-1}\) \cdot min\(^{-1}\), but is inferior to DSE at an infusion rate of 10 \(\mu\)g \cdot kg\(^{-1}\) \cdot min\(^{-1}\). Further studies are needed to determine whether adjunctive HBO\(_2\) improves the sensitivity and specificity of DSE.

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REFERENCES

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