

Review

Clinical review: How to identify high-risk surgical patients

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Abstract

Postoperative outcome is mainly influenced by ventricular function. Tests designed to identify myocardial ischemia alone will fail to detect cardiac failure and are thus inadequate as a screening test for identification of cardiac risk in noncardiac surgical patients. We find that the degree of cardiac failure is the most important predictor of morbidity and mortality. We use cardiopulmonary exercise testing to establish the anaerobic threshold as the sole measure of cardiopulmonary function as well as to detect myocardial ischemia. Patients with an anaerobic threshold <11 ml/min/kg are at risk for major surgery, and perioperative management must be planned accordingly. Myocardial ischemia combined with moderate to severe cardiac failure (anaerobic threshold <11 ml/min/kg) is predictive of the highest morbidity and mortality.

Keywords anaerobic threshold, exercise test, postoperative complications

Introduction

Once upon a time, a small village in the mountains of Switzerland was troubled by the number of tourists involved in accidents coming down the steep hill into the village. The tourists were apparently more interested in the scenery than in the road. The problem facing the village elders, with what little money they had, was the choice between building more beds in the hospital or building safety barriers at the roadside to prevent the accidents.

Do you believe prevention is better than cure? Do you believe in identifying your high-risk patients before they identify themselves by the need for yet another intensive care unit (ICU) bed? The concept of admitting patients to the ICU postoperatively when they have deteriorated on the ward results in poor outcomes due to the high severity of illness at the time of ICU admission. The issues in identifying high-risk patients are, specifically, what to look for and what tests to perform. We present our case for a new safety barrier.

Recent myocardial infarction [1] and congestive cardiac failure [2] were known historically to be associated with high

mortality. The Confidential Enquiry into Perioperative Deaths, a series of more than 500,000 patients, in 1987 showed that the majority of postoperative deaths occurred in elderly patients, with pre-existing cardiac or pulmonary disease, undergoing major surgery [3]. A later report from Finland in 1995 showed the same findings, this time in more than 325,000 patients [4]. These articles verified the work of Goldman and colleagues, who published the first index of cardiac risk in noncardiac surgery in 1977 [2]. Clowes and Del Guercio had, in 1960, related operative mortality specifically to the inability to increase cardiac output postoperatively [5].

Defining the problem

There are two main components in identification of high risk for surgery. The first relates to the type of surgery and the second to the cardiopulmonary functional capacity of the patient. These components must be assessed independently. Postoperative management may influence the final outcome; identification of high-risk patients will thus only be of value if there is a change in the management prompted by abnormal findings. This is important for the effective use of ICU beds for postsurgical patients.

Surgical risk also has two components: the extent and, to a lesser degree, the duration of the procedure both cause an increase in postoperative oxygen demand [6]. We, and other workers, have shown that major intra-abdominal surgery is associated with an increase in oxygen demand of 40% or more [7]. This must be met by an increase in cardiac output or an increase in oxygen extraction. The latter is limited, in the postoperative setting, to an absolute value of 35–40%.

Patients having surgery such as abdominoperineal resection of the rectum, oesophagectomy or repair of an abdominal aortic aneurysm should thus be managed in the ICU because the oxygen demand of the patient will be high and their postoperative care will be complicated. It has been shown that patients with poor ventricular function who are unable to increase cardiac output to meet the postsurgical demand have much higher mortality [8]. For lesser surgery, such as an inguinal hernia repair, there is little or no measurable increase in oxygen demand and postoperative cardiovascular complications would not be expected even in a patient with poor ventricular function. The concept of 'surgery-specific risk' has been well described in the American College of Cardiology/American Heart Association guidelines [9].

The functional capacity of the patient determines their ability to support the postoperative demand of increased oxygen consumption and therefore of cardiac output. We have shown that myocardial ischemia only becomes part of this equation if the ischemia limits ventricular function and cardiac output. The presence or absence of this limitation is the pivotal issue, not the diagnosis of ischemia *per se*.

How should we assess functional capacity?

Del Guercio and Cohn showed that standard clinical preoperative assessment of the elderly for surgery was inadequate. Hemodynamic monitoring revealed serious abnormalities in 23% of patients; all in this group who underwent surgery despite a warning died [10]. This was the first work to identify risk on the basis of physiologic measurement. In a similar study, Older and Smith found that up to 13% of elderly patients had serious cardiopulmonary abnormalities that made them a high risk for surgery, undetected on prior clinical examination [7].

In a study of operative mortality, Greenburg and colleagues found that physiologic senescence is a real phenomenon and that age was less of a mortality factor than physiologic status – an effect of aging. They also found that survivors from geriatric surgery did not have congestive cardiac failure [11]. Although aging is associated with a decline in organ system function, Wasserman has pointed out that we all age physiologically at different rates. Chronologic age is thus a poor discriminator of individual surgical risk [12].

There are many commonly performed investigations for cardiac disease and, while they are sensitive in detecting or

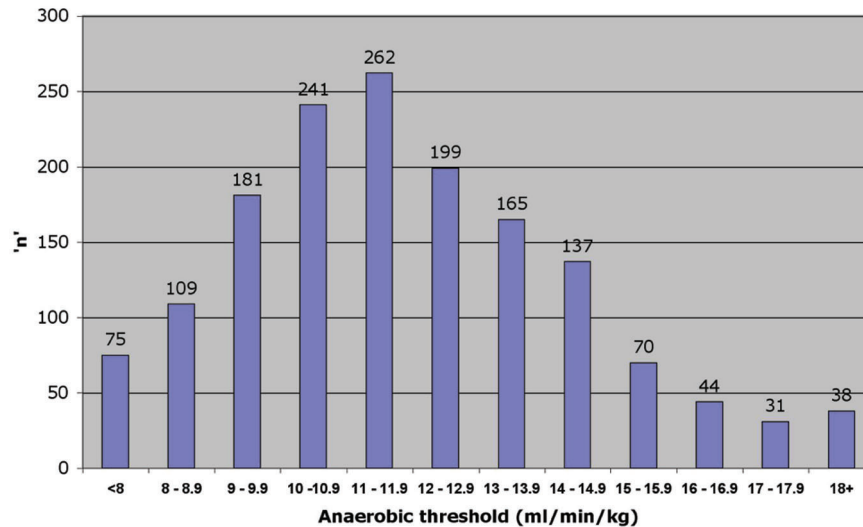
delineating the extent of ischemic heart disease, none were designed specifically as preoperative screening tests. Because the incidence of adverse cardiac events following major surgery is less than 10%, the positive predictive value of the special investigations ranges from only 10% to 20% [13]. Sadly, many or most of the current clinical 'risk indices' still highlight issues such as age, risk factors for coronary artery disease, valvular heart disease, arrhythmias and findings on physical examination.

There is a current conviction that transthoracic echocardiography or radionuclide ventriculography assess functional capacity. Transthoracic echocardiography is noninvasive and easy to perform, which may be the reason for its ready acceptance. It assesses systolic wall motion and diastolic wall motion but, as may be suspected, there is a poor correlation between transthoracic echocardiography findings and functional capacity; ventricular dysfunction on echocardiography may well be associated with moderate to good functional capacity. A study performed by the Study of Perioperative Ischaemia Research Group did not support the use of transthoracic echocardiography in the assessment of cardiac risk prior to noncardiac surgery [14].

It is now accepted that the ejection fraction assessed by radionuclide ventriculography correlates poorly with the exercise capacity and the peak oxygen uptake. Froelicher showed a poor correlation between the ejection fraction and the maximal oxygen uptake in patients with coronary artery disease not limited by angina [15]. In a study by Dunselman and colleagues of New York Health Association class II and class III patients with an ejection fraction <40%, only oxygen-derived data were able to show differences between groups. Their article further states that objective determination of exercise capacity is the only way to select patients for studies on heart failure [16].

Dobutamine stress echocardiography is used for evaluation of myocardial ischemia. While wall motion abnormalities may be detected, no objective measurement of functional capacity can be obtained. The sensitivity and specificity for the detection of myocardial ischemia is high and, as such, dobutamine stress echocardiography is a useful adjunct in evaluating coronary artery disease. However, dobutamine stress echocardiography is not appropriate for preoperative screening.

A study carried out by the Study of Perioperative Ischemia Research Group showed that dipyridamole-thallium scintigraphy was not a valid screening test for prediction of postoperative cardiac events [17]. Following these results, single-photon emission computed tomography was developed. The combination of this technique with radionuclide angiography was used as a screening test in 457 patients scheduled for abdominal aortic reconstructive surgery. The authors concluded that dipyridamole-thallium single-photon emission

Figure 1

Frequency distribution of the anaerobic threshold for 1645 patients (mean, 12.1 ml/min/kg).

computed tomography was not an accurate screening test of cardiac risk for abdominal aortic surgery [18].

The alternative paradigm

Having elucidated the shortcomings of the traditional (and existing) approach, what are the alternatives?

Evidence for a new paradigm came from work performed in the 1980s. Gerson and colleagues compared history and clinical examination, laboratory data and radionuclide data with exercise testing. They found that an inability to perform 2 min of supine bicycle exercise to raise the heart rate above 99 beats/min was the only independent predictor of peri-operative complications [19].

In discussing the aforementioned study by Greenburg and colleagues [11] regarding operative mortality and the physiologic effects of aging, Schrock commented that "a missing ingredient in the study is some measure of physiologic reserve. Functional reserve is critical in determining response to minor and major problems" [11]. Schrock then asked the crucial question: "Is there some way to quantitate this particular factor?" [11].

Greenburg and colleagues replied "Measurement of physiologic reserve becomes more difficult when one evaluates the number of pre-existing illnesses the patient has" [11].

Goldman stated in 1987 at the London Sepsis Conference that "exercise testing using a bicycle could identify patients at risk that were not identified by the cardiac risk index" (personal communication).

The requirement is for a screening test that quantifies functional reserve independently of other factors. We postulated in 1993 at the Washington Colo-Rectal Meeting that such a test should be objective, should be specific and sensitive for detection of cardiac failure and myocardial ischemia at subclinical levels, should be noninvasive, should be able to be performed at short notice on inpatients or on outpatients, and should be quick and inexpensive to perform. This virtually defines cardiopulmonary exercise testing (CPX).

CPX measures oxygen uptake at increasing levels of work and objectively determines cardiopulmonary performance under conditions of stress. This test is normally performed on a bicycle ergometer using respiratory gas analysis and an electrocardiogram. Oxygen consumption and carbon dioxide production are measured during a 'ramp' exercise protocol. Oxygen consumption is a function of oxygen delivery and thus of total cardiopulmonary performance. Under exercise conditions, oxygen consumption becomes a linear function of cardiac output. The measurement of aerobic capacity thus becomes a surrogate for the measurement of ventricular function. The test takes less than 1 hour and the cost is limited to the cost of consumables once the metabolic cart has been purchased.

The most repeatable and relevant measurement on CPX testing is the anaerobic threshold (AT). This is the point at which aerobic metabolism is inadequate for maintenance of high-energy phosphate production in the exercising muscles, thus forcing the anaerobic metabolism to make up the deficit. This point is nonvolitional and is readily determined with high accuracy. The AT is expressed as a value of oxygen consump-

tion indexed to body mass (ml/min/kg). Anaerobic metabolism occurs in any tissue where oxygen delivery is inadequate to meet energy requirement. This leads to our concepts of a 'surgical anaerobic threshold' and 'postoperative cardiac failure'; the inability of the heart to meet the demand of postoperative stress.

In our database of over 1600 patients we have established a range of average values for the AT of 12.2 ± 2.7 ml/min/kg in an elderly population (Fig. 1). We do not believe it possible to make a clinical differentiation between patients with an AT in the range 10–14 ml/min/kg. Such differentiation is vital in preoperative assessment and perioperative management and can only be made by CPX testing.

We have used CPX testing for preoperative risk stratification since 1988. We have demonstrated that an exercise anaerobic threshold >11 ml/min/kg predicts postoperative survival with high sensitivity and specificity [20,21]. Cardiovascular deaths in all our studies are virtually confined to patients with AT <11 ml/min/kg (i.e. there are very few false negatives). Current mortality figures show a cardiovascular mortality rate of 0.9% in 750 patients, all in patients with AT <11 ml/min/kg.

It is interesting and very relevant that in a recent study of medical patients with cardiac failure, unrelated to surgery, AT <11 ml/min/kg was associated with poor prognosis [22].

Our work suggests that cardiac failure is responsible for more deaths than myocardial ischemia. The presence or absence of myocardial ischemia *per se* does not influence outcome; however, the temporal relationship of ischemia to AT is important. We have found that in patients in whom myocardial ischemia develops at reduced work rates, the anaerobic threshold is usually reduced, implying that ischemia is limiting the cardiac performance of the patient. Our hypothesis is that those patients in whom ischemia develops early in exercise are at higher risk of postoperative ventricular dysfunction than those in whom ischemia develops late [23].

Competing interests

The authors declare that they have no competing interests.

References

- Rao TL, Jacobs KH, El-Etr AA: **Reinfarction following anesthesia in patients with myocardial infarction.** *Anesthesiology* 1983, **59**:499-505.
- Goldman L, Caldera DL, Nussbaum SR, Southwick FS, Krogstad D, Murray B, Burke DS, O'Malley TA, Goroll AH, Caplan CH, Nolan J, Carabelleo B, Slater EE: **Multifactorial index of cardiac risk in noncardiac surgical procedures.** *N Engl J Med* 1977, **297**:845-850.
- Buck N, Devlin HB, Lunn JN: *The Report of a Confidential Enquiry into Perioperative Deaths.* London: King's Fund Publishing Office; 1987.
- Tikkanen J, Hovi-Viander M: **Death associated with anaesthesia and surgery in Finland in 1986 compared to 1975.** *Acta Anaesthesiol Scand* 1995, **39**:262-267.
- Clowes GH Jr, Del Guercio LR: **Circulatory response to trauma of surgical operations.** *Metabolism* 1960, **9**:67-81.
- Waxman K, Shoemaker WC: **Management of postoperative and posttraumatic respiratory failure in the intensive care unit.** *Surg Clin N Am* 1980, **60**:1413-1428.
- Older P, Smith R: **Experience with the preoperative invasive measurement of haemodynamic, respiratory and renal function in 100 elderly patients scheduled for major abdominal surgery.** *Anaesth Intensive Care* 1988, **16**:389-395.
- Shoemaker WC, Appel PL, Kram HB, Waxman K, Lee TS: **Prospective trial of supranormal values of survivors as therapeutic goals in high-risk surgical patients.** *Chest* 1988, **94**:1176-1186.
- Eagle K, Brunage B, Chaitman B: **Guidelines for perioperative cardiovascular evaluation for noncardiac surgery. Report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines. Committee on Perioperative Cardiovascular Evaluation for Non-cardiac Surgery.** *Circulation* 1996, **93**:1278-1317.
- Del Guercio LR, Cohn JD: **Monitoring operative risk in the elderly.** *JAMA* 1980, **243**:1350-1355.
- Greenburg AG, Saik RP, Pridham D: **Influence of age on mortality of colon surgery.** *Am J Surg* 1985, **150**:65-70.
- Wasserman K: **Preoperative evaluation of cardiovascular reserve in the elderly.** *Chest* 1993, **104**:663-664.
- Bodenheimer MM: **Noncardiac surgery in the cardiac patient: what is the question?** *Ann Intern Med* 1996, **124**:763-766.
- Halm EA, Browner WS, Tubau JF, Tateo IM, Mangano DT: **Echocardiography for assessing cardiac risk in patients having noncardiac surgery. Study of Perioperative Ischemia Research Group.** *Ann Intern Med* 1996, **125**:433-441.
- Froelicher V: **Interpretation of specific exercise test responses.** In *Exercise and the Heart*, 2nd edition. Edited by Froelicher V. Chicago, IL: Year Book Medical Publishers; 1987:83-145.
- Dunselman PH, Kuntze CE, van Bruggen A, Beekhuis H, Piers B, Scaf AH, Wesseling H, Lie KI: **Value of New York Heart Association classification, radionuclide ventriculography, and cardiopulmonary exercise tests for selection of patients for congestive heart failure studies.** *Am Heart J* 1988, **116**:1475-1482.
- Mangano DT, London MJ, Tubau JF, Browner WS, Hollenberg M, Krupski W, Layug EL, Massie B: **Dipyridamole thallium-201 scintigraphy as a preoperative screening test. A reexamination of its predictive potential. Study of Perioperative Ischemia Research Group.** *Circulation* 1991, **84**:493-502.
- Baron JF, Mundler O, Bertrand M, Vicaut E, Barre E, Godet G, Samama CM, Coriat P, Kieffer E, Viars P: **Dipyridamole-thallium scintigraphy and gated radionuclide angiography to assess cardiac risk before abdominal aortic surgery.** *N Engl J Med* 1994, **330**:663-669.
- Gerson MC, Hurst JM, Hertzberg VS, Doogan PA, Cochran MB, Lim SP, McCall N, Adolph RJ: **Cardiac prognosis in noncardiac geriatric surgery.** *Ann Intern Med* 1985, **103**:832-837.
- Older P, Smith R, Courtney P, Hone R: **Preoperative evaluation of cardiac failure and ischemia in elderly patients by cardiopulmonary exercise testing.** *Chest* 1993, **104**:701-704.
- Older P, Hall A, Hader R: **Cardiopulmonary exercise testing as a screening test for perioperative management of major surgery in the elderly.** *Chest* 1999, **116**:355-362.
- Gitt AK, Wasserman K, Kilkowski C, Kleemann T, Kilkowski A, Bangert M, Schneider S, Schwarz A, Senges J: **Exercise anaerobic threshold and ventilatory efficiency identify heart failure patients for high risk of early death.** *Circulation* 2002, **106**:3079-3084.
- Older P, Hall A: **Myocardial ischaemia or cardiac failure: which constitutes the major perioperative risk? In 2003 Year Book of Critical Care and Emergency Medicine.** Edited by Vincent J. New York: Springer-Verlag; 2003.