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FEASIBILITY OF USING NEAR INFRARED SPECTROSCOPY IN DETERMINING VO2 FOR PREOPERATIVE RISK ASSESSMENT

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ABSTRACT

Cardiopulmonary exercise testing (CPX) has been used to identify elderly patients at high risk for mortality during major surgery. Older demonstrated that postoperative cardiovascular-related deaths were predicted by an anaerobic threshold (AT) < 11 ml/kg/min1. This methodology is limited by the uncomfortable and claustrophobic facemask used for standard CPX. During cycling, pulmonary-derived oxygen consumption (VO2) is equivalent to twice muscle VO2. Our research group has developed novel methods of using near infrared spectroscopy (NIRS) to determine muscle oxygen saturation (SmO2), muscle pH and hemoglobin (Hct). Hypothesis: NIRS parameters, in combination with heart rate (HR) monitoring, may be used to estimate VO2.

METHODS

Ten healthy subjects (SMF) performed CPX. Whole-body VO2 was determined with a metabolic cart (True One 2400, Parvo Medics, Salt Lake City, UT). VO2 analysis with NIRS-derived SmO2 was calculated using the Fick equation: VO2 = HR x [C(a-v)O2], where VO2 then stroke volume from HR during exercise. Using the gender specific equation for SV, NIRS VO2 closely approximated whole-body VO2 to the AT. The limits of agreement between VO2 analysis were 0.69 and 0.52 liters per minute (L/min) and the limits of agreement were -0.8 and 0.7 liters per minute (L/min).

RESULTS

1. SV was gender specific and a mathematical equation was developed to calculate SV from HR during exercise.
2. Whole body VO2 from pulmonary measures determined with standard metabolic cart (True One 2400, Parvo Medics, Salt Lake City, UT) was used to determine VO2 at each HR interval during exercise.
3. NIRS sensor adhered to the skin over vastus lateralis muscle to measure pH, SmO2, Hct.
4. HR measured with heart rate monitor (810S, Polar Electro Inc, Lake Success, NY).

Fick Equation

\[ SV = C(1 - e^{-0.0132(180-HR-27.45)}) \]

Obtained with NIRS

Stroke Volume

Research shows that SV progressively increases to VO2 max in trained and untrained subjects, and SV found to be related to HR4. Therefore, stroke volume was estimated from HR based upon population models of SV response during exercise (Krip et al6). Using the average of three subjects’ resting seated stroke volumes from echocardiographic measures, predicted percent change at each HR interval during exercise was used to determine SV values during graded exercise protocol.

Typical male subject plot

Typical female subject plot

Equation was modified for gender and applied to remaining subjects

HYPOTHESIS

Near infrared spectroscopy (NIRS), in combination with heart rate monitoring, may be used to determine VO2 at the anaerobic threshold.

DISCUSSION

• The best fit equation to estimate SV was found to be an exponential with offset multiplier. The multiplier ‘C’ is effectively the stroke volume at maximum VO2 for the last.
• The equation was applied to all subjects, and C was varied until the best fit was obtained for each subject.
• C was found to have one value for male and a different value for female subjects.
• Bias = 0.046
• Limits of agreement -0.64, 0.73
• Discordant values of pulmonary VO2 above 2.5 L/min attributed to one subject, an elite athlete who did not fit the general model

CONCLUSIONS

• NIRS-derived muscle VO2 and whole body VO2 are strongly correlated for exercise up to the AT.
• After the AT, larger errors may be attributed to differences between SmO2 and SmO2Hct.
• The Fick equation assumes we measure SvO2, but for VO2 > AT, myoglobin desaturation may contribute substantially to SmO2, thereby overestimating VO2 with the NIRS method.
• Additional work is required to determine whether the limits of agreement between the two methods of measuring VO2 are small enough to be of clinical value.

LIMITATIONS

This study utilized a small sample of young, healthy subjects, whose responses may not be representative of the elderly population who might benefit most from preoperative risk assessment.

• The SV values were estimated based on HR responses for three subjects, and this model may not be accurate for all individuals.

REFERENCES

3. Yang et al. Optics Express. 2007, 15:13175-13170