British Journal of Anaesthesia Page 1 of 7 doi:10.1093/bja/aen310

CLINICAL PRACTICE

Assessing fitness for surgery: a comparison of questionnaire, incremental shuttle walk, and cardiopulmonary exercise testing in general surgical patients

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> **Background.** Morbidity and mortality are higher in patients with poor preoperative cardiorespiratory reserve. This study aimed to ascertain fitness and therefore risk in elective patients, comparing three measures: Duke Activity Status Index (DASI) questionnaire, incremental shuttle walk test (ISWT), and cycle cardiopulmonary exercise testing (CPET). We looked for correlation between the measures and for thresholds on the questionnaire or shuttle test which could identify fit patients and render CPET unnecessary.

> **Methods.** A prospective cohort trial of 50 patients having intra-abdominal surgery. Each performed DASI, ISWT, and CPET during a single visit to the hospital.

Results. There was a significant correlation between measured oxygen consumption and both ISWT and DASI. Receiver operator curve showed both the shuttle walk test and the DASI are sensitive and specific predictors of VO₂peak >15 ml O₂ kg⁻¹ min⁻¹ and anaerobic threshold (AT) >11 ml O₂ kg⁻¹ min⁻¹. Thirty-two patients would be considered lower risk, having achieved both VO₂peak and AT cut-offs. Setting an ISWT threshold of 360 m identified 13 of the lower risk patients [positive predictive value (PPV) 1.0, negative predictive value (NPV) 0.49]. Setting a DASI threshold score of 46 identified nine lower risk patients (PPV 1.0, NPV 0.44).

Conclusions. We found a significant correlation between the tests. However, many patients with poor questionnaire scores or shuttle walks had satisfactory CPET results. Hence, the ability of either simple test to determine risk in a heterogeneous surgical population is poor. CPET provides an objective measurement of cardiopulmonary fitness; however, evidence for this information improving patient outcome is limited and requires further research.

Br J Anaesth 2008; 101: 1-7

Keywords: assessment, preanaesthetic; cardiorespiratory system, responses; metabolism, oxygen consumption; oxygen, uptake; surgery, abdominal

Accepted for publication: September 18, 2008

Major surgery produces a systemic inflammatory response associated with a marked increase in oxygen consumption in the immediate postoperative period.^{1 2} In patients with poor cardiorespiratory reserve, the inability to meet this increased demand may lead to avoidable morbidity and mortality.¹⁻³

Identification of high- and low-risk patients allows planning of appropriate perioperative care and improves the quality of informed consent. Multiple strategies have been shown to improve outcome^{1 4 5} and could be targeted at high-risk patients. These strategies may require intensive care resources and increased levels of monitoring. To date, there is no consensus on the best way to identify high-risk patients before operation;⁶ however, routine history, physical examination, and investigations do not identify them.⁷

Measured or estimated exercise tolerance may indicate ability to increase oxygen delivery after surgery. In several studies, most of the postoperative morbidity and mortality occurred in patients with low exercise tolerance.^{5 7–11} Although there is no clear agreement on the best single predictor of outcome, thresholds of peak oxygen consumption (VO₂peak) of 15 ml O₂ kg⁻¹ min^{-1 10 12 13} and an oxygen consumption at the anaerobic threshold (AT) of 11 ml O₂ kg⁻¹ min^{-1 5 9} have been shown to discriminate between higher and lower risk patients in non-cardiac surgery. Therefore, any patient who exceeds these exercise thresholds would be regarded as at lower risk of postoperative cardiorespiratory events.

The American College of Cardiology and American Heart Association (ACC/AHA) guidelines on perioperative cardiovascular evaluation and care use a derivative of the Duke Activity Status Index (DASI) questionnaire¹⁴ to estimate functional status.¹⁵ For elective patients undergoing major surgery without active cardiac conditions, the ACC/AHA algorithm questions the patient about their functional status. Patients with a reported exercise tolerance above 4 metabolic equivalent tasks (METS) proceed to major surgery without the need for additional investigations or modification of perioperative management. This exercise tolerance equates to 14 ml O₂ kg⁻¹ min⁻¹ or a DASI questionnaire score above 11.6. The questionnaire, however, was developed with cardiology patients and has not been validated in a general surgical population. As such, its use in this context is questionable.

Objective measures of exercise tolerance give an estimate of oxygen consumption and might be easily used for preoperative screening. Incremental shuttle walk test (ISWT) is easy to perform and has been shown to correlate with measured peak oxygen consumption in patients with chronic obstructive pulmonary disease (COPD),^{16 17} cardiac disease,¹⁸ and those undergoing lung resection surgery.^{10 19} However, a significant proportion of elderly patients may have comorbidities which may limit their ability to walk.

The gold standard for measuring exercise tolerance is a cardiopulmonary exercise test (CPET) which provides a comprehensive assessment of cardiorespiratory fitness. CPET gives values for key measurements including VO₂peak and AT, along with other features of importance such as ECG changes, cardiac, and ventilatory function.²⁰ Low AT has been shown to correlate to poor outcome after surgery.^{5 9} Using a bicycle for the test reduces stress on joints and may be easier for some patients than walking. However, CPET requires dedicated equipment and staffing.

Our hypothesis was that either (or both) the ISWT or the DASI would reliably identify lower risk patients, that is, those patients with a VO₂peak above 15 ml O₂ kg⁻¹ min⁻¹ and an AT above 11 ml O₂ kg⁻¹ min⁻¹. Formal CPET would therefore be unnecessary in these patients.

Methods

Study design and population

The study was approved by Cornwall and Plymouth Research Ethics Committee (Ref: 06/Q2103/121). All elderly or high-risk patients undergoing elective intra-abdominal surgery in one institution were eligible for recruitment. The patients were either >65 yr of age or

younger with diagnoses of significant but stable myocardial ischaemia, cardiac failure, or respiratory disease.

Patients were referred at the discretion of their surgeon and were given written information before being contacted by the study team for consideration of enrolment. Absolute and relative exclusion criteria were taken from the American Thoracic Society and American College of Chest Physicians Statement on CPET.²¹ The exclusion criteria include unstable or critical cardiorespiratory disease or acute illness that might be exacerbated by exercise. These conditions overlap with the active cardiac conditions defined in the ACC/AHA algorithm. No study patient was excluded because of orthopaedic impairment. On the day of the study, informed consent was obtained and a medical history taken. All patients were asked to eat and drink normally and to take their regular medications.

Access to the cardiopulmonary exercise equipment meant that we were unable to randomize the order of the tests. All patients underwent walking test and questionnaire in the morning followed by CPET in the afternoon. Time constraints associated with the need to proceed to surgery precluded practice sessions for the patients.

Questionnaire

We recorded the summed DASI questionnaire score, which has 12 questions about activities of daily living each of which has a weighted value attached to it (Appendix 1). The sum of the positive answers gives the DASI score that ranges from 0 to 58.2.¹⁴

Incremental shuttle walk test

We recorded the distance each patient completed during an ISWT as described by Singh and colleagues.¹⁶ Patients walked a 10 m course on a flat corridor. A series of chimes determined the time allowed for each 'shuttle' and hence walking pace. Each minute, the time between chimes reduced—and therefore the required pace to complete the shuttle increased. In the first minute, the patient was required to complete three shuttles rising to 14 shuttles in the 12th minute. The test continued until the patient was unable to complete the shuttle before the next chime. After an explanation and encouragement in the first few shuttles, no further encouragement was given. Resting and recovery heart rate, oxygen saturations, and arterial pressure were recorded.

All patients rested for at least 4 h between exercise tests and were encouraged to have a light meal.

Cardiopulmonary exercise test

The CPET test was conducted in accordance with ATS/ ACCP recommendations²¹ using an Oxycon Delta metabolic cart (Jaeger, Hoechberg, Germany) and VIAsprint 150P Analog Ergometer (Viasys Healthcare, Warwick, UK). Each patient was connected to a 12-lead ECG and seated on the cycle ergometer. Inspired and expired gases were measured through a facemask. Each patient rested for 2 min before cycling. Patients warmed up for 3 min by cycling against no load before the workload was increased. A ramp protocol was selected to allow the patient to pedal for 6-10 min. The patient was encouraged throughout the test. The test was stopped when the patient was unable to maintain a cadence at 40 rpm (typically due to fatigue or dyspnoea) or developed new arrhythmia, more than 2 mm of ST elevation or depression, or an arterial pressure of more than 220 mm Hg systolic or 120 mm Hg diastolic. The patient was monitored until heart rate was within 10 beats min⁻¹ of resting values and any ECG changes resolved.

The CPET apparatus reports multiple variables. We have reported the peak oxygen consumption (VO₂peak) and AT. AT is the point during exercise where metabolic demands outstrip the body's ability to deliver oxygen and anaerobic metabolism supplements aerobic. At this point, lactate production is buffered by bicarbonate producing additional CO₂. The slope of the plot of CO₂ production against O₂ consumption increases from this threshold. This point of inflection is the AT and this method of AT determination is commonly called the V-slope method. The point was confirmed by ventilatory equivalents²⁰ and agreed upon by two researchers.

Follow-up

The patient's treatment was not altered according to results. However, we sent a letter summarizing the results to the patient's surgical consultant and general practitioner and a copy was placed in the notes to allow access for the rest of the perioperative team. The letter referenced the management algorithm derived by Older and colleagues.⁵

Sample size and statistical analysis

Examination of the original work of Hlatky and colleagues¹⁴ and Singh and colleagues¹⁶ determined that a sample size of 50 patients should allow determination of pairwise relationships with 95% confidence. Data were tabulated in an Excel worksheet and then analysed using SPSS version 15.0.1 running on a personal computer under Windows XP.

Mortality in an unselected population after elective general surgery is low. Therefore, there was no attempt to power this study to demonstrate a difference in outcome between those patients stratified as high and low risk.

Pairwise relationships and strength of relationships were determined between the measures of ISWT, DASI, and CPET using regression analyses. The linear regression model used VO₂peak or AT as the dependent variable and ISWT distance or DASI score as independent variables. Receiver operator curve (ROC) analysis was used to establish threshold values of DASI, ISWT, or both which will render CPET unnecessary. Positive predictive value (PPV) and negative predictive value (NPV) were determined at these thresholds.

Results

Patients were recruited between March 2007 and January 2008. All 50 patients completed the sections without incident and none of the tests was halted due to a complication (Table 1). Thus, all patients reached their maximal effort and hence a peak VO_2 . One patient did not exercise on CPET long enough to demonstrate an AT. More detailed patient information is presented in Appendix 2, online.

Correlation of tests and predictive value of fitness

Thirty-nine patients had a measured VO₂peak of 15 ml O₂ kg⁻¹ min⁻¹ or greater. Pearson's correlation and linear regression analysis revealed a strong relationship between distances walked and measured VO₂peak (R^2 =0.57, P<0.0001) (Fig. 1). Regression analysis suggested less strong correlation between DASI and measured peak oxygen consumption (R^2 =0.45, P<0.0001) (Fig. 2).

ROC analysis showed that both shuttle walk test and DASI are sensitive and specific predictors of VO₂peak >15 ml O₂ kg⁻¹ min⁻¹ [ISWT area under the curve (AUC) 0.882, 95% CI 0.770–0.993, P=0.0001 vs DASI

Table 1 Summary of patient characteristics and outcome measures

Sex (M/F)	40/10
Age (yr) (mean, range)	79 (53-90)
BMI (kg m^{-2}) (mean, sD)	28.6 (4.7)
Surgery type	Number
Vascular	29
Colorectal	10
Urology	9
Upper gastrointestinal	2
Duke Activity Status Index score (mean, sd)	30.2 (15)
Shuttle walk distance (m) (mean, sp)	284 (207)
CPET peak VO ₂ (ml O ₂ kg ^{-1} min ^{-1}) (mean, sD)	18.7 (5.1)
CPET AT (ml O_2 kg ⁻¹ min ⁻¹) (mean, sd)	12.7 (3.3)



Fig 1 Correlation between ISWT distance (m) and VO₂peak (ml O₂ kg⁻¹ min⁻¹). The linear regression line VO₂peak (ml O₂ kg⁻¹ min⁻¹)=13.43+0.02×shuttle walk test distance (m) is plotted together with its 95% confidence limits (R^2 =0.57, P<0.0001).



Fig 2 Correlation between DASI and VO₂peak (ml O₂ kg⁻¹ min⁻¹). The linear regression line VO₂peak (ml O₂ kg⁻¹ min⁻¹)=11.82+0.23×DASI is plotted together with its 95% confidence limits (R^2 =0.45, P<0.0001).

AUC 0.765, 95% CI 0.620-0.9, P=0.0002] (Fig. 3). Adding DASI score to the distance walked did not significantly improve the regression model.

All patients who walked more than 320 m had a $VO_2peak > 15$ ml O_2 kg⁻¹ min⁻¹ (PPV 1.0, NPV 0.31) and likewise all patients with a DASI score of more than 37.45 achieved this threshold (PPV 1.0, NPV 0.32).

Sixteen patients had an AT <11 ml O₂ kg⁻¹ min⁻¹ whereas 33 had AT \geq 11. Again ROC analysis suggested that there was no significant difference in the sensitivity or specificity of either DASI or ISWT for predicting AT \geq 11 ml O₂ kg⁻¹ min⁻¹ (ISWT AUC 0.783, 95% CI 0.645–0.945,



Fig 3 ROC curves for predicting VO₂peak>15 ml O₂ kg⁻¹ min⁻¹ from shuttle walk test distance (m) and DASI. AUC is 0.882 for shuttle walk test distance (95% CI 0.770–0.993, P=0.0001) and 0.765 for DASI score (95% CI 0.620–0.911, P=0.0002).



Fig 4 ROC curves for predicting AT >11 ml O₂ kg⁻¹ min⁻¹ from DASI and shuttle walk test distance (m). AUC is 0.783 for shuttle walk test distance (95% CI 0.645–0.945, P=0.001) and 0.767 for DASI (95% CI 0.630–0.994, P=0.003).

P=0.001 *vs* DASI AUC 0.767, 95% CI 0.630–0.994, *P*=0.003) (Fig. 4). All patients who walked 360 m had an AT >11 ml O₂ kg⁻¹ min⁻¹ (PPV 1.0, NPV 0.44) and all with a DASI over 46 also had an AT >11 (PPV 1.0, NPV 0.40).

Overall 32 patients managed to achieve both VO₂peak above 15 ml O_2 kg⁻¹ min⁻¹ and AT above 11 ml O_2 kg⁻¹ min⁻¹ and would be considered low risk for postoperative cardiorespiratory complications.

Thirteen patients who walked 360 m or more on ISWT achieved peak O_2 consumption >15 ml O_2 kg⁻¹ min⁻¹ and also had an AT >11 ml O_2 kg⁻¹ min⁻¹. However, 19 patients not able to walk 360 m achieved the goal oxygen consumptions on CPET. PPV for ISWT of 360 m was 1.0 and NPV 0.49. Setting a threshold DASI score of 46 identified nine patients who had both VO₂peak above 15 ml O_2 kg⁻¹ min⁻¹ and AT above 11 ml O_2 kg⁻¹ min⁻¹. However, it failed to identify the other 23 low-risk patients giving a PPV of 1.0 and an NPV of 0.44.

Surgical outcomes

The study was not powered to compare outcomes between the patients determined as fit and unfit. Thirty-nine of the 50 patients proceeded to the proposed major surgery, of whom 26 had been categorized as fit and 13 as unfit (Appendix 2: see Supplementary Material online). There was a single death in the first 30 days after surgery. The patient died from a myocardial infarction 8 days after elective repair of an abdominal aortic aneurysm. This patient had been stratified as unfit based on a low AT (AT 10.0 ml O₂ kg⁻¹ min⁻¹). The other 11 patients did not proceed to the proposed surgery—of whom six had been stratified as fit and five unfit. Five patients chose not to have surgery, four had lower risk surgery, and two had inoperable conditions (Appendix 2).

Discussion

In our study of elderly patients undergoing elective intra-abdominal surgery, we confirmed good correlation between both ISWT and DASI questionnaire and measured oxygen consumption. In particular, all patients able to walk 360 m or with a DASI score >46 had a VO₂ peak above 15 ml O_2 kg⁻¹ min⁻¹ and AT above 11 ml O_2 kg⁻¹ min⁻¹ and so are in a lower risk group for cardiorespiratory complications after surgery. However, a significant proportion of patients with poor performance on both ISWT and DASI were able to achieve satisfactory peak oxygen consumption and AT on CPET. Therefore, patients should not be assessed as high risk solely on the basis of a poor ISWT or low DASI score. Utilizing either test as a screening tool would have negated formal CPET in a relatively low number of patients. ISWT identified 13 lower risk patients and DASI nine in our sample of 50. Using ISWT as the screening tool would necessitate 37 CPET tests and using DASI would necessitate 41 CPET tests to correctly stratify cardiorespiratory risk for the other patients.

We defined patients as being 'fit' or 'unfit' based on thresholds of VO₂peak >15 ml O₂ kg⁻¹ min⁻¹ and AT >11 ml O₂ kg⁻¹ min⁻¹. There is clear evidence that after major surgery patients have increased oxygen consumption¹⁻³ and that patients with poor preoperative reserve have greater chance of perioperative complications.^{5 7–10} However, the evidence as to the threshold between fit and unfit is less clear.

The ACC/AHA algorithm recommends a threshold of 4 METS (equating to 14 ml O₂ kg⁻¹ min⁻¹) based on level IIa and IIb evidence¹⁵ and the evidence for VO₂peak >15 ml O₂ kg⁻¹ min⁻¹ predicting outcome is from thoracic surgery.^{10 12 13} In lieu of any clearer evidence, we used a measured VO₂peak of 15 ml O₂ kg⁻¹ min⁻¹ as one of our thresholds. VO₂peak is a measure of the maximum oxygen consumption of a patient—and is dependent on the volition of the patient. The VO₂peak is dependent on the effort of the patient but has the advantage that it might be estimated by less sophisticated methods than CPET.

AT is a measure of functional capacity that is reproducible and independent of patient effort, but requires formal measurement of oxygen consumption and carbon dioxide production.²⁰ It commonly occurs at 50–60% of the predicted VO₂peak and was achieved in all but one of our patients. Published evidence for the utility of AT in major surgery comes from a single centre. In an initial study of 187 patients, mortality was 18% in those with an AT <11 ml O₂ kg⁻¹ min⁻¹ and 0.8% in those with an AT above 11.⁹ In a subsequent study, the same centre triaged 543 patients to care according to AT. Those with an AT <11 ml O₂ kg⁻¹ min⁻¹ went to the intensive care unit for preoperative goal-directed fluid and haemodynamic therapy and had a 4.6% cardiovascular and 8.5% all-cause

mortality rate. Those with AT >11 had less intensive perioperative care and had 0.5% cardiovascular and 2.1% allcause mortality.⁵ Subsequent studies have suggested other variables obtained during CPET may be as valuable in predicting short- and medium-term outcome.¹¹

Recruitment was determined by referral from the responsible surgeon and may have biased our population. Potentially, the surgeons only referred patients whom they considered 'unfit'. Our population also contained a high proportion of vascular patients as these surgeons were particularly interested in stratifying risk for their patients.

The conduct of our exercise tests may have influenced the results of our study. Previous studies have suggested that there is a learning curve to the shuttle walk test—with an improvement of around 7% after a practice walk¹⁸ while evidence of a learning curve for CPET is inconclusive.²¹ There is no evidence of a learning curve for DASI questionnaire. However, in the original paper, the initial group (with questionnaire administered by a researcher) had a higher correlation than the validation group who self-administered the questionnaire.¹⁴

In the context of limited time before major surgery, we were unable to have the patient attend for a practice walk. We were also constrained by access to the cycle ergometer—the walking test had to be performed in the morning and the cycle test in the afternoon. This meant we were unable to randomize patients to perform either ISWT or CPET first, which may have influenced our results.²¹

The study was not powered to look at outcomes and so cannot evaluate prognostic value of the results obtained.

Our results for the correlation for DASI and peak VO₂ are similar to the original study by Hlatky and colleagues.¹⁴ It is, however, worth noting that the weighting of the original questionnaire was determined in 50 cardiology patients with an R^2 value of 0.64. When the questionnaire was then applied to an independent group of another 50 patients, it had an R^2 value of 0.34. Although both Hlatky and our study have impressive 'P' values to their correlations, there is a significant scatter around the regression lines (Fig. 2). The DASI threshold suggested by the American College of Cardiology of 11.6 is well below the score of 46 required to reliably identify lower risk patients in our study. This and the low NPV of our threshold suggest that using the questionnaire in the current ACC/AHA algorithm will not reliably identify elective patients with poor functional status. This therefore raises some questions around the validity of that part of the ACC/AHA algorithm.

Our results show similar correlations of ISWT to peak VO_2 and regression slopes to previous studies of heart failure patients¹⁶ and COPD patients.¹⁸ There is, however, a significant difference in the *y*-intercept which is likely to be due to the severity of underlying pathology in these studies. However, other explanations include the absence of a practice walk, the heterogeneity of underlying pathologies, and the inclusion of many elderly patients with orthopaedic impairment.

Our discriminatory threshold of 360 m on the ISWT is comparable with the 350 m reported for outcomes after oesophagectomy⁸ and the 400 m reported for lung resection surgery.¹⁹ The proportion of our patients who failed to reach the ISWT threshold but were found to be lower risk on CPET was similar to the latter study.

In conclusion, the ability of both the shuttle walk test and the DASI questionnaire to discriminate between potentially higher and lower risk patients in a heterogeneous general surgical population is poor. Using either test as a determinant of preoperative fitness will give a large number of patients with equivocal results. CPET allows objective measurement of cardiopulmonary fitness and is therefore an attractive preoperative screening tool. Evidence that this information improves patient outcome is, however, limited and resolving this should be the focus of future research in this field.

Supplementary material

Supplementary material is available at British Journal of Anaesthesia online.

Funding

Plymouth Hospitals NHS Trust League of Friends funded the Cycle ergometer used in this study. The cost of consumables was met by local resources. The authors' work is independent of this funding.

Appendix 1: Duke Activity Status Index

Can you:

		Index	Yes	No
1	Take care of yourself, that is, eat dress, bathe or use the toilet?	2.75		
2	Walk indoors, such as around your house?	1.75		
3	Walk 200 yards on level ground?	2.75		
4	Climb a flight of stairs or walk up a hill?	5.50		
5	Run a short distance?	8.00		
6	Do light work around the house like dusting or washing dishes?	2.70		
7	Do moderate work around the house like vacuuming, sweeping floors, or carrying groceries?	3.50		
8	Do heavy work around the house like scrubbing floors or lifting or moving heavy furniture?	8.00		
9	Do yard work like raking leaves, weeding or pushing a power mower?	4.50		
10	Have sexual relations?	5.25		
11	Participate in moderate recreational activities like golf,bowling, dancing, doubles tennis, or throwing a ball?	6.00		
12	Participate in strenuous sports like swimming, singles tennis, football, basketball, or skiing?	7.50		

Duke Activity Status Index (DASI) = sum of 'Yes' replies

 VO_2 peak = (0.43xDASI)+9.6

 VO_2 peak = ml kg⁻¹ min⁻¹

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