Feasibility of Using Near Infrared Spectroscopy in Determining VO$_2$ for Preoperative Risk Assessment

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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 anerobic threshold (AT) < 11 ml/min/kg. 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 simultaneously with NIR spectromeasures from the thigh. Muscle VO2 was calculated using the Fick equation (VO2 = SV x HR x C(a-v)O2) where stroke volume was estimated from HR. Oxygen content difference was calculated from Hct and SmO2 obtained with NIRS. VO2 from pulmonary measures and NIRS VO2 were compared by Bland-Altman analysis. AT was identified spectrally determined pH. Results: SV was gender specific and a mathematical equation was developed to calculate SV from HR during exercise. Using the gender specific equation for SV, NIRS VO2 closely approximated whole-body VO2 up to the AT. The limits of agreement between VO2 measured by NIRS and VO2 measured from metabolic cart were -0.05 L/min, and the limits of agreement were -0.6 and 10.7 L/min (HR = 88%). Larger errors were observed for VO2 > AT. Conclusion: Our results demonstrate the feasibility of using NIRS-derived parameters and HR during exercise to estimate VO2 for preoperative risk assessment.

INTRODUCTION

Postoperative morbidity and mortality may be reduced by identifying high risk individuals before surgery. Among the parameters identified by cardiopulmonary exercise testing (CPX) is the anaerobic threshold (AT), a point readily obtained by measuring oxygen consumption (VO2). Older has shown that postoperative cardiovascular-related deaths are restricted to patients with an AT < 11 ml/min/kg. He used these preoperative measurements as a means to appropriately triage patients postoperatively (i.e., ICU vs. ward admission). However, restrictive and claustrophobic masks during CPX VO2 analysis may deter some patients. Grasso has shown that the response of pulmonary-derived whole body and two times the invasively-measured muscle VO2 during cycling exercise are similar1. Our group has used noninvasive near infrared spectroscopy (NIRS) to measure hemoglobin parameters such as pH, Hct, and capillary oxygen saturation (denoted SmO2, as the sensor does not differentiate myoglobin and hemoglobin oxygen saturation) at these NIRS-derived parameters may be used for screening of patients with low AT during exercise in a manner that is more comfortable to the subject.

HYPOTHESIS

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

METHODS

Protocol
• 10 healthy subjects (5M, 5F)
• Graded cycle ergometry protocol which began at 50 W and increased 50 W per stage every 3 minutes until volitional fatigue
• Whole body VO2 from pulmonary measures determined with standard metabolic cart (True One 2400, Parvo Medics, Salt Lake City, UT)
• NIRS sensor adhered to the skin over vastus lateralis muscle to measure pH, SmO2, Hct
• HR measured with heart rate monitor (810S, Polar Electro Inc, Lake Success, NY)

Fick Equation

\[ VO_2 = SV \times HR \times C(a-v)O_2 \]

Obtained with NIRS

Figure 1

Stroke Volume
• Research shows that SV progressively increases to VO2 max in trained and untrained subjects, and VO2 bound 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
• Stroke volumes estimates for three subjects were plotted versus HR and the resulting best fit equation was obtained.
• Equation was modified for gender and applied to remaining subjects

Determination of AT
• Identified by NIRS-measured change in pH (denoted the H’ threshold, which is shown to be highly correlated with classic metabolic indicators of AT7)

Data Analysis
• NIRS-measured muscle VO2 plotted versus pulmonary VO2 up to AT
• The two methods of measurement compared with Bland-Altman analysis and correlation coefficient

RESULTS

• 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 least.
• 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.

Males: \[ C = 0.154 \pm 0.018 \]

Females: \[ C = 0.096 \pm 0.018 \]

DISCUSSION

• 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 SmO2.
• 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 response for three subjects, and this model may not be accurate for all individuals.

CONCLUSIONS

• Using NIRS is a feasible method of measuring VO2 up to the AT in young active subjects, but this method must be validated in the target population.
• The accuracy of this technique might be improved if myoglobin desaturation is accounted for and better estimates of SV during exercise are obtained (work on-going).
• Ultimately, NIRS monitoring may prove to be useful alternative to the more invoved and potentially uncomfortable technique of measuring VO2 using a metabolic cart.

ACKNOWLEDGMENTS

Funded by the Foundation for Anesthesia Education and Research and the National Space Biomedical Research Institute. Thanks to Peter Scott, Pat Phillips, Sherry Grobstein, and Luxtec Corporation for their contributions to this project.

REFERENCES