Effect Of Perioperative Control Of Functional Capacity On Outcome After Major Abdominal Surgery

An Essay
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$\dot{V}_{O2max}$	Maximal Oxygen Uptake
$a\text{–}\dot{V}_{O2}$	Arteriovenous Oxygen Difference
HR	Heart Rate
SV	Stroke Volume
METs	Metabolic Equivalents
$\dot{V}_E/\dot{V}O_2$	Ventilatory Equivalent For Oxygen
$\dot{V}_E/\dot{V}CO_2$	Ventilatory Equivalent For Carbon Dioxide
$P_{ET}O_2$	End-Tidal Oxygen Pressure
$P_{ET}CO_2$	End-Tidal Carbon Dioxide Pressure
MI	Myocardial Infarction
IL	Interleukin
COPD	Chronic Obstructive Pulmonary Disease
ASA	American Society Of Anesthesiologists
$PaCO_2$	Carbon Dioxide Partial Pressure
PFT	Pulmonary Function Tests
PPCs	Postoperative Pulmonary Complications
AAA	Abdominal Aortic Aneurysm
ICD	Implantable Cardioverter Defibrillator
CAD	Coronary Artery Disease

PCI	Percutaneous Coronary Angioplasty
NYHA	New York Heart Association
PND	Paroxysmal Nocturnal Dyspnea
CABG	Coronary Artery Bypass Graf
RCI	Revised Cardiac Index
IPPB	Intermittent Positive Pressure Breathing
CPAP	Continuous Positive Airway Pressure
ACT	Airway Clearance Therapy
CPT	Chest Physiotherapy
HFCWO	High-Frequency Chest Wall Oscillation
CLRT	Continuous Lateral Rotational Therapy
DVT	Deep Vein Thrombosis
PE	Pulmonary Embolism
TEE	Transesophageal Echocardiography

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Introduction

Throughout the last few decades noncardiac surgery has made substantial advances in treating diseases (e.g., cancer) and improving patient quality of life (e.g., arthroplasty). As a result, the number of patients undergoing noncardiac surgery is growing worldwide. However, such surgery is associated with significant cardiac morbidity, mortality and consequent cost ***(Mangano, 1999)*.**

Patients developing serious complications after major surgery often exhibit features of inadequate global or local tissue oxygenation during the perioperative period, usually as a result of inadequate cardiorespiratory function ***(Jhanji et al., 2008).***

Patients undergoing noncardiac surgery are at risk of major perioperative cardiac events (cardiac death, nonfatal MI and nonfatal cardiac arrest). Patients experiencing an MI after noncardiac surgery have a hospital mortality rate of 15%–25% ***(Kumar et al., 2001).***

Following abdominal surgery, a change in lung volume occurs in response to dysfunction of muscle in chest wall mechanics. Vital capacity (VC), residual volume (RV), and forced expiratory volume in one second (FEV1), as well as functional residual capacity (FRC) all decreased after operation, with the maximum decrease on days 1 and 2 and a gradual return toward preoperative values by day 5. Patients with 40% or less decrease in FRC after operation do not develop pulmonary complications ***(Warner, 2000).***

The purpose of perioperative optimization of the functional capacity is not to clear patients for elective surgery, but rather to evaluate and, if necessary, implement measures to prepare higher risk patients for surgery. Preoperative outpatient medical evaluation can decrease the length of hospital stay as well as minimize postponed or cancelled surgeries ***(Macpherson and Lofgren, 1994).***

Chapter I

Functional Capacity
A Physiological Perspective

Functional capacity is the ability of an individual to perform aerobic work as defined by the maximal oxygen uptake ($\dot{V}_{O2max}$), that is, the product of cardiac output and arteriovenous oxygen ($a–\dot{V}_{O2}$) difference at physical exhaustion, as shown in the following equation:

$$\dot{V}_{O2max} = (HR \times SV) \times a–\dot{V}_{O2}\ diff$$ ***(Rowell., 1998).***

Although $\dot{V}_{O2max}$ is measured in liters of oxygen per minute, it usually is expressed in milliliters of oxygen per kilogram of body weight per minute to facilitate intersubject comparisons. In addition, functional capacity, particularly when estimated from the work rate achieved rather than directly measured (=3.5 ml O2. kg^{-1} . min^{-1}). In this instance, functional capacity is commonly expressed clinically as a multiple of the resting metabolic rate ***(Fleg et al., 2005).***

. $\dot{V}_{O2max}$ in a young world-class male endurance athlete can exceed 80 ml O_2. kg^{-1}. min^{-1}, whereas a value of 15 ml O_2. kg^{-1}. min^{-1} falls within the 50^{th} percentile for a sedentary but healthy 80-year-old woman. Aerobic capacity typically declines an average of 10% per decade in nonathletic subjects, mediated by a decrease in stroke volume, maximal heart rate, blood flow to skeletal muscle, and skeletal muscle function ***(Fleg et al., 2005). (Hollenberg et al., 2006).***

Consideration of these age and gender differences in $\dot{V}_{O2max}$ is important when functional capacity in a given individual is interpreted.

(Schulman et al., 1996).

Functional capacity, exercise capacity, and exercise tolerance are generally considered synonymous and imply that a maximal exercise test has been performed and maximal effort has been given by the individual. However, these terms also are used occasionally to express an individual's capacity to perform submaximal activities using one of a variety of tests. Therefore, to avoid confusion, the type of exercise evaluation should be specifically described. A distinction should also be made between estimated and directly measured $\dot{V}_{O2}$. This issue becomes particularly important in patients with cardiovascular disease. Slower oxygen uptake on exertion can create a large discrepancy between estimated and measured $\dot{V}_{O2}$ in which the former dramatically overestimates the latter, especially when aggressive exercise testing protocols are used ***(Myers et al., 1991).***

Directly measured $\dot{V}_{O2}$ is more precise and is the preferred measure clinically, but it is less often available, requires secondary expertise to operate, and includes costs to purchase/maintain the required equipment.

The measurement of $\dot{V}_{O2max}$ implies that an individual's physiological limit has been reached. True attainment of $\dot{V}_{O2max}$ (physiological $\dot{V}_{O2max}$) has historically been defined by a plateau in $\dot{V}_{O2}$ between the final 2 exercise work rates, indicating that maximal effort is achieved and sustained for a specified period. Because this determination is subjective, can be difficult to define, and is rarely observed in tests of patients with cardiovascular or pulmonary disease, the term peak $\dot{V}_{O}$ is more commonly used clinically to express exercise capacity. Conversely, the term $\dot{V}_{O2max}$ typically is used to describe aerobic capacity in apparently healthy individuals in whom achievement of a plateau in $\dot{V}_{O2}$ is more likely ***(Wasserman et al., 2005).***

Because most daily activities do not require maximal effort, a widely used submaximal index of aerobic capacity is the anaerobic or ventilatory threshold (VT), defined by the exercise level at which ventilation begins to increase exponentially relative to the increase in $\dot{V}_{O2}$. The term anaerobic threshold is based on the concept that at a given work rate, oxygen supply to the muscle does not meet the oxygen requirements. This imbalance increases anaerobic glycolysis for energy generation, yielding lactate as a metabolic byproduct (lactate threshold). An increase in ventilation is needed to eliminate the excess CO_2 produced in response to a sustained rise in blood lactate ***(Wasserman et al., 1990)***.

Although the VT usually occurs at 47% to 64% of measured $\dot{V}_{O2max}$ in healthy untrained subjects, it generally occurs at a higher percentage of $\dot{V}_{O2max}$ in endurance-trained individuals. Exercise training has been shown to increase $\dot{V}_{O2}$ at the VT to a degree that is similar to that for $\dot{V}_{O2max}$ (typically 10% to 25% for previously sedentary individuals) ***(Jones et al., 2000).***

The 2 most common definitions of the VT are the following:

1. The point at which a systematic increase in the ventilatory equivalent for oxygen ($\dot{V}_E/\dot{V}O_2$) occurs without an increase in the ventilatory equivalent for carbon dioxide ($\dot{V}_E/\dot{V}CO_2$).
2. The point at which a systematic rise in end-tidal oxygen pressure ($P_{ET}O_2$) occurs without a decrease in the end-tidal carbon dioxide pressure ($P_{ET}CO_2$) ***(Santos et al., 2004).***

Exercise Mode and Protocol Selection

(Shimizu et al., 1991).

Several studies have demonstrated a consistent relationship between aerobic capacity determined with a treadmill and a cycle ergometer, although the latter mode of exercise tends to produce a lower peak $\dot{V}_{O2}$. To rectify the discrepancy between treadmill and cycle ergometry peak $\dot{V}_{O2}$, the following formula has been suggested:

treadmill METs = 0.98 (cycle ergometer METs) + 1.85

Multiplication of the value obtained from this equation by 3.5 produces a treadmill peak $\dot{V}_{O2}$ value in milliliters of O_2 per kilogram per minute ***(Armstrong et al., 2006).***

In addition, cycle ergometry may be preferred in subjects with gait or balance instability, severe obesity, or orthopedic limitations or when simultaneous cardiac imaging is planned. Although arm ergometry may be used to assess the aerobic capacity of wheelchair athletes or other individuals with lower-limb disabilities, most persons cannot achieve work rates comparable to those obtained with leg exercise because of the smaller, often deconditioned muscle mass ***(Shimizu et al.,1991).***

The selection of an appropriate exercise test protocol for assessing functional capacity is of critical importance, especially when aerobic capacity is to be estimated from exercise time or peak work rate. Exercise test protocols with large stage-to-stage increments in energy requirements generally have a weaker relationship between measured $\dot{V}_{O2}$ and work rate ***(Myers et al., 1991).***

Functional capacity also can be accurately determined with the use of a “ramp” protocol in which small increments in work rate occur at intervals of <10 to 60 seconds. Regardless of the specific protocol chosen, the protocol should be tailored to the individual to yield a fatigue-limited exercise duration of ≈8 to 12 minutes ***(Myers et al., 1991).***

Even with exercise test protocols using modest increases in workload, results may still indicate a nonlinear relationship between $\dot{V}_{O2}$ and work rate when test duration is <6 minutes. Conversely, when such protocols result in exercise durations >12 minutes, subjects may terminate exercise because of specific muscle fatigue or orthopedic factors rather than cardiopulmonary end points ***(Myers et al., 1991).***

A frequent consideration in the assessment of functional capacity, especially in nonclinical settings, is whether to perform maximal or submaximal testing. Although maximal testing provides the only accurate determination of aerobic capacity, submaximal testing may be desirable in several situations. These include fitness assessments in facilities in which maximal testing increases subject risk and exposure to potential facility liability, especially in individuals who may be at greater risk for cardiovascular events and particularly when a physician is not on site, and when field testing large numbers of subjects ***(Armstrong et al., 2006).***

Submaximal testing typically relies on an extrapolation from the work rate achieved at a given submaximal heart rate relative to an age-predicted maximal heart rate to estimate maximal aerobic capacity. Achievement of 70% of heart rate reserve {0.70 × [(220-age) - resting heart rate] + resting heart rate} and 85% of age-predicted maximal heart rate [0.85 × (220 - age)] have been proposed as termination criteria for submaximal testing ***(Armstrong et al., 2006).***

Regardless of the equation used, a significant potential for error exists because of the 10- to 12-bpm standard deviation in the estimate of maximal heart rate in normal subjects. Even greater heart rate variation is encountered in patients with cardiac disease. Additionally, individuals taking cardioactive medications may have an altered heart rate response to exercise, further reducing the ability to accurately predict maximal aerobic capacity ***(Lauer et al., 1996).***

Lastly, the potential error in estimating maximal heart rate will be compounded by the errors inherent in estimating aerobic capacity from the highest work rate achieved. For these reasons, maximal exercise testing in a clinical laboratory setting