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

Nathan Marengi

University of Massachusetts Medical School

Follow this and additional works at: http://escholarship.umassmed.edu/ssp

Part of the Analytical, Diagnostic and Therapeutic Techniques and Equipment Commons, and the Cardiology Commons

Repository Citation


http://escholarship.umassmed.edu/ssp/63

This material is brought to you by eScholarship@UMMS. It has been accepted for inclusion in Senior Scholars Program by an authorized administrator of eScholarship@UMMS. For more information, please contact Lisa.Palmer@umassmed.edu.
FEASIBILITY OF USING NEAR INFRARED SPECTROSCOPY IN DETERMINING \( VO_2 \) FOR PREOPERATIVE RISK ASSESSMENT

Marengi N*, Yang Y*, Lee SMC§, Wilson C§, Heard SO*, Soller BR*
*Department of Anesthesiology, University of Massachusetts Medical Center, Worcester, MA; §Exercise Physiology Laboratory, NASA Johnson Space Center

ABSTRACT

Introduction: 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 anesthesiologist threshold (AT) < 11 ml/min/kg. This methodology is limited by the uncomfortable and claustrophobic facemask used for standard CPX. During cycling, pulmonary-derived oxygen consumption (VO\(_2\)) is equivalent to whole muscle VO\(_2\). Our research group has developed novel methods of using near infrared spectroscopy (NIRS) to determine muscle oxygen saturation (SmO\(_2\)) muscle pH and hemoglobin (Hb) content. Hypothesis: NIRS parameters, in combination with heart rate (HR) monitoring, may be used to estimate VO\(_2\). Methods: Ten healthy subjects (SMIF) performed CPX. Whole-body VO\(_2\) was determined with a metabolic cart simultaneously with NIR spectrums (True One 2400, Parvo Medics, Salt Lake City, UT). NIRS VO\(_2\) from pulmonary measures and NIRS VO\(_2\) were compared by Bell-Adams analysis. AT was identified from spectrums determined pH. Results: VO\(_2\) was gender specific and a mathematical equation was developed to calculate SV from HR during exercise. Using the gender-specific equation for SV, NIRS VO\(_2\) closely approximated whole-body VO\(_2\) up to the AT. The method had better VO\(_2\) and SmO\(_2\) for VO\(_2\) > AT, and the limits of agreement were -0.6 and 10.7 L/min (HR = 88). Larger errors were observed for VO\(_2\) > AT. Conclusion: Our results demonstrate the feasibility of using NIRS-derived parameters and HR during exercise to estimate VO\(_2\) 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 anesthesiologist threshold (AT), a point readily obtained by measuring oxygen consumption (VO\(_2\)). Older has shown that postoperative cardiovascular-related deaths are restricted to patients with an AT of <11 ml/kg/min. 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 VO\(_2\) analysis may deter some patients.

Grassi has shown that the response of pulmonary-derived whole body and two times the invasively-measured muscle VO\(_2\) during cycling exercise are similar. Our group has used noninvasive near infrared spectroscopy (NIRS) to measure hemoglobin parameters such as pH, HbO\(_2\), and capillary oxygen saturation (denoted SmO\(_2\)) as the sensor does not differentiate myoglobin and hemoglobin oxygen saturation. These NIRS-derived parameters may be used for screening of patients with low AT during exercise in a manner more comfortable to the subject.

HYPOTHESIS

Near infrared spectroscopy (NIRS), in combination with heart rate monitoring, may be used to determine VO\(_2\) at the anesthesiologist threshold.

METHODS

Protocol

• 10 healthy subjects (SMIF)
• Graded cycle ergometry protocol which began at 50 W and increased 50 W per stage every 3 minutes until volitional fatigue
• Whole body VO\(_2\) 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, SmO\(_2\), HbO\(_2\)
• HR measured with heart rate monitor (810S, Polar Electro Inc, Lake Success, NY)

NIRS

Equation

\[ SV = C(1 - e^{0.0132(187 - 27.45)}) \]

Obtained with NIRS

• Myoglobin desaturation may contribute substantially to SmO\(_2\), thereby overestimating VO\(_2\) with the NIRS method.

Stroke Volume

• Research shows that SV progressively increases to VO\(_2\) max in trained and untrained subjects, and SV found to be related to HR
• Therefore, stroke volume was estimated from HR based upon population models of SV response during exercise (Krip et al.)
• 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 volume 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\(_{1/2}\) threshold, which is shown to be highly correlated with classic metabolic indicators of AT)

Data Analysis

• NIRS-measured muscle VO\(_2\) plotted versus pulmonary VO\(_2\) 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 VO\(_2\) for the test.
• 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

\[ CO: 0.154 \pm 0.035 \]

• Additional work is required to determine whether the limits of agreement between the two methods of measuring VO\(_2\) are small enough to be of clinical value.

CONCLUSIONS

• Using NIRS is a feasible method of measuring VO\(_2\) 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 ongoing).
• Ultimately, NIRS monitoring may prove to be useful alternative to the more invasive and potentially uncomfortable techniques of measuring VO\(_2\) 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