ARTP Association for Respiratory Technology & Physiology

Inspire

The ARTP Journal

December 2016 VOLUME 17, ISSUE 3

INSIDE THIS ISSUE:

40th Anniversary 1976 - 2016

www.artp.org.uk

FIRST WORD

VOLUME 17, ISSUE 3. DECEMBER 2016

Welcome to the Christmas issue of 'Inspire' where I have taken the liberty of replacing ARTP blue for festive red. Before you email and complain I want to stress this is strictly a limited edition! This issue sees the new ARTP logo in 'Inspire' for the first time (the correct colour scheme is at the top of page 2), the final airing of the ARTP 40th anniversary logo and a final archive article from '*Breath*', this time from March 1977, a time when one could buy a scientific textbook for £9. The article looks at the relationship between chronic airflow obstruction and smoking and I noted while preparing the issue that the battle to make smoking less 'glamorous' continues to this day (https://www.theguardian.com/society/2016/nov/30/tobacco-firms-uk-introduction-plain-packaging-court-of-appeal). I hope you have enjoyed reading the archive issues as much as I have. Remember that ARTP members can read archive issues online by following the link at the top of the article.

I have added a 'Communications' section which compiles ARTP announcements since the last issue. This may be a useful way to keep track of some of the work ARTP is doing between issues, which Karl alludes to in his 'Word from the Chair' We have part II of the *"Role of Respiratory and Sleep Physiology in the preoperative risk assessment of patients undergoing elective surgery"*, this time covering Exercise Testing. The role of exercise testing in predicting the length of hospital stay post-surgery is also addressed by another article, an ARTP grant winner for the author to attend the recent ERS conference. This article does not support the predictive value of CPET as previously found, which may be due to the exclusion criteria used but which highlights the need for larger, multicentre prospective studies. The presentations from the recent ARTP 'National Strategy Day' have just been released for members and make interesting reading. A Christmas cracker of 'On the Blower' is produced for the first time by Matthew Rutter (no pressure, Matt!), where they are seeking YOUR ideas on what the future may hold for lung function. I say a fond farewell and thank you to Paul Burns, who has stepped down as 'Inspire' Deputy Editor to concentrate on his roles in ARTP Paediatrics and Education and who knows what else besides!

As usual, I end by requesting you contact me if there is anything you would like changed about 'Inspire', things you don't like (the red cover, perhaps?!) and ideas for how it could be improved. I may try and release a survey about this in the near future. Best wishes for a **Happy Christmas and New Year** and I look forward to meeting you at ARTP conference early in 2017.

Aidan Laverty inspire@artp.org.uk.

ALL CORRESPONDENCE TO:
ARTP Administrator, Executive Business Support Ltd.,
Unit E1 City Wharf,
Davidson Road,
Lichfield,
Staffordshire WS14 9DZ
Tel: 01543 442141
Fax: 0121 355 2420
e-mail: admin@artp.org.uk

OBITUARY

Professor Neil Pride

We regret to hear of the recent loss of one of the world's greatest respiratory physiologists, Professor Neil Pride, aged 85. Neil Pride was a brilliant physician and scientist who could think clearly, design studies and perform research to incredibly high standards. His work on lung mechanics revolutionised our understanding of how the lung changes in disease. He wrote early seminal papers on the static pressure–volume curves with John Gibson and his collaborations with Mike Hughes have produced textbooks that are the mainstay of our profession. His writing was clear and always simplified complex ideas into understandable concepts. He was always a quiet, kind and modest man and it was my enormous pleasure to award him his ARTP Lifetime Award at Conference. He seemed almost embarrassed to receive it, such was his modesty. He was a Fellow of the ERS, Emeritus Professor at Imperial, London and was a brilliant teacher of respiratory physiology. ARTP wish his family and colleagues our deepest sympathy for the end of a great life, well spent for the benefit of all.

Dr B G Cooper, Consultant Clinical Scientist, Hon. Senior Research Fellow, Birmingham 2016

A WORD FROM THE CHAIR

Dr. Karl Sylvester

ARTP Honorary Chair

Festive greetings to you all. I hope you are all set and ready to go for the holidays. This is a bumper Christmas edition of Inspire in a lovely new blood red colour. This is also the last edition for 2016, ARTP's 40th celebration year. I hope it's been a good one for you all. It's been a busy time within ARTP, with a new branding exercise completed, progress made towards our next guidelines edition (watch this space), a new spirometry handbook, production of an NHS England spirometry competency document, progress on a commissioning guide for spirometry training and much, much more. As Chair I am very proud of what the ARTP committees have achieved in a voluntary capacity. Remember that all roles within ARTP are voluntary and people give up their time to work tirelessly on behalf of the ARTP membership, while holding down extremely busy day jobs and home lives.

I attended a joint Board meeting between the RCCP and AHCS recently. At a previous National Strategy Day I urged these two organisations to begin to work more closely together on the areas where there was commonality. One of these areas is regulation of the physiological workforce. I am pleased to say they have heeded this call to action and the first meeting went very well. There does appear to be a drive towards closer working on the common areas. One point of discussion was a single register to avoid the confusion of which register to join. There appears to be a desire to generate this one register, but discussions are in the very early stages and I will keep you updated of progress.

I was very fortunate to attend the Academy for Healthcare Science conference in Cardiff at the beginning of December. This was held jointly with the Welsh Government and I was very impressed with how embedded healthcare scientists are into the healthcare structure in Wales. The Chief Scientific Adviser, Christine Morrell, has done an amazing job in raising the profile of healthcare science within the Welsh health system. There is also an impressive level of support from the Deputy Chief Medical Officer too. The theme in Wales is very much about Prudent Healthcare. Only doing what you can do and nothing more. This includes streamlining the requests for diagnostic investigations to only those that are absolutely necessary for the diagnosis and management of patients. Certainly I'm sure within our practice we can identify requests where they were "nice to have" rather than essential. With the direction the healthcare system is taking across the UK I believe this is a strategy we all should be adopting to ensure we can keep up with the demands on our services without an increase in capacity.

Our own conference is only round the corner now and the excitement is building for our trip to Belfast. ARTP conference's first visit to Northern Ireland, truly ensuring we are a UK wide organisation. I hope you have already registered to attend or are planning to do so shortly. This will be an amazing conference in terms of scientific and educational content and evening entertainment. As the prices of travel tend to increase closer to the departure date I would encourage you to book your flights or boats early to ensure a good price.

All it leaves me to do is wish you all a Merry Christmas and a successful and prosperous New Year.

Karl

ARTP
Association for Respiratory Technology & Physiology

We are delighted to announce that the 2017 ARTP Annual conference will be taking place at the World Famous Europa Hotel which is located in the heart of Belfast City Centre. This will be the first ever ARTP conference to be held in Northern Ireland and we have been truly overwhelmed by the welcome and support we have received from 'Visit Belfast' in arranging the venue.

This promises to be a superb conference filled with engaging speakers, covering topics from a range of physiology and new innovations.

Some members have suggested that Belfast is too far away and difficult to travel to. Nothing could be further from the truth. Return flights from most UK airports are in the region of £70 return. There are flights on a number of airlines, multiple times per day from most UK airports to either Belfast City or Belfast International airport.

For more information on the programme and travel options, please visit

www.artp.org.uk

Introducing F&P Brevida™. Gaining patient confidence is key to successful CPAP therapy and patient confidence begins with a mask that fits and is comfortable. Developed from extensive patient-centred research, F&P Brevida features both a simple, adjustable headgear to deliver an individual fit, and the innovative AirPillow cushion which inflates to form a 'pillow' of air in and around the nose for a gentle and effective seal. For patient confidence and comfort, choose a Fisher & Paykel Healthcare nasal pillows mask. **The Mask Matters Most**™.

Fisher & Paykel HEALTHCARE

www.fphcare.co.uk

DreamWear minimal contact nasal mask

Come to our stand at the ARTP Conference to see how quick and easy DreamWear is to fit – then get a fun photo taken and instantly printed wearing our award-winning mask!

PHILIPS

ERS CONFERENCE GRANT WINNER

The Utilisation of Cardiopulmonary Exercise Testing (CPET) to Predict Length of Hospital Stay (LOS) after Radical Cystectomy (RC)

Edward Parkes[1] and Vicky Moore[2]

1. Clinical Physiologist, 2. Clinical Scientist.

Department of Respiratory and Sleep Physiology, Heartlands Hospital, Birmingham, UK

Introduction

Transitional Cell Bladder Cancer (TCBC) is the most common type of urothelial carcinoma, which has been reported to exist in 90% of all bladder cancer diagnoses[1]. Radical Cystectomy (RC) combined with pelvic lymph node dissection and ileal conduit reconstruction remains the 'gold standard' and is indeed the most common surgical intervention for muscle invasive bladder cancer[2]. Although regarded as the 'gold standard', RC is related with significant postoperative complications (PC) in the short and long term periods as well as high rates of mortality (6-11%)[3-7] and morbidity (19-64%)[8-14]. TCBC is associated with smoking and environmental exposures and therefore this population of patients are at an increased risk of both cardiovascular and respiratory disease[15].

Over the past 5 years guidelines published by the Royal College of Surgeons and The Department of Health[16] have recommended that patients who require major abdominal surgical intervention should undergo objective risk stratification. This would allow the most appropriate, consultant led care and either admission to high dependency unit (HDU) or intensive therapy unit (ITU) postoperatively. Current approaches to discriminate between high and low risk patients lack the correct level of sensitivity and specificity to predict postoperative outcomes after RC[17-20]. In addition, some proposed methods of risk stratification including dynamic stress echocardiography are only capable of identifying the risk of postoperative complication that is associated with a single organ or organ group[19-20].

Cardiopulmonary exercise testing (CPET) is frequently used in perioperative medicine and has been shown to provide information regarding post-operative outcomes[5, 21-27]. Initial research carried out in the 1990s suggested that certain parameters and thresholds, derived from CPET, be used to assess a patient's fitness for major abdominal surgery. Older[23, 28] has demonstrated that pre-operative CPET can be utilised to assess a patient's ventilatory, ventilatory-perfusion, cardiovascular and metabolic responses to incremental exercise. A patient's ability to increase their oxygen consumption during an incremental exercise test has been shown to strongly correlate with the ability to maintain an increased organ oxygenation and therefore functional organ status during the post-operative period. Older[23, 28] has shown that the uptake of O_2 (VO_2) at the anaerobic threshold (AT) allows identification of high-risk patients, including those patients who have normal cardiopulmonary function at rest measured by pulmonary and cardiac function testing.

The purpose of this study was to investigate if any correlations exist between the parameters derived from the performance of preoperative CPET and length of hospital stay (LOS) in patients who were admitted for elective RC surgery for TCBC.

Patients and Methods

Consecutive patients who were referred to the CPET service from the Urology Surgical team between July 2013 and July 2015 for preoperative CPET were retrospectively reviewed. The study received Local Ethics Committee approval at the Heart of England NHS Foundation Trust as an audit. Patients were excluded if: 1) they performed a submaximal CPET 2) CPET was terminated early due to reasons that precluded safe continuation 3) surgical intervention was not a RC 4) patient did not achieve an AT.

Cardiopulmonary Exercise Testing

CPET was performed according to departmental protocol based on American Thoracic Society (ATS) guidelines[29]. Tests were performed using a cycle ergometer (Ergoline cycle ergometer) with breath –by-breath gas analysis (Carefusion Jaeger JLAB v5.7). Gas calibration was performed before the commencement of each clinic with volume calibration being performed before each test. The patient's incremental workload was calculated according to Cooper and Storer[30]. After saddle height adjustment, patients were seated on the cycle ergometer and connected to continuous 12-lead electrocardiography (ECG), blood pressure and oxygen saturation (SpO_2) monitoring. Baseline data was taken over a 2-minute resting period, followed by the commencement of cycling for 2 minutes in an unloaded exercise phase. After this point a 1-minute incremental workload phase was initiated and the patient would exercise until a symptom-limited end point was reached. A pedal cadence of 60rpm was required throughout exercise. Test termination criteria included but were not limited to: abnormal ECG rhythm or ischaemic changes; excessive BP increases or decreases, significant arterial desaturation and patient signs and symptoms. The patient was monitored during an unloaded recovery phase for a minimum of 2 minutes. The AT was determined manually after each test using the 'gold standard' V-slope (VCO_2 vs VO_2) technique[31] and confirmed using the breathing equivalents for O_2 and CO_2 (Eq.O_2 and Eq.CO_2)[30] Peak VO_2 was calculated as an average over the last 5 breaths of exercise.

Data Collection and Statistical Analysis

Patient demographics (age, height and weight) including the results of the CPET were retrospectively collected. The patient's electronic record (EPR) was accessed to record LOS, which was calculated from the date of surgery to the date of discharge.

Statistical analysis was performed using SPSS software (IBM). Correlations between data sets were made using Spearman's rank order correlation and Mann Whitney U statistical tests.

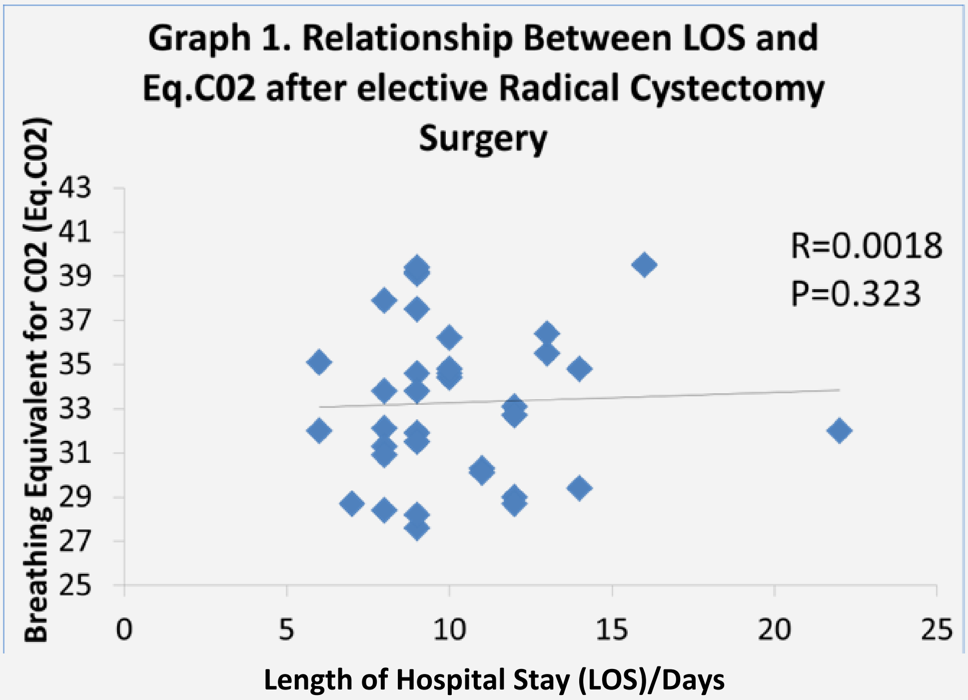
Results

The total number of referrals made to the CPET service was 530. In total 60 (11%) patients were referred for preoperative CPET from Urology. A total of 25 patients were excluded from data analysis. Thirty-five patients remained, of which 27 were males and 8 were females. The median age of all patients was 69 (interquartile range, IQR 64-75) years and mean BMI was 27.8 (IQR 25.9-30.4). 3% of patients had been previously diagnosed with lung disease and 14% with cardiac disease. The median peak VO_2 for the cohort was 17.3ml.min.kg (IQR 14.4-19.7), VO_2 AT was 10.7ml.min.kg (IQR 9.2-12.5) and Eq.CO_2 was 33.1 (IQR 30.0-35.5) (Table 1).

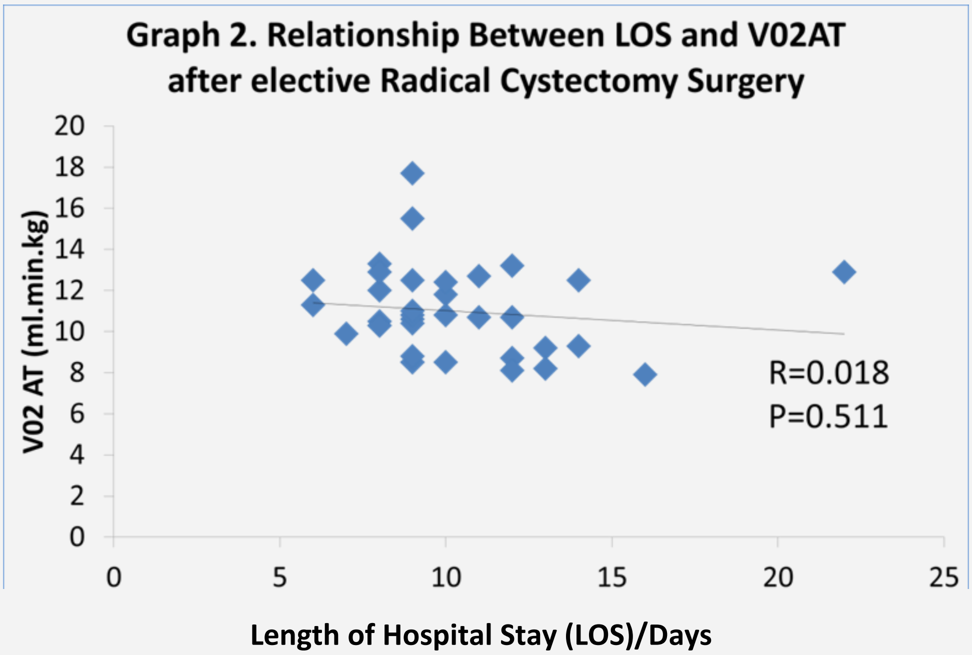
Table 1- Patient demographics and CPET data. Data presented as median values (IQR).

	N=35
% Males	77
Median BMI	27.8 (25.9-30.4)
Median FEV_1 /L	2.7 (2.28-3.17)
% with respiratory disease	2.9
% with cardiac disease	14.3
Median VO_2 at anaerobic threshold (ml/min/kg)	10.9 (9.2-12.5)
Median peak VO_2 (ml/min/kg)	17.3 (14.4-19.7)
Median breathing equivalent for CO_2	33.1 (30.3-35.5)
Median length of hospital stay (days)	9 (8-12)

The median LOS for all patients was 9 (IQR 8-12) days. Spearman's rank correlation coefficient showed that LOS did not correlate with peak VO_2 (p=0.269), $Eq.CO_2$ (r=0.018 p=0.511) (Graph 1) and VO_2AT (r=0.0018 p=0.323) (Graph 2). Furthermore, analysis using the Mann-Whitney U-test identified that when an $Eq.CO_2$ threshold of < or > 33 was applied there was no statistically significant relationship with LOS (p=0.082).



Graph 1. Relationship between LOS and $Eq.CO_2$ in patients undergoing RC. RC=Radical cystectomy LOS=Length of hospital stay $Eq.CO_2$=Breathing equivalent for carbon dioxide.



Graph 2. Relationship between LOS and VO_2AT in patients undergoing RC. RC=Radical cystectomy LOS=Length of hospital stay VO2AT=Uptake of O_2 at Anaerobic Threshold.

Discussion

The utilisation of preoperative CPET to allow adequate risk stratification of perioperative care has been previously documented[21-28]. The current study aimed to identify if any correlation's existed between LOS and parameters derived from the performance of preoperative CPET, namely peak VO_2, VO_2AT and Eq.CO_2 in a cohort of patients diagnosed with TCBC undergoing RC, but no relationships were found with any parameters.

Foundational research by Older[23, 28] performed 20 years ago described a relationship between VO_2AT and postoperative mortality in a heterogeneous non-cardiac surgical population. A VO_2AT threshold of < or > 11.0l.min.kg was identified as allowing discrimination between those patients who require more intensive and specialised postoperative care. Older[23] reported a 1% mortality rate in those patients achieving a VO_2AT >11ml.min.kg compared to an 18% mortality rate in those patients achieving a VO_2AT <11ml.min.kg. Interestingly, those patients who demonstrate cardiac ischaemia have an increased mortality rate of 42%, thus increasing the likelihood of a postoperative myocardial infarction (MI). However, in a variety of different surgeries including abdominal aortic aneurysm repair, nephrectomy and radical cystectomy (RC), the VO_2AT threshold may not fully translate into single surgical type cohorts.

Previous studies investigating preoperative CPET and its postoperative predictive value with homogeneous surgical cohorts have described positive correlations between LOS and VO_2AT after RC[15, 22]. Prentis[22] identified a VO_2AT threshold of 12ml.min.kg as a major predictor of LOS while Tolchard[15] identified that an Eq.CO_2 >33 was the single most important predictor of LOS. This study provides information that does not support the notions of neither Tolchard[15] nor Prentis[22]. Reasons for this inconsistency may include the exclusion of patients from RC whom, due to a low preoperative fitness, as defined by a VO_2AT value <11.ml.min.kg, would have required a greater LOS.

The results of this study also need to be accepted in context with its limitations. The small sample size from a single centre cohort may explain the differences in the predictive power of both the Eq.CO_2 and VO_2AT that have been previously reported in larger scale studies[15, 22]. As such, there is a recognised need to perform larger, multicentre, prospective studies in order to further substantiate the usefulness of preoperative CPET in RC. LOS was allocated as the main outcome variable in this study, however others have included postoperative complications as well as the need for either HDU or ITU postoperative care. The assessment of these outcome measures and the relationship between previously described CPET variables will be an avenue of future research.

In summary, preoperative CPET has been described to provide valuable clinical information that can be used to tailor a patient's perioperative care and predict the likelihood of a higher level of postoperative medical support in either HDU or ITU[21-28]. Although this study does not support previous notions[15, 22] regarding the relationship between LOS and VO_2AT or Eq.CO_2 it should not be overlooked as it highlights the need for further research in this area of perioperative medicine.

References

1. Cancer Research UK (2016). Types of Bladder Cancer, retrieved September 21st 2016, from http://www.cancerresearchuk.org/about-cancer/type/bladder-cancer/about/types-of-bladder-cancer
2. Stein, J.P & Skinner, D.G. (2006). Radical cystectomy for invasive bladder cancer: long-term results of a standard procedure. *World Journal of Urology* 24: 296–304
3. Isbarn, H., Jeldres, C., Zini, L et al. (2009). A population-based assessment of perioperative mortality after cystectomy for bladder cancer. *Journal of Urology* 182: 70–711
4. Quek, M.L., Stein, J.P., Daneshmand, S et al. (2006). A critical analysis of perioperative mortality from radical cystectomy. *Journal of Urology* 175: 886–9012
5. Chahal, R., Sundaram, S.K., Iddenden, R., Forman, D.F, Weston, P.M., Harrison, S.C. (2003). A study of the morbidity, mortality and long-term survival following radical cystectomy and radical radiotherapy in the treatment of invasive bladder cancer in Yorkshire. *European Urology* 43: 246–5713
6. Weizer, A.Z., Joshi, D.D., Daignault, S.S et al. (2007). Performance status is a predictor of overall survival of elderly patients with muscle invasive bladder cancer. *Journal of Urology* 177: 1287–9314
7. Liedberg, F. (2010). Early complications and morbidity of radical cystectomy. *European Urology Supplement* 9: 25–30
8. Chang, S.S., Cookson, M.S., Baumgartner, R.G et al. (2002). Analysis of early complications after radical cystectomy: results of a collaborative care pathway. *Journal of Urology* 167: 2012–64
9. Smith, J.A. (2005). Early and late treatment-related morbidity following radical cystectomy. *Journal of Urology* 173: 2033–45
10. Fairey, A.S., Jacobsen, N-E.B., Chetner, M.P et al. (2009). Associations between comorbidity, and overall survival and bladder cancer specific survival after radical cystectomy: results from the Alberta Urology Institute Radical Cystectomy database. *Journal of Urology* 182: 85–936
11. Shabsigh, A., Korets, R., Vora, K.C et al. (2009). Defining early morbidity of radical cystectomy for patients with bladder cancer using a standardized reporting methodology. *European Urology* 55: 164–747
12. Meller, A.E., Nesrallah, L.J., Dall'Oglio, M.F et al. (2008). Complications in radical cystectomy performed at a teaching hospital. *International Brazilian Journal of Urology* 28: 522–58
13. Thalmann, G.N & Stein, J.P. (2008). Outcomes of radical cystectomy. *British Journal of Urology International* 102: 1279–889
14. Buscarini, M., Pasin, E., Stein, J.P. (2007). Complications of radical cystectomy. *Minerva Urologica e Nefrologica* 59:67–87
15. Tolchard, S., Angell, J., Pyke, M., Lewis, S., Dodds, N., Darweish, A., White, P and Gillatt, D (2015). Cardiopulmonary reserve as determined by cardiopulmonary exercise testing correlates with length of hospital stay and predicts complications after radical cystectomy. *British Journal of Urology International* 115 pp554-561
16. Leow, J, Reese, S., Jiang, W et al. (2014). Propensity-matched comparison of morbidity and costs of open and robot-assisted radical cystectomies: a contemporary population-based analysis in the United States. *European Urology* 66: 569–76
17. Clark, P.E., Stein, J.P., Groshen, S.G et al. (2005). Radical cystectomy in the elderly: comparison of clinical outcomes between younger and older patients. *Cancer*104: 36–4316

18. Horovitz, D., Turker, P., Bostrom, P.J et al. (2012). Does patient age affect survival after radical cystectomy? *British Journal of Urology International* 110: E486–9317

19. Fairey, A., Chetner, M., Metcalfe, J et al. (2008). Associations among age, comorbidity and clinical outcomes after radical cystectomy: results from the Alberta Urology Institute radical cystectomy database. *Journal of Urology* 180:128–3418

20. Prasad, S.M., Ferreria, M.M., Berry, A.M et al. (2009). Surgical apgar outcome score: perioperative risk assessment for radical cystectomy. *Journal of Urology* 181: 1046–53

21. Ting, S.M.S., Iqbal, H., Hamborg, T., Imray, C.H.E., Hewins, S., Banerjee, P., Bland, R., Higgins, R and Zehnder, D (2013). Reduced functional measure of cardiovascular reserve predicts admission to critical care unit following kidney transplantation. *Public Library of Science ONE* 8(5) e64335

22. Prentis, J.M., Trenell, M.I., Vasdev, N., French, R., Dines, G., Thorpe, A and Snowden, C.P (2013). Impaired cardiopulmonary reserve in an elderly population is related to postoperative morbidity and length of hospital stay after radical cystectomy. *British Journal of Urology International* 112(2) E13-19

23. Older, P., Smith, R., Courtney, P and Hone, R (1993). Preoperative Evaluation of Cardiac Failure and Ischemia in Elderly Patients by Cardiopulmonary Exercise Testing. *Chest* 104(3) pp701-704

24. Goodyear, S.J., Yow, H., Saedon, M., Shakespeare, J., Hill, C.E., Watson, D., Marshall, C., Mahmood, A., Higman, D and Imray, C.H (2013). Risk stratification by pre-operative cardiopulmonary exercise testing improves outcomes following elective abdominal aortic aneurysm surgery: a cohort study. *Perioperative Medicine* (London) 2(10) pp1-13

25. Dunne, D.F., Jones, R.P., Lythgoe, D.T., Pilkington, F.J., Palmer, D.H., Malik, H.Z., Poston, G.J., Lacasia, C., Jack, S and Fenwick, S.W (2014). Cardiopulmonary exercise testing before liver surgery. *Journal of Surgical Oncology* 110(4) pp439-44

26. Colson, M., Baglin, J., Bolsin, S and Grocott, M.P.W (2012). Cardiopulmonary exercise testing predicts 5 yr survival after major surgery. *British Journal of Anesthesia* 109(5) pp735-741

27. Ow ,M.M., Erasmus, P., Minto, G., Struthers, R., Joseph, M., Smith, A., Warshow, U.M., Cramp, M.E and Cross, T.J (2014). Impaired functional capacity in potential liver transplant candidates predicts short-term mortality before transplantation. *Liver Transplant* 20(9) pp1081-1088

28. Older, P., Hall, A and Hader, R (1999). Cardiopulmonary Exercise Testing as a Screening Test for Preoperative Management of Major Surgery in the Elderly. *Chest* 116(2) pp355-360

29. American Thoracic Society (ATS)/American College of Chest Physicians (ACCP). 2003. Statement on Cardiopulmonary Exercise Testing. *American Journal of Respiratory and Critical Care Medicine*, 167 (2) (2003) pp211-277

30. Cooper, C.B & Storer, T.W. (2001). *Exercise testing and interpretation. A practical approach*. Cambridge University Press.

31. Beaver, W.L., Wasserman, K., Whipp, B.J. (1985). A new method for detecting anaerobic threshold by gas exchange. *Journal of Applied Physiology* 60(6):2020-7

The Role of Respiratory and Sleep Physiology in the preoperative risk assessment of patients undergoing elective surgery

Adrian H Kendrick, Department of Respiratory Medicine, University Hospitals, Bristol, & Department of Applied Science, University of the West of England, Bristol

Part II: Exercise Testing

Summary

This review outlines the case for the role of both the lung function and sleep services in the assessment of patients undergoing elective surgery.

Part I LUNG FUNCTION TESTING ***('Inspire', August 2016)*** showed the FEV_1 and the DL_{co} are the two primary indices used in the assessment of patients for lung resection. The evidence for other indices, including arterial blood gases, non-invasive blood gases and measurements of static lung volumes is, in most cases, not supportive of their routine use but may be useful in particular patient groups. For example, the measurement of static lung volumes may be appropriate in patients who have significant obesity, and blood gas measures may be useful in patients within known airflow obstruction.

In this issue EXERCISE TESTING. The tests of stair climbing, shuttle walk test, 6-minute walk test and CPET have all been assessed as part of the overall assessment of patients, with the simpler tests generally being more available away from specialist centres. In lung resection, there is strong evidence of the role of exercise testing using the different modalities. New evidence from other surgical procedures, away from lung resection perhaps need further investigation, but the available evidence points to the use of a number of indices, some of which might be specific to a particular organ.

Finally, SLEEP (in the next *'Inspire', April 2017*) constitutes about one-third of our day, and the prevalence of obesity leading in many to obstructive sleep apnoea is an important component of the pre-operative assessment. This should not be overlooked as there is evidence that sleep apnoea may present some difficulties in the post-operative phase.

The role of respiratory and sleep departments in the pre-operative assessment of patients is here to stay, and will increase the demands placed upon these services. Challenges will include the assessment of an increasingly older population who wish to have surgery. None of the tests we undertake should be seen as preventing patients from having surgery, more they should be seen as advising the patient about the likely risks of having the surgery and possibly to explore appropriate alternatives.

From Part I. Cardiopulmonary Exercise Tests (CPET):

In the preoperative setting, CPET can be used to assess a patients' functional capacity and allow prediction as to whether they will tolerate the physiological stress of surgery. One key advantage of CPET is the integration of the assessments of cardiac, respiratory and metabolic variables in a situation that mimics surgery. A potential downside of CPET is it involves facilities that not every centre has available, essentially requires an hour-long appointment, so may be regarded as time-consuming, and requires a skilled practitioner (Senior Physiologist/ Scientist or anaesthesiologist) to perform and analyse the test. There is a degree of uncertainty about the predictive value of CPET on perioperative morbidity and mortality, and about how CPET results should be used in the clinical environment to inform preoperative optimisation and perioperative management.

A single article provided low grade evidence from a retrospective cohort analysis (Goodyear et al, 2013). There was some evidence of a decreased length of stay and reduced 30-day mortality, but it was noted that there may be bias and imprecision in the data as this was not a true RCT.

There were sixteen observational studies covering abdominal aortic aneurysm (Barakat et al, 2015; Carlisle & Swart, 2007; Grant et al, 2015; Hartley et al, 2012; Prentis et al, 2012), lung resection surgery (Bruneli et al, 2009; Bruneli et al, 2012; Licker et al, 2011; Torchio et al, 2010), colorectal surgery (West et al, 2014), pancreaticoduodenectomy (Ausania et al, 2012; Junejo et al, 2014) and other surgery (Junejo et al, 2012; McCullough et al, 2006; Prentis et al, 2013; Snowden et al, 2010). These articles will be reviewed later under the CPET testing section, with generally all the evidence being classified as low grade. The evidence for using anaerobic threshold (AT), oxygen uptake (VO_2), peak VO_2 and the ventilatory equivalent for carbon dioxide (V_E/ VCO_2) as predictors is unclear and is regarded across all forms of surgery as of low quality for predicting mortality at 30-days, 90-days or 3 years. Furthermore, postoperative complications were not that well predicted, based on the assessment criteria used. The guideline group arrived at the conclusion that *"...there is not enough robust evidence to recommend or not recommend CPET testing before surgery"*.

Exercise Testing

The benefits of any cancer treatment must be balanced against the potential harm, so the traditional risk assessment requires a form of evaluation of the patient's performance status. Performance status is known to be an independent predictor of survival in patients receiving chemotherapy and/or radiotherapy (*Sculier, Chansky, Crowley, et al, 2008*).

Patient-reported scoring systems rely very much on subjective factors, and may not closely correlate with the patients' own perceptions of their functional status (*Dajczman, Kasymjanova, Kreisman, et al, 2008*).

To overcome these limitations, we need an objective methodology to evaluate the functional status and exercise capacity of a patient - exercise testing therefore provides that opportunity.

In lung cancer, or where there is concern regarding the operability of a patient, exercise testing is generally used in the preoperative assessment of patients for lung resection to risk-stratify them, as exercise capacity is associated with the perioperative risk for morbidity and mortality. Exercise testing in those patients with advanced lung cancer - nonsurgical patients - and in survivors is also important. It is noted in the 1990's that exercise testing was regarded as controversial, as consensus was in favour of some form of exercise testing procedure as part of the work-up for patients undergoing surgery for cancer.

Similarly to lung cancer surgery, aortic aneurysm surgery will place significant metabolic demands upon the patient in the perioperative period due to wound healing, haemostasis, ventilation, intra-operative haemodynamic changes and catecholamine stress response to surgery (*Attia et al, 1976; Silverstein et al, 1979; Waxman, 1987; Baxendale et al, 1996; Salatash et al, 2001; Pearson et al, 2005*).

Determination of functional capacity is a key component in preoperative cardiac risk assessment. It is generally measured in metabolic equivalents (METs), where 1 MET equals the basal metabolic rate (*Ainsworth et al, 2011*). Exercise testing provides an objective assessment of functional capacity. If formal testing is not available, the functional capacity may be estimated from the ability to perform activities of daily living.

One MET is the metabolic demand at rest and is equivalent to a VO_2 of 3.5 $mL.min^{-1}.kg^{-1}$ (*Fleg et al, 2000*). Climbing two flights of stairs at a slow pace demands at least 4 METs (*Hlatky et al, 1989; Eagle et al, 2002*), and is regarded a good predictor of peri-operative complications associated with major non-cardiac surgery (*Reilly et al, 1999; Girish et al, 2001*). Strenuous sports, such as swimming require > 10 METS (**Figure 1**).

we know that a maximum exercise tolerance is limited by the oxidative ability of skeletal muscle and/or cardiac output. With increasing exercise intensity, VO_2 increases and reaches a point at which increasing exercise intensity no longer leads to an increase in VO_2 and a plateau is observed – this is $VO_{2,max}$. If an individual becomes fatigued before this plateau is observed, this is defined as the peak oxygen uptake - $VO_{2,peak}$ (*Fleg et al, 2000*). The anaerobic threshold (AT) is the point where oxygen-independent (or 'anaerobic') metabolism is required in addition to aerobic metabolism to sustain exercise performance. This is usually due to increased flux through the (oxygen independent) glycolytic pathway, increasing pyruvate generation and lactate production. AT is usually determined by lactate or ventilatory thresholds and although the aetiology of these thresholds may be different (*Spurway, 1992*), the term 'anaerobic threshold' in pre-operative evaluation usually refers to the ventilatory threshold. The ventilatory threshold is usually reproducible and safe to measure, even in patients with myocardial ischaemia and heart failure (*Older, Hall & Hader, 1999; Fleg et al, 2000*).

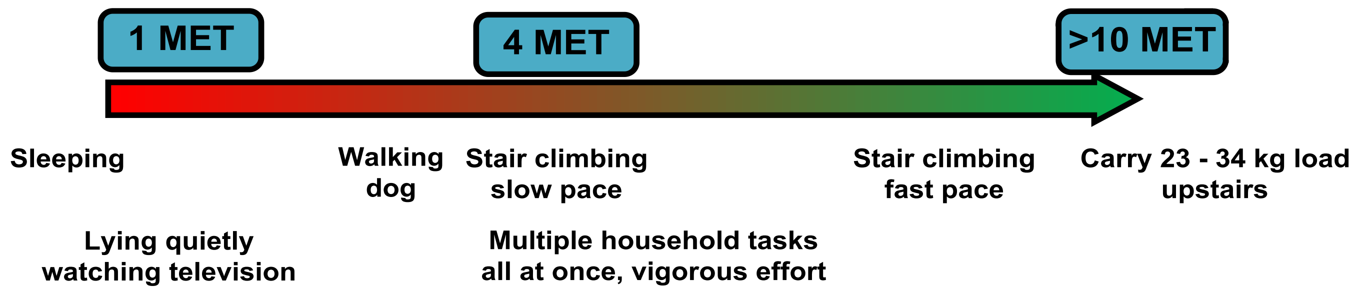


Figure 1. Relationship of METs to activities, with 1 MET being equivalent to sleeping up towards greater than 10 METs

The inability to climb two flights of stairs or run a short distance (< 4 METs) indicates poor functional capacity and is associated with an increased incidence of post-operative complications (POC's) or events. After thoracic surgery, a poor functional capacity has been associated with an increased mortality (relative risk 18.7; 95% CI 5.9 – 59), but in comparison with thoracic surgery, a poor functional status is not associated with an increased mortality after noncardiac surgery (relative risk 0.47; 95% CI 0.09–2.5) (*Biccard, 2005*). This may reflect the importance of pulmonary function as a major predictor of survival after thoracic surgery, since resting pulmonary function is related to functional capacity.

For example, in the study of *Wiklund, Stein & Rosenbaum (2001),* who assessed 5939 patients scheduled for non-cardiac surgery, the pre-operative functional capacity measured in METs showed a relatively weak association with post-operative cardiac events or death. Where the functional capacity is high, the prognosis is excellent, even in the presence of stable Ischaemic Heart Disease or other risk factors (*Morris et al, 1991*). However, where the functional capacity is poor or indeed unknown, the presence of, and the number of risk factors in relation to the risk of surgery will likely determine the pre-operative risk stratification and hence, the perioperative management.

When we undertake exercise testing in healthy subjects,

A normal $VO_{2,max}$ will generally exclude significant pulmonary, cardiovascular, haematological, neuropsychological, and skeletal muscle disease (*American Thoracic Society & American College of Chest Physicians, 2003*) and hence this procedure is now regarded as the standard measurement of cardiopulmonary fitness (*Arena & Sietsema, 2011*).

However, in patients with cancer, exercise limitations may be due to the effects of the cancer itself, coexisting morbidities, and/or the effects of treatment. Cancer-related anaemia (*Bokemeyer, Oechsle, Hartmann, 2005*), muscle atrophy and dysfunction (*Christensen et al,* *2014)* may all limit oxygen transport through a reduction in oxygen content (anaemia) and oxygen utilization. In patients with coexisting lung disease limitations of ventilation and gas exchange can occur, whilst in patients with coexisting heart disease, chronotropic incompetence and ventricular dysfunction due to ischaemia and/or remodelling can limit cardiac output.

Cancer treatment itself may lead to impairments in pulmonary and/or cardiovascular function. In time, the inactivity that accompanies cancer, its comorbidities, and treatment related effects can reduce muscle strength and conditioning, further reducing exercise capacity.

The four most common exercise test procedures used in the pre-operative assessment of patients are 1) Stair Climbing test (SCT), 2) 6-minute walk test (6MWT), 3) Shuttle walk test (SWT) and 4) Cardiopulmonary Exercise Testing (CPET). Current international and national guidelines, make recommendations based on the use of SCT, SWT and CPET, with no current guidelines including the 6MWT (*Brunelli A, et al, 2009; Lim et al, 2010; Brunelli et al, 2013*).

Stair Climbing

Whilst stair climbing may not normally be the province of many lung function laboratories, there is a strong body of literature outlining its use in clinical practice and in the assessment of presurgical patients (*Olsen et al, 1991; Brunelli et al, 2001; Brunelli et al, 2002; Bruneli et al, 2008a; Bruneli et al, 2008b; Brunelli et al, 2010; Berasconi et al, 2012; Brunelli et al, 2012a*). This is not a new test (*Sounders, 1961; Van Norstrand, Kjeslberg & Humphrey, 1968; Bolton et al, 1969*) and is the most used low-technology exercise test by thoracic surgeons (*Charloux et al, 2009*).

In general, the inability of a patient to walk up two flights of stairs predicts poor outcomes (*Van Norstrand, Kjeslberg & Humphrey, 1968*), in relation to mortality, longer postoperative intubation and hospital stay. The odds ratio of death when walking ≤2 flights is 18.7 (5.9 – 58.6), based on a number of studies in patients undergoing thoracic surgery (*Colman et al, 1982; Holden et al, 1992; Pate et al, 1996; Brunelli et al, 2002*).

The use of the stair walk also allows an estimation of stair climb $VO_{2, peak}$ (Olsen et al, 1991) as follows –

Work (watts) = Step height (m) x $steps.min^{-1}$ x Wt (kg) x 0.1635 ($kg\text{-}m.min^{-1}$ to watts).

$VO_{2,peak}$ ($mL.min^{-1}$) = 5.8 x Wt (kg) + 151 + (10.1 x work)

Therefore, for a step height of 0.174 m, a body weight of 79 kg and completing 85 steps/min, the work is 191 watts and the estimated $VO_{2,peak}$ is 2539 $mL.min^{-1}$ (97% pred) or 32.1 $mL.min^{-1}.kg^{-1}$. This would equate to a METs value of 32.1 ÷ 3.5 or 9.17, hence fit for surgery!

Holden et al (1992) compared the use of a stair climb to the 6-minute walk test and a maximal CPET test, and noted that being able to achieve > 44 steps was predicted of a successful surgical outcome. They used the relationship of *Olsen et al (1991)* to predict the $VO_{2,peak}$ from the stair climb. In those patients who survived (n = 11), the mean estimated $VO_{2,peak}$ was 22.7 ± 1.6 $mL.min^{-1}.kg^{-1}$ compared to only 17.6 ± 3.8 $mL.min^{-1}.kg^{-1}$ in those who did not (n = 5), albeit that there was not a perfect discrimination between the two groups. The number of steps was 71 ± 23 versus 42 ± 24, which was statistically significantly different ($p < 0.05$). In general, when the estimated $VO_{2,peak}$ was > 20 $mL.min^{-1}.kg^{-1}$, the outcome at 90 days was much better.

Girish et al (2001) assessed the use of stair-climbing in a range of surgical patients undergoing high-risk surgery. The authors reviewed the 30-day post-operative complications (POC's). 21/83 (25%) had POC's. The FEV_1 was significantly lower in those who had complications (1.8 ± 0.77 vs 2.3 ± 0.82, p = 0.02), and these patients had longer ICU days (6.5 ± 2.0 vs 1.3 ± 0.16, p = 0.03) and spent more time in hospital (19 ± 3 vs 8 ± 1, p = 0.003). In terms of stair-climbing and POC's, the inability to climb two flights of stairs (18 steps/flight and 16.5 cm height) was associated with a positive predicted value of 82% for developing a POC. Interestingly, stair climbing did not predict the 30-day mortality rate well, with two of three deaths occurring in patients who had climbed three or more flights of stairs, whilst only one death occurred in the nine patients (11%) unable to climb a single flight of stairs.

Brunelli et al (2001) showed that in patients pre and post lung resection, there was a significant decrease in stair climbing capability, with the greater decrease (21.4%) occurring in pneumonectomy patients as compared to a 14% reduction in lobectomy patients. In a subsequent paper, *Brunelli et al (2002b)* demonstrated the usefulness of stair climbing in predicting cardiopulmonary complications after lung resection. In patients who had complications, it was observed that they were significantly older (70.6 ± 5.9 vs 65.5 ± 9.9 yrs), had lower FEV_1%predicted (75.4 ± 16.7 vs 87.3 ± 19.3 %) and climb fewer steps, as assessed by step altitude (*Pate et al, 1996)* or distance of stairs climb (14.96 ± 5.5 vs 20.6 ± 4.62 m or 96 vs 133 steps with a step height of 0.155 m). Of note the Diffusion constant (K_{co}) was not significantly different. Of all the measures undertaken in this study, stair climbing was the only independent predictor of cardiopulmonary complications after lung resection.

In a further analysis, *Brunelli et al (2008a)* showed that when patients achieved < 12 m altitude (75 steps), cardiopulmonary complications, mortality and costs were 2-fold, 13-fold and 2.5-fold higher than in patients who achieved > 22 m (142 steps). The authors recommended that a patient who was unable to achieve 12 m altitude (75 steps) should undergo a formal CPET test with VO_2 measurements in order to optimize their perioperative management.

Nikolić et al (2008) wished to assess the usefulness of stair climbing combined with pulse oximetry in relation to postoperative complications in patients with an FEV_1 of < 2 litres. Separating out those patients having lobectomy in relation to complications, the pulse rate and oxygen saturation at 40 steps were the most discriminant indices in separating between minor/no complications from severe complications/death.

Brunelli et al (2010) further studied this relationship. The authors highlighted two key issues –

- The test is difficult to standardise – stair height, instructions to patients, monitoring information, such as SpO_2 and heart rate (HR).
- It's a low technology test that provides little useful direct evidence of the physiological responses to exercise, as compared to CPET testing.

To determine the accuracy of this test, in terms of $VO_{2,peak}$, the authors assessed 109 pre-surgical lung resection candidates using the stair-climb test but with the addition of a telemetric portable gas analyser system. There was a high correlation between those subjects who achieved a $VO_{2,peak}$ < 15 $mL.min^{-1}.kg^{-1}$ and achieved < 14 m altitude on the stair-climb. On the other hand, those achieving > 22 m altitude on the stair climb had a $VO_{2,peak}$ > 15 $mL.min^{-1}.kg^{-1}$ and in some cases > 20 $mL.min^{-1}.kg^{-1}$. There was a clear relationship between a number of factors –

$VO_{2,peak}$ = 11.17 + (0.547 x altitude) + (0.413 x speed of ascent) – 0.248 BMI

So for example -

$VO_{2,peak}$ = 11.17 + (0.547 x 35.2) + (0.413 x 15.2) – (0.248 x 27.34) = 29.9

This provides very similar results to the previous calculations above for the same subject. The authors noted in this group of patients, more than 50% potentially had a $VO_{2,peak}$ < 15 $mL.min^{-1}.kg^{-1}$ who should then be referred for a formal CPET test. Also of note, the authors pointed out that in patients achieving > 22 m, they would have developed a $VO_{2,peak}$ > 20 $mL.min^{-1}.kg^{-1}$ and so would have met the recently published European guidelines by *Brunelli et al (2009).*

One question that remains to be answered is whether or not stair-climbing can predict survival from cancer surgery. In patients undergoing surgery for Stage 1 non-small cell lung cancer (NSCLC), *Brunelli et al (2012a)* observed that the threshold of altitude from stair-climbing was 18 m, and any patient who climbed further than this had a median survival of 97 months (95% CI: 89 to 105 months) versus 74 months (95% CI: 63 to 85 months) if less than 18 m. The equivalent 5-year survival was 77% versus 54%. Even within the limitations of this study, it is clear that survival is improved if a patient is able to achieve a higher level of exercise, i.e. they are fitter, before surgery. Those patients who are less fit, may need to be considered for some form of pre-rehabilitation in the weeks prior to operation, as an improvement in fitness may have a better prognostic outcome both in the short-term and longer term (*Jones et al, 2008*).

In a more recent study, *Lee et al (2014)* showed that the fitter an individual was, in terms of the amount of energy expenditure per week, the lower their mortality was (**Figure 2**).

Bernasconi et al (2012) compared a 20 m stair climb against a treadmill exercise test and found no significant difference in $VO_{2,peak}$ (22.4 vs 22.7 mL.min^{-1}.kg^{-1}). The speed of ascent was an important variable in that achieving ≥15 m.min^{-1} accurately identified subjects for who were fit for a pneumonectomy, with these patients having a $VO_{2,peak}$ > 20 mL.kg^{-1}.min^{-1}. This group further assessed the usefulness of a 20 m stair climb in a group of patients in relation to the ACCP and ERS/ESTS guidelines in lung cancer patients and concluded that SCT has the potential to reduce both time and resource usage in patients who are at moderate risk, based on dividing the subjects in high, moderate and low risk groups using ppoFEV_1% and ppoDL_{co}% (*Bernasconi, Diacon, Koegelenberg (2016)*.

In the most recent study, *Reddy et al (2016)* assessed the time taken to complete a 20 m stair climb in patients undergoing a range of abdominal surgery procedures. The mean time taken to complete the 20 m stair climb was 18.0 seconds (range 6 to 108). In reviewing their data, univariable analysis showed that age and stair climb time were two key factors in predicting complications. In essence the longer taken to climb the stairs, the higher the complication rate. It was also observed that there was a relationship between length of time to climb the stairs and length of stay and there were also more complications in patients undergoing colorectal surgery. The authors concluded that SCT provided a measureable stress and predicted postoperative complications, and was easy to administer.

Clearly the ability of stair climbing to indicate potentially increased mortality associated with thoracic surgery but not with all major non-cardiac surgery may be related to the different degree of importance of pulmonary function to survival in the two groups. Stair climbing capacity is known to correlate linearly with maximum minute ventilation in thoracic patients (*Pollock et al, 1993)*.

The FEV_1 is a key measure of the prediction of survival after lung resection surgery (*Beckles et al, 2003*). Patients who climb three flights of stairs may be expected to have an FEV_1 > 1.7 L (*Bolton et al, 1987*), and indeed the FEV_1 x 40 gives an indication of the maximum potential ventilation for a given individual. For an FEV_1 of 1.7 Litres, the estimated maximal ventilation would therefore be 68 L.min^{-1}, which should be sufficient to achieve the level of exercise ventilation required to climb three flights of stairs and still have sufficient reserve ventilation.

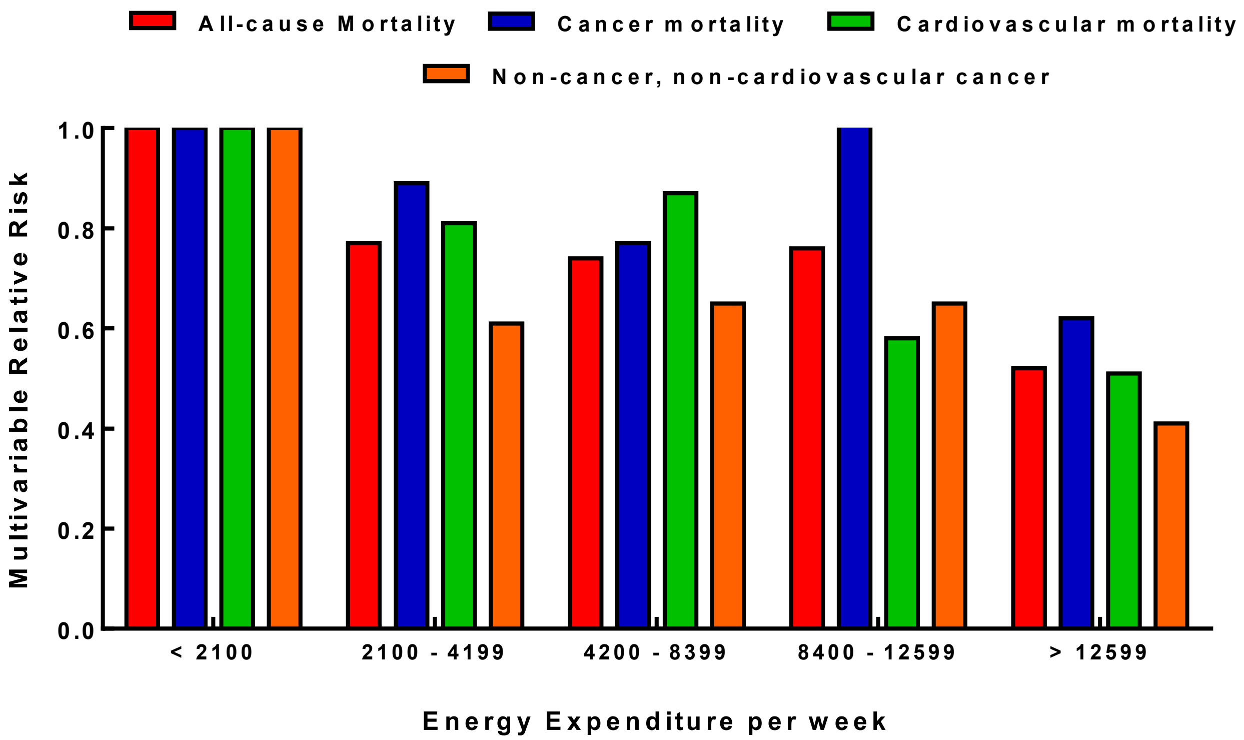


Figure 2. Relative risks of mortality by physical level. Data from Lee et al, 2014.

The observations in patients with lung cancer are in contrast to those in major non-cardiac surgery, where poor stair climbing capacity is not directly associated with an increased risk of postoperative pulmonary complications (*Reilly et al, 1999*).

Is Stair-Climbing a Useful Clinical Tool?

So, why are there differences between the two groups of patients, and how can stair climbing be applicable for the pre-operative assessment of patients requiring surgery?

We know that poorer functional capacity can be secondary to associated co-morbidities that are known to increase peri-operative risk, these including diabetes, congestive heart failure and a higher ASA score (*Reilly et al, 1999; Lee et al, 1999; American Society of Anesthesiologists, 1963*).

We also know that a minimum aerobic capacity is needed to survive the metabolic stresses of the peri-operative period. The metabolic requirements of the postoperative stress response are generally regarded as being less than the pre-operative aerobic capacity required to predict the post-operative survival (*Biccard, 2004*). To sustain a postoperative VO_2 of 5 $mL.kg^{-1}.min^{-1}$, an anaerobic threshold of > 11 $mL.kg^{-1}.min^{-1}$ will be needed (*Older et al, 1993; Older et al, 1999*). What is interesting about both the studies of Older et al, is that it suggests that aerobic capacity is a predictor of peri-operative survival. Using the cut-off of 11 $mL.kg^{-1}.min^{-1}$ permits the separation of the patient's postoperative care. Older also showed that an AT > 4 $mL.kg^{-1}.min^{-1}$ is associated with good peri-operative outcome. So why is it then that the inability to climb two flights of stairs is unable to predict mortality, especially when we know that climbing a flight of stairs has been estimated to be 4.0 METs at a slow pace, and up to 8.0 METs at a fast pace *(Ainsworth et al, 2011)?*

The differences between stair climbing and anaerobic threshold in non-cardiac surgery would suggest that there are significant physiological differences between the two tests. The duration of the peri-operative stress response after major surgery demands that it is sustained by aerobic metabolism (*Biccard, 2004*). Simply put, stair climbing is not a marker of maximal aerobic capacity, whilst the anaerobic threshold is (*Older et al, 1999; Bassett & Howley, 2000*). There are a number of physiological and technical reasons that support this observation.

Test Duration: In undertaking a CPET test, we aim for a test duration of 6 - 10 minutes as this determines the contribution of aerobic and oxygen-independent metabolic pathways to performance (*Fleg et al, 2000*), and approximates to that of anaerobic threshold testing (*Older et al, 1999*). Compare this to the time taken by patients undergoing lobectomy who completed 91 ± 5.8 steps in an average time of 91.0 ± 15.9 seconds, and those patients undergoing other types of surgery who completed 83.8 ± 15.8 steps in an average time of 89.4 ± 19.1 seconds (*Nikolić et al, 2008*).

Metabolism at the start of exercise is principally oxygen-independent, with oxidative phosphorylation lasting for a short period of time (*McArdle, Katch & Katch, 2014*).

Heart failure, COPD, peripheral vascular disease and diabetes, which many patients undergoing assessment will have one or more of, will increase the time to oxidative phosphorylation. So, despite stair climbing having an apparently greater number of METs than the AT required to survive major surgery, a significant component of this is from oxygen-independent metabolism, leading to an overestimate of aerobic capacity (*Spurway, 1992; Swinburn, Wakefield & Jones, 1985*).

Inter-relationships: There is not a consistent relationship between $VO_{2,peak}$ and AT in patients with ischaemic heart disease and heart failure, with AT varying from between 50% to 100% of $VO_{2,peak}$. This may explain why the anaerobic threshold is a more sensitive predictor of outcome than $VO_{2,peak}$ in patients with heart failure (*Gitt et al, 2002; Kavanagh et al, 2003; Sun et al, 2010; Sun et al, 2012; Wasserman, et al, 2012*). Indeed *Kavanagh et al (2003)* noted that for each 1.0 $mL.min^{-1}.kg^{-1}$ increase in $VO_{2,peak}$ there was generally a 10% reduction in cardiac mortality.

The relationship between AT and $VO_{2,peak}$ may contribute to the overestimation of perioperative aerobic capacity using stair climbing as the METs achieved only relate to $VO_{2,peak}$ (*Pate et al, 1996*) and not to AT, as AT may be only 50% of the $VO_{2,peak}$ (*Fleg et al, 2000*). Overestimation of aerobic capacity may, therefore explain the unexpected deaths in patients who appear to have good functional capacity.

Performance: Exercise performance is, in part, dependent on the mechanical efficiency with which the subject performs exercise. Peri-operative survival should solely depend on cardiorespiratory capacity, without consideration of the musculoskeletal function of the patient.

Patients with an acceptable aerobic capacity may be included in the poor functional group due to musculoskeletal factors. Although these patients are unlikely to die of cardiovascular failure in the peri-operative period, they are at increased risk of postoperative complications (*Reilly et al, 1999; Girish et al, 2001*). Anaerobic threshold testing may minimise peripheral factors by limiting weight-bearing with cycling, although this would not be so obvious where a treadmill was being used.

Conclusions: *It is clear that stair climbing is acceptable in the assessment of patients undergoing thoracic surgery, as it can be used to predict peri-operative survival and post-operative complications.*

However, in patients undergoing major non-cardiac surgery, stair climbing may be less useful, as the evidence suggests that the test is unable to predict the aerobic capacity needed to survive the stress responses.

6-minute Walk Test (6MWT)

The 6MWT has not been commonly used in the pre-operative assessment of patients with cancer. Previous studies using the original 12-minute walk test demonstrated a poor association between the distance walked (12MWD) and pulmonary (*Bagg, 1984*) and cardiopulmonary (*Markos et al, 1989*) complications.

The 6MWT has been used in a number of studies in lung cancer. The 6-minute walking distance (6MWD) was associated with respiratory failure (*Pierce et al, 1994*). Where a 6MWD of > 300 m (1000 ft) was achieved, the predicted survival at 90 days post-surgery was significantly greater (*Holden et al, 1992*).

In a study involving patients with advanced lung cancer, *Kasymjanova et al (2009)* assessed patients with stage III to IV NSCLC. They observed that a 6MWD > 400 m was the only variable associated with improved survival using a multivariable analyses (HR = 0.44, p = 0.001).

In those patients who undertook a 6MWT before and after chemotherapy, the mean 6MWD decreased after two cycles of chemotherapy from 462 m to 422 m.

Jones et al (2012) assessed the prognostic value of the 6MWD in stage IIIB to IV NSCLC. The authors observed that the 6MWD was an independent predictor of survival, with each 50-m improvement in the 6MWD associated with a 13% reduction in the risk for death. Patients who achieved a 6MWD of > 450 m had a better prognosis than those who achieved around 350 m.

Nakagawa et al. (2014) described significant correlations between VO_{2max} and the 6MWD and oxygen desaturation in normal subjects. There was a significant correlation between distance walked (m) and $VO_{2,peak}$, $SpO_{2,rest}$, $SpO_{2,min}$ and $DSpO_2 \leq 4\%$. Using ROC curves, it was noted that the distance walked from the 6MWT was not the best predictor of a $VO_{2,peak}$ >15 $mL.min^{-1}.kg^{-1}$, rather $DSpO_2 \leq 4\%$ was, giving sensitivity and specificity of 80.6% and 75% respectively. It was therefore suggested that where a CPET is not available, or if the patient is unable to perform CPET adequately, a 6MWT would be an alternative. Furthermore, in the context of the adopted Japanese Association for Chest Surgery (JACS) guidelines (*Colice et al, 2007*), the authors suggest that this would be potentially an acceptable alternative.

Granger et al (2015) compared the 6MWT to CPET in a cohort of lung cancer patients, and whilst the 6MWT has a logical appeal, their study showed that, in terms of criterion validity the relationship between $VO_{2,peak}$ and 6MWD was poor (r = 0.24, p = 0.329).

Marjanski et al. (2015) retrospectively analysed data on 253 patients undergoing lobectomy, all of whom had had a 6MWT. It was noted that for a walking distance of ≥500 m there were fewer postoperative complications compared to those patients who walked < 500 m. The authors conclude that – *"the 6MWT seeks to identify a high-risk group of patients in whom surgeon should optimize monitoring, care and treatment in order to reduce the complication rates".*

The conclusion from this limited number of studies suggests that where the 6MWD is at least 300 m and ≥ 500m, there appears to be a lower risk for perioperative complications.

Shuttle-Walk Test (SWT)

As with the SCT and the 6MWT, the SWT is a low-cost form of exercise test that may be the only viable means of assessing exercise performance in some centres (*Singh et al, 1992*). The distance walked correlates well with the $VO_{2,peak}$ (*Singh et al, 1994*). Where a more complex test, such as CPET, is not available, the British Thoracic Society (BTS) recommended the use of the SWT as a screening tool before undertaking the more complex CPET test (*Lim et al, 2001*).

The SWT is a maximal, progressive, paced test. The BTS recommended the use of 25 shuttles, which equates to 5 minutes of exercise, a distance of 250 m, and importantly, a VO_2 of 15 $mL.min^{-1}.kg^{-1}$. How is this related to actual testing?

Singh et al (1994) showed that there was a relationship between VO_2 on a treadmill and the SWT in patients with COPD by directly measuring VO_2 during exercise. The studies of *Booth et al (2001), Morales et al (1999), Morales et al (2000)* and *Win et al (2006)* demonstrated an association between SWT distance and VO_2, but did not actually directly measure the VO_2 during the SWT itself. Therefore, apart from the original *Singh study (1994)*, there is no direct evidence of exactly what we are measuring in relation to the VO_2 at a chosen cut-off.

Win et al (2006) compared the shuttle walk and measured $VO_{2,peak}$ in patients with lung cancer. All patients completed both the SWT and a CPET using a treadmill. The rationale of this study was to validate the concept that failure to complete 250m should result in surgery not being attempted (*Lim et al, 2001; Beckles et al, 2003)*. In those patients who failed to walk 400 m, a significant proportion had a $VO_{2,peak}$ < 15 $mL.min^{-1}.kg^{-1}$, and in those patients who achieved < 250 m, the majority similarly exceeded the VO_2 cut-off. The authors recommended that in patients who failed to walk 400 m, a CPET was required to highlight those patients who would achieve a $VO_{2,peak}$ < 15 $mL.min^{-1}.kg^{-1}$.

Benzo & Sciurba (2010) using a simultaneously measured VO_2 throughout the SWT showed a clear relationship between distance walked and VO_2 (**Figure 3**). In their analysis the authors noted that there was a degree of discrepancy between the BTS recommendations of 250 m and 15 $mL.min^{-1}.kg^{-1}$. Using ROC analysis, the authors shoed that for these precise cut-offs, the SWT had a sensitivity of 94% with a false-positive rate of 23% (Specificity – 77%). The more shuttles patient's walked, the lower the false-positive rate became, going from 17% (27 shuttles) to 0% (38 shuttles), the latter of which coincides with a previous study (*Win et al, 2006*). One important technical point that the authors make is that the VO_2 may have been higher in this study as it uses walking, whilst if the subjects had used a cycle ergometer, the VO_2 when body mass is supported is generally lower by around 10% (*Hansen JE, 1984*).

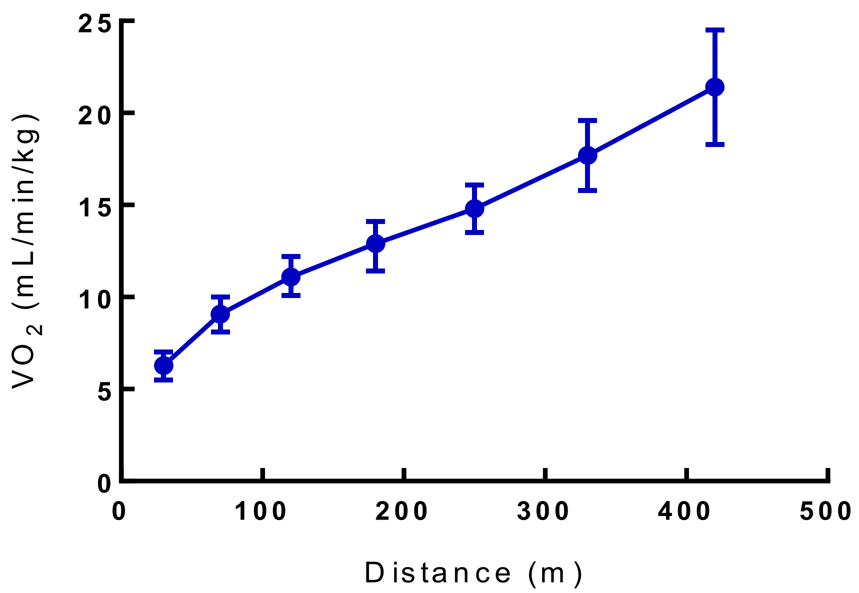


Figure 3. Mean (95% CI) for VO_2 vs distance walked during a shuttle walk test. Data from Benzo and Sciurba, 2010.

In a study that compared the SWT, 6MWT and CPET, *Granger et al (2015)* demonstrated that in NSCLC patients, there was greater criterion validity of the SWT test to $VO_{2,peak}$ from CPET ($r = 0.61$, $p = 0.007$) compared to the 6MWD ($r = 0.24$, $p = 0.329$). This is perhaps not surprising as the SWT is an incremental test, and hence very similar to the incremental CPET test used in routine practice. This study supports the findings of the study of *Win et al (2006).*

Cardiopulmonary Exercise Testing (CPET)

The CPET test is basically a test of physiological status and is used for risk stratification in patients being considered for surgery (*Brunelli et al, 2014*). It is regarded by many as the "gold standard" for testing, as it will challenge the whole system under increasing stress levels resulting from increasing the workload from rest to maximal achievable by a patient at that given point in time.

The importance of using a full CPET test is that it provides a significant amount of information that may be used to assess respiratory, cardiac and muscle functional status in one test. The principal measure, often quoted, is the VO_2 either at peak exercise or at the anaerobic threshold (AT).

In terms of the peak values, a value of > 20 $mL.min^{-1}.kg^{-1}$ is deemed fit for almost all surgery, and certainly for lung cancer, whilst a value of < 10 $mL.min^{-1}.kg^{-1}$ may be regarded as unsuitable for surgery in general (Fig.16). The precise use of CPET in a range of different cancer groups will be elucidated in this section of the review.

Abdominal Aortic Aneurysm

Nugent et al (1998) investigated the role of CPET in AAA patients as part of pre-operative assessment. A treadmill test was undertaken in 30 patients, with mean diameter of 6.3 cm (3.8 – 8.7 cm) without difficulties. Although there was a trend in relation to $VO_{2,peak}$ as being lower overall in those patients who had complications, there was no overall significant difference (18.6 ± 1.3 vs 21.8 ± 1.4 $mL.min^{-1}.kg^{-1}$). Four patients were deemed medically unfit for surgery and all had a $VO_{2,peak}$ < 20 $mL.min^{-1}.kg^{-1}$. The conclusion from this study was that although CPET may be useful in identifying patients more likely to be at risk of post-operative complications, albeit with limited, strong evidence to support this from the data within this study.

Carlisle & Swart (2007) assessed the mid-term survival of patients following aortic aneurysm surgery. They noted that VE/VCO_2 was a key predictor of survival both at 30-days and in the long-term. An increase of +1 in VE/VCO_2 was associated with a hazard ratio of 1.13 for death. The key value for differentiating those fit for surgery as against those unfit was a $VE/VCO_2 > 42$.

Thompson et al (2011) assessed the usefulness of CPET in predicting 30-day and 30-month mortality in patients with AAA. They used 4 variables – AT, $VO_{2,peak}$, V_EO_2 and V_ECO_2. Fitness for surgery was based partly on CPET data as well as co-morbidities and the size of the AAA. An AT > 11 $mL.min^{-1}.kg^{-1}$ was considered ideal for surgery. Sixty -three patients had open repair and were deemed fit for surgery, whilst 36 patients were unfit for surgery. Those in the fit group had a higher $VO_{2,peak}$ (15.1 vs 13.1 $mL.min^{-1}.kg^{-1}$; $p < 0.001$), a higher AT (12.0 vs 10.7 $mL.min^{-1}.kg^{-1}$; $p < 0.001$) and a lower V_E/VCO_2 (35 vs 37; $p = 0.005$). In terms of the AT, the 30-month mortality showed that patients with higher AT values survived longer, and that AT was the best predictor of mortality. Survival was 87.9% for the fit group, but only 61.1% for the unfit group.

Hartley et al (2012) used CPET prospectively in a large group of patients with AAA undergoing repair either via EVAR or open repair. Using univariable analysis, in relation to 30- and 90-day mortality showed that the odds ratios for an AT < 10.2 $mL.min^{-1}.kg^{-1}$ (OR – 4.5 and 3.46), a $VO_{2,peak}$ < 15 $mL.min^{-1}.kg^{-1}$ (OR – 5.4 and 8.0) and $V_E/VCO_2 > 42$ (OR – 3.11 and 3.06) were significant contributors. Using multivariable analysis, in relation to 30-day mortality showed an increased OR for AT < 10.2 $mL.min^{-1}.kg^{-1}$ (OR – 6.35), whilst for 90-day mortality a $VO_{2,peak}$ < 15 $mL.min^{-1}.kg^{-1}$ had an OR of 8.59. The authors suggest that the use of CPET variables contribute to the risk management of patients undergoing AAA surgery.

Prentis et al (2012a) provided the first evidence of the use of CPET to predict outcome in abdominal aortic aneurysm (AAA) patients undergoing endovascular repair (EVAR). Of 185 patients, 101 underwent the EVAR procedure whilst 84 had open repair. In those patients undergoing open repair, $VO_{2,peak}$, AT and the workload (Watts) were predictive of postoperative complications, with the only significant independent variable being AT. ROC curve analysis showed the optimal value of AT to be 10 $mL.min^{-1}.kg^{-1}$, and using this value, there was a significantly longer overall critical care LOS in the patients with values < 10, compared to those > 10 (median 4.1 vs 1.2, $p = 0.02$), as well as total hospital LOS (median 16 vs 8, $p < 0.01$). Cox regression analysis showed age and AT were predictors of hospital LOS, but only age predicted critical care LOS. In the EVAR group, AT predicted hospital LOS.

Goodyear et al (2013) assessed retrospectively, 188 AAA who had had CPET, along with a control group of 128 AAA, who had not had CPET as it was not available at the time. Patients having CPET were divided into three groups – **Pass** (AT > 11 $mL.min^{-1}.kg^{-1}$), **Fail** (AT < 11) and **submaximal** (no AT). Patients either underwent open AAA surgery or had EVAR surgery. The primary outcomes of this analysis were focused on total LOS and survival. LOS (open) was lower in the CPET-pass group (median 10 days) compared to the CPET-fail group (median 11.5 days) and was also lower in both groups compared to the control group (median 13 days). In EVAR patients LOS was a median of 4 days regardless of CPET-pass or fail, and was lower than the control group (median 6 days). The 30-day mortality is shown in **Figure 4**. All-cause mortality was lower following the introduction of CPET testing compared to pre-CPET testing (Open - 8.0% vs 41.4%; EVAR – 4.3% vs 32%).

The authors concluded that there is clear benefit from CPET testing, and that stratifying patients above and below AT > 11 $mL.min^{-1}.kg^{-1}$ is a useful guide.

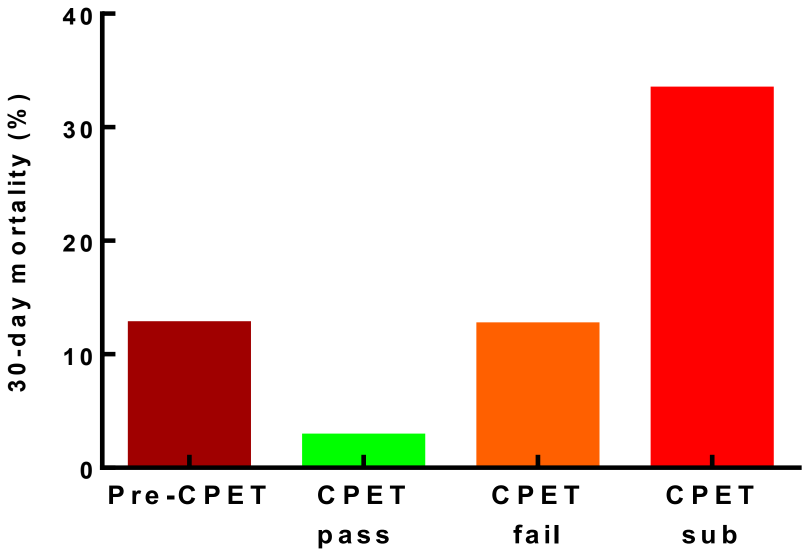


Figure 4 30-day mortality in patients undergoing AAA repair, regardless of surgery type (Open vs EVAR), comparing pre-CPET to CPET and dividing the CPET patients into three subcategories of CPET-pass (AT > 11 $mL.min^{-1}.kg^{-1}$), CPET-fail (AT< 11) and CPET-submaximal (no AT). Data from Goodyear (2013).

Grant et al (2015) used CPET to assess patients undergoing for AAA repair. Three indices were assessed – AT < 10.2 $mL.min^{-1}.kg^{-1}$, $VO_{2,peak}$ < 15 $mL.min^{-1}.kg^{-1}$ or V_E/VCO_2 > 42. Survival was better at 1-year and at 3-years when either none or just one CPET variable was abnormal (**Figure 5**). There were a number of global indices that were independent predictors of survival, of which $VO_{2,peak}$ < 15 $mL.min^{-1}.kg^{-1}$ (HR = 1.63) and V_E/VCO_2 > 42 (HR = 1.68) were important. These results, which included both open and EVAR, AAA repair were deemed applicable to both types of surgery.

Abdominal & Upper GI Surgery

Older et al (1993) assessed cardiac failure and ischaemia in elderly patients undergoing major intra-abdominal surgery. The authors observed that where the AT was < 11 $mL.min^{-1}.kg^{-1}$, there was a greater mortality, than when the AT was > 11 $mL.min^{-1}.kg^{-1}$, this being 18% (< 11) compared to 0.8% (> 11). In those patients with an AT < 11 and myocardial ischaemia, the risk doubles. The authors recommended that all patients with an AT < 11 should be admitted to an ITU postoperatively.

Older et al (1999) followed up on his previous study in 1993, using CPET as a screening test for perioperative management of major intra-abdominal surgery in the elderly. From this study, and reviewing the outcomes in terms of ICU, HDU and Ward for the postoperative triage site, a flow chart was created (**Figure 6, overleaf**). There are some important points from this study. Firstly, age should not be used to prevent patients from having surgery. In this study, 62 patients were 80+ years of age, yet the AT was within 1 SD covers the entire group. The implication of using age only is that fit, older people may be denied life-saving surgery, when they should not be. The other key point is that CPET testing takes about one hour and rarely results in an adverse event due to the test procedure. Indeed the authors quote 3: >2000 (< 0.15%) possible adverse events, depending on the definition used for adverse events.

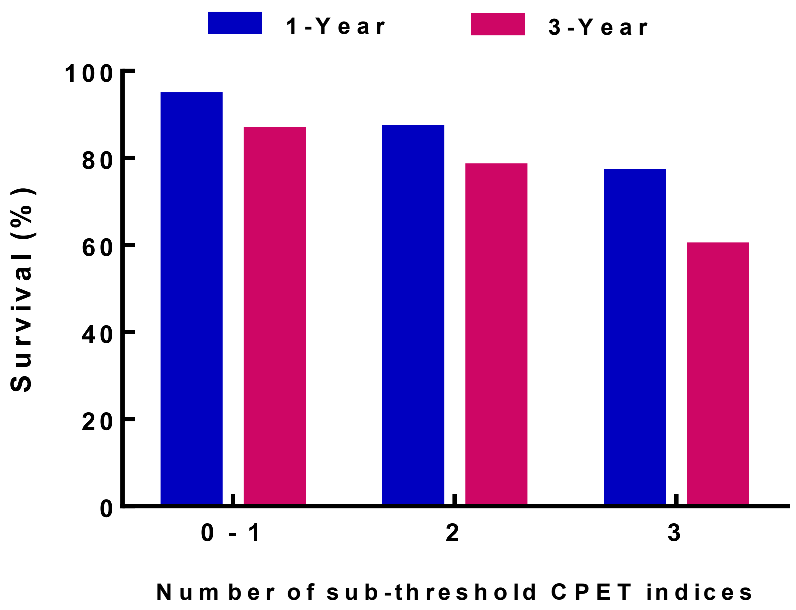


Figure 5 Survival after elective AAA repair stratified by the number of sub-threshold indices from a CPET test. Data from Grant et al, 2015.

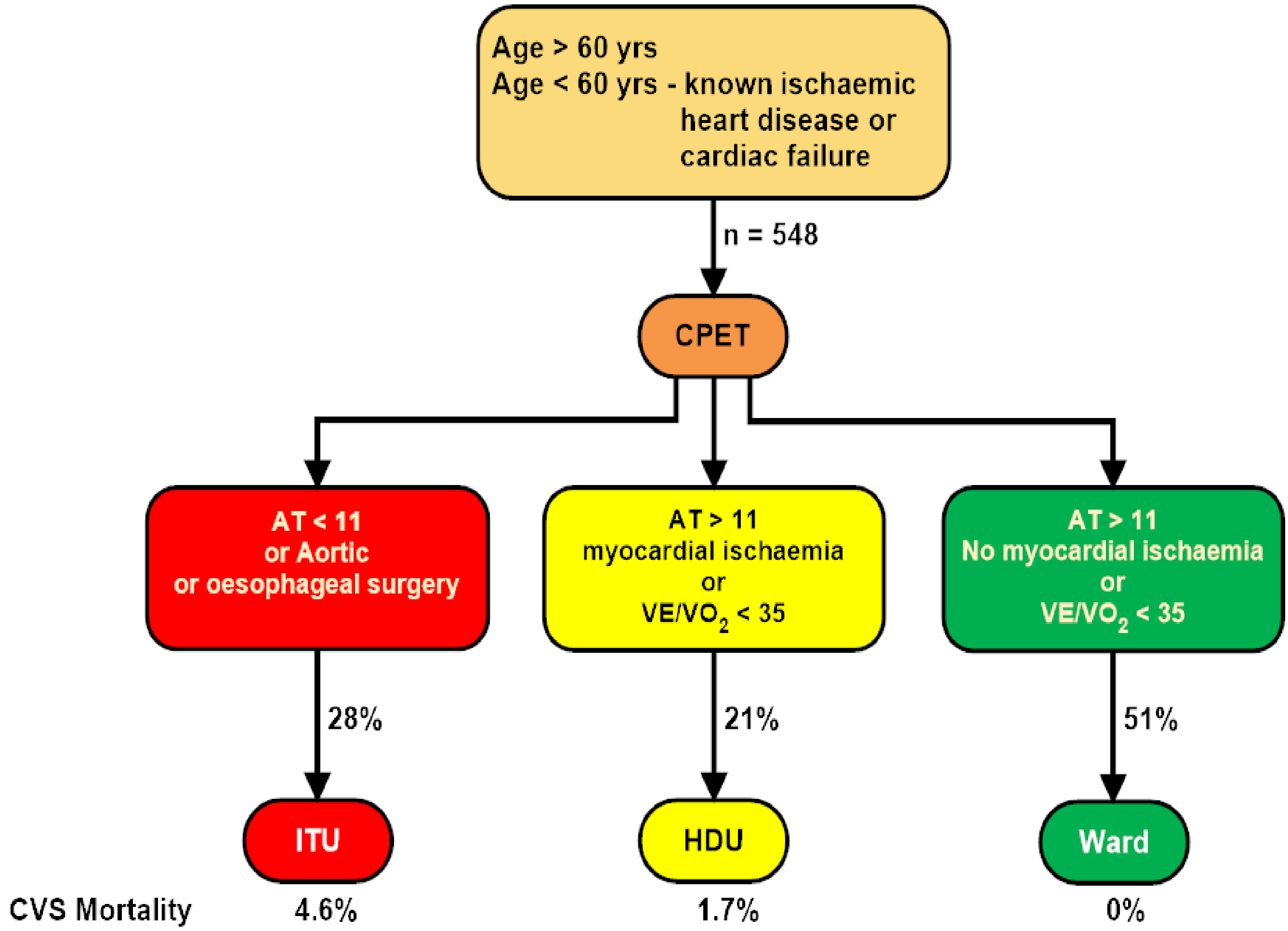


Figure 6 Flow chart showing the postoperative triage site and outcomes following major surgery. AT is expressed in units of mL.min^{-1}.kg^{-1}, the V_E/VO_2 is the ventilatory equivalent for oxygen and CVS is the mortality due to the cardiovascular system. Percentages are of the total group of n = 548. Modified from Older et al, 1999.

The final aspect of this study is that the number 11.0 for AT has become fixated into the mind-set, but I'll return to that issue later.

Nagamatsu et al (2001) assessed the usefulness of CPET and resting lung function in patients having oesophagectomy.

Patients with cardiopulmonary complications, had a $VO_{2,peak}$/BSA significantly lower than patients with no complications (0.79 ± 0.15 vs 0.97 ± 0.12 mL.min^{-1}.kg^{-1}, $p < 0.001$). AT/BSA was not significantly different between the two groups. None of the resting lung function data was helpful separating out the two groups.

Using ROC analysis, the authors subdivided the patients in different bands for $VO_{2,peak}$/BSA and observed that 86% of patients with a value < 699 mL.min^{-1}.m^{-2} had cardiopulmonary complications, rising to 0% complications with a value of ≥ 1100 mL.min^{-1}.m^{-2}. An acceptable cut-off was deemed to be > 800 mL.min^{-1}.m^{-2}, where only 10% of patients had complications.

Struthers et al (2008) reviewed the usefulness of the incremental shuttle walk test and CPET as compared to a questionnaire in a group of general surgical patients undergoing intra-abdominal surgery. Using the Duke Activity Status Index (DASI; *Hlatky et al, 1989*) and the ISWT, the authors noted that where the $VO_{2,peak}$ > 15 mL.min^{-1}.kg^{-1} and an AT > 11 mL.min^{-1}.kg^{-1}, there was good sensitivity using ROC curves. However, using the CPET cut-offs, there were 36 patients identified as "low risk". The ISWT identified 13 where the threshold as 360 m, and 9 patients where the DASI score was 46. These results illustrated that even where DASI and ISWT test data indicated poor outcomes, the use of CPET indicated a potentially satisfactory outcome from surgery, suggesting that simpler tests may not be as good as CPET itself.

Forshaw et al (2008) assessed the usefulness of CPET in oesophagectomy patients. In patients who had cardiopulmonary or noncardiopulmonary complications or an unplanned ITU admission, there was minimal difference between the AT or the $VO_{2,peak}$ compared to those who did not have complications (**Figure 7**). The authors concluded that CPET was of limited use.

Snowden et al (2010) assessed the usefulness of a CPET test in 171 patients with a low level of subjective function capacity (METs < 7.0). In those patients who had > 1 complication at day 7 post surgery, there was a longer LOS (26 vs 10 days, $p < 0.001$), AT was lower (9.1 vs 11.9 $mL.kg^{-1}.min^{-1}$, $p = 0.001$). Analysis using ROC curves showed an optimal value of AT to be 10.1 $mL.kg^{-1}.min^{-1}$ and this measurement was one of the independent predicators of complications.

Wilson et al (2010) assessed the effects of impaired capacity on all-cause mortality following elective intra-abdominal surgery. In a large cohort, it was noted that a clinical history of ischaemic heart disease (RR 3.1; 95% CI 1.3 – 7.7), a $V_E/VCO_2 > 34$ (RR 4.6; 95% CI 1.4 – 14.8), and an AT $\leq$ 10.9 $mL.kg^{-1}.min^{-1}$ (RR 6.8; 95% CI 1.6 – 29.5) were significant predictors of all-cause hospital and 90-day mortality. The effect of a reduced AT was most noticeable in patients with no apparent history of cardiac risk factors (RR 10.0; 95% CI 1.7 – 61.0).

Hightower et al (2010) assessed the usefulness of CPET in relation to the ASA system in abdominal surgery. They devised three new indices – %predicted AT (AT%), DHR – change in HR from rest to AT and HR at AT. Using univariate and multivariate analysis, the authors demonstrated that AT% and DHR were useful predictors of ASA outcome as was a combined index of (AT% + DHR). The authors point out these new indices need further exploratory studies to determine if they are better than those currently use.

Swart & Carlisle (2012) undertook a case-controlled study of critical care vs surgical ward in patients undergoing open colorectal surgery. They used cut-off points of ± 11 $mL.min^{-1}.kg^{-1}$. All patients with a threshold > 11 were allocated to ward care, whilst those < 11 were allocated either to ward care of critical care. The age of the < 11 group was significantly higher compared to the > 11 group. In the < 11, ward group there was a higher

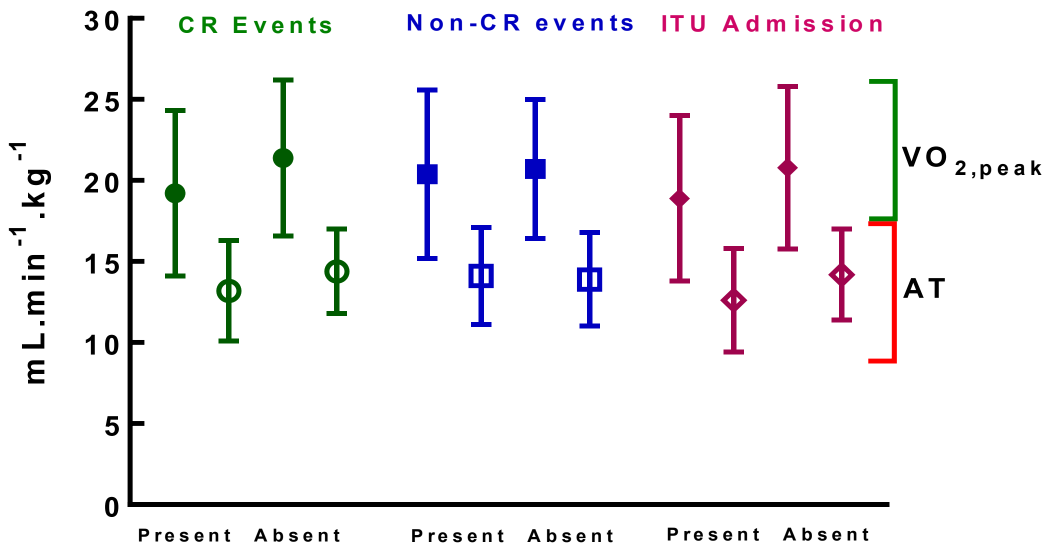


Figure 7 Outcomes predictions from CPET testing. Differences in $VO_{2,peak}$ and AT in patients with and without cardiopulmonary events or an unplanned ITU admission, sowing the mean ± SD for each index with the events present or absent. Data from Forshaw et al, 2008.

incidence of adverse cardiac events. There was a shorter overall stay in the > 11 group compared to either of the < 11 groups. These results appear to be in broad agreement with the previous studies of *Older et al (1993)* and *Older et al (1999).*

Hennis et al (2012) assessed the potential usefulness of CPET in predicting outcomes in gastric bypass surgery. At this point in history, there was no study that had been undertaken to specifically predict outcomes in this growing group of patients, using cycle ergometry, the only previous study using a treadmill (*McCullough et al, 2006*). The mean $VO_{2,peak}$ of the 106 patients was 15.7 (15.1 - 16.4) $mL.min^{-1}.kg^{-1}$. Eleven patients did not however achieve an AT, giving a mean AT of 11.0 $mL.min^{-1}.kg^{-1}$ (10.6 – 11.3) and the V_E/VCO_2@AT of 25.9 (25.5 – 26.3). Postoperative morbidity (POMS) in these patients was greater where the AT was significantly lower (11.7 ± 1.7 vs 9.9 ± 1.5; p=0.049) with $VO_{2,peak}$ and V_E/VCO_2@AT adding nothing. An AT of 11 $mL.min^{-1}.kg^{-1}$ was the optimal value, obtained from ROC curves, for predicting morbidity. A similar AT – 11.4 was noted as the optimal value for predicting length of stay (LOS) of > 3 days. One interesting component of the analysis was the attempt to express the mean $VO_{2,peak}$ and AT as a function of predicted adipose tissue free mass – PATFM ($mL.min^{-1}.kg^{-1}$; *Heymsfield et al, 2007*), which on this occasion did not add anything overall. The overall conclusion was that AT was the best predictor of LOS and POMS.

Colson et al (2012) undertook an extensive review of 1725 patients who underwent a range of surgical procedure, but all having CPET testing. The aim was to determine the CPET variables associated with 5-year survival. Using single variable analysis and 30-day, one-year and 5-year mortality showed none of the CPET variables chosen were sufficiently strong to warrant any further analysis. Categorizing patients into their surgical group and assessing the 5-year outcome using Kaplan-Meier curves, showed that vascular surgery had the best long-term outcome (mean days survived – 1609), whereas the worst outcome was for upper GI (mean days survived – 1120). Whilst CPET variables did not within the key indices, some of the derived variables were noted to have a strong effect, including AT/HR, AT and AT-RER. **CPET variables are helpful in predicting 5-year survival after major surgery.**

Prentis et al (2013) assessed the usefulness of CPET in patients undergoing radical cystectomy, where there are known high levels of both morbidity and mortality. Outcome measures included morbidity defined by the Clavien-Dindo system (*Dindo, Demartines & Clavien, 2004; Clavien et al, 2009*) and LOS. It was observed that in patients with major complications (Clavien score > 3) the LOS was greater compared to those who did not (30 vs 16 days, p < 0.001; HR – 3.6). The AT was the only index from CPET that differentiated between the major (Clavien > 3) and minor (Clavien < 3) postoperative complications (13.2 ± 3.6 vs 10.8 ± 1.8, p = 0.03; OR 0.74). Using an optimal AT of 12 $mL.min^{-1}.kg^{-1}$ showed a significant relationship between fitness and LOS with “unfit” staying 22 days as against the “fit” staying 16 days. The authors concluded that cardiopulmonary reserve was related to major morbidity, increased LOS and increased use of critical care services, so increasing the overall cost of service provision for these patients.

Moyes et al (2013) studied 108 patients undergoing resection for oesophagogastric cancer. Patients underwent a CPET test and the AT and $VO_{2,peak}$ assessed in relation to LOS and postoperative morbidity and mortality. Where the AT was < 9 $mL.min^{-1}.kg^{-1}$, 42% of patients had cardiopulmonary complications, reducing to 20% for an AT > 11 $mL.min^{-1}.kg^{-1}$. In the group with cardiopulmonary complications, the mean AT was 9.9 $mL.min^{-1}.kg^{-1}$ compared to 11.9 in the group with no complications. From ROC analysis, the AT that best predicted cardiopulmonary complications was 9.0 $mL.min^{-1}.kg^{-1}$, which is lower than that proposed by *Older et al (1993).*

Lee et al (2013) assessed the usefulness of the 6MWT and CPET to predict complications at 30-days in patients undergoing colorectal surgery. There was a significant relationship between $VO_{2,peak}$ and the 6MWT distance (r^2 = 0.52, p < 0.0001) according to the equation -

$$VO_{2,peak} = 0.042\text{distance} - 1.13$$

where $VO_{2,peak}$ is in $mL.min^{-1}.kg^{-1}$. Complications were less likely to occur in patients achieving a longer walking distance and increasing age. The authors concluded that if CPET was not available, the a 6MWT could provide acceptable prognostic information.

Ting et al (2013) in a further study in Chronic Kidney Disease (CKD) wished to assess whether they could identify patients at high perioperative risk after kidney transplant, and therefore likely to need admission to CCU. As with the previous study, the use of AT was the desired marker of outcome. 14/70 patients (20%) needed CCU admission after transplant. These patients had a lower AT (9.7 vs 12.5 $mL.kg^{-1}.min^{-1}$), lower $VO_{2,peak}$ (16.8 vs 22.1 $mL.kg^{-1}.min^{-1}$) and $O_{2,pulse}$ (9.0 vs 11.8 $mL.beat^{-1}$) and a higher V_E/VCO_2 (33.9 vs 31.2). The most significant index was the AT, both independently and in multivariable analysis. Using ROC analysis, the optimal cut-off for AT was 11.31 $mL.kg^{-1}.min^{-1}$. This study, along with the other study by the same group, indicates the usefulness of CPET testing and in particular the relevance of estimating AT for the management of patients with CKD.

Ting et al (2014) assessed the CPET responses in CKD patients who are known to have significant exercise intolerance as a comorbid factor. The study of 240 CKD patients included follow-up for 5 years. The key index used was AT < 40% predicted $VO_{2,peak}$. Of the patients, 124 (51.7%) received a transplant and in these patients the AT was lower than in the non-transplant patients (37.1% vs 40.4%, $p = 0.01$). 24 (10%) of the patients died during follow-up. These patients, compared to the survivors, had no difference in spirometry, but did have lower $VO_{2,peak}$ (50.1% vs 65.2%, $p < 0.001$), lower AT (7.9 vs 10.7 $mL.kg^{-1}.min^{-1}$, $p < 0.001$) and lower AT%predicted $VO_{2,peak}$ (29.9% vs 39.7%, $p < 0.001$). In terms of the 5-year survival, from all-cause mortality, those patients with an AT ≥ 40%predicted $VO_{2,peak}$ had a survival rate of 94.4%, whilst those with a value < 40% had a survival of 46.6%. Using tertiles, survival was 38.5%, 67.1% and 100% for AT's of < 9.4, 9.4 – 11.4 and > 11.4 $mL.kg^{-1}.min^{-1}$ respectively. The authors concluded that the use of AT was a good objective index of cardiovascular reserve in patients with CKD.

Junejo et al (2014) assessed the usefulness of CPET in patients undergoing pancreaticoduodenectomy for cancer. CPET testing was undertaken on patient > 65 years or where comorbidities existed. Of 118 patients who had surgery, 64 had CPET, the remainder being classed as low-risk. In terms of in-hospital mortality and 30-day mortality, the V_E/VCO_2 was the best predictor. $VO_{2,peak}$ and AT were unhelpful in this group.

Using ROC analysis, the optimal cut-off point was a $V_E/VCO_2 < 41$ for indicating better long-term survival (**Figure 8**). CPET indices did not help in predicting morbidity.

Tolchard et al, (2014) assessed the usefulness of CPET in patients undergoing radical cystectomy, either by open surgery or robot guided. They assessed 105 patients with outcomes being complications and LOS. Within the study, at various points, staff looking after and following up the patients were blinded to the CPET data. The Clavien-Dindo scoring system was used to define complications, the LOS was recorded in days and the 90-day follow-up was recorded. Patients who had

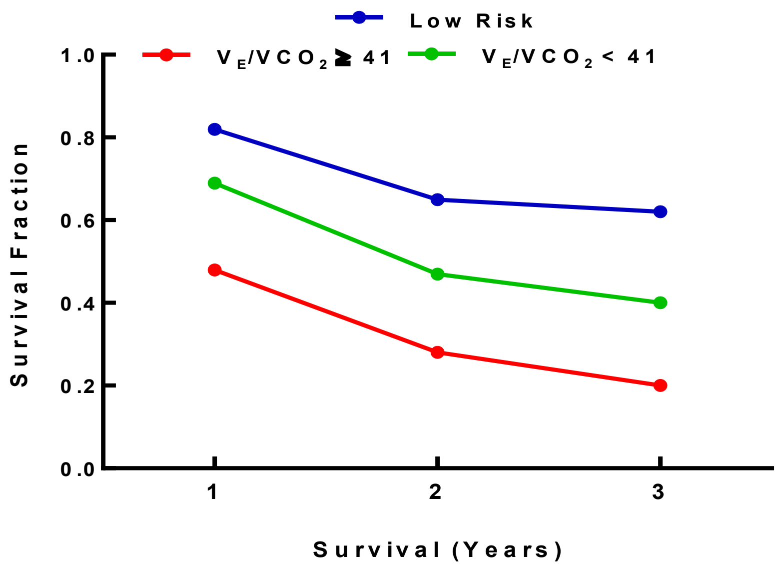


Figure 8 Survival at 1, 2 and 3 years in patients undergoing Pancreaticoduodenectomy for cancer. Data from Junejo, 2014.

complications had a significantly lower AT (10.6 vs 11.8, $p < 0.007$), $VO_{2,peak}$ (14.3 vs 15.4, $p = 0.022$) and a higher V_E/VCO_2 (33.3 vs 30.2, $p = 0.007$).

Multivariate logistic regression analysis showed that AT, V_E/VCO_2 and presence of hypertension were significant pre-operative factors with regards to postoperative complications at ≤90 days. When 90-day complications were stratified based on an AT ≤11 $mL.kg^{-1}.min^{-1}$ and/or V_E/VCO_2 of ≥33 and/or presence of hypertension, a high-risk and low-risk group was definable, with those at high risk having a 5.55 greater risk of complications at 90 days, compared with those in the low risk group. Putting this into context - the odds of a complication at ≤90 days falls by 1.38 for each +1 rise in AT, whilst the odds rise by 1.16 for a +1 increase in V_E/VCO_2 and in those patients with hypertension the odds rise by 3.44. For LOS, a V_E/VCO_2 cut-off of 33 $mL.kg^{-1}.min^{-1}$ is important, with higher values indicating potentially longer stays. This study demonstrated that the use of both AT and the V_E/VCO_2, which are less dependent on muscle mass and patient effort, were the two principle indices from the CPET testing in terms of LOS and 90-day outcomes.

West et al (2014) undertook a prospective and blinded trial of CPET in patients undergoing major colonic surgery. They assessed patients with CPET (reported blind to clinical state) and recoded morbidity (assessed blind to CPET) as well as post-operative outcome and LOS. In comparing the patients who had complications to those who did not, the former were older, and more had heart failure, otherwise there was not real differences between the groups.

In terms of the CPET data, the group with complications had a lower AT and $VO_{2,peak}$ and a higher V_E/VCO_2 with $O_{2,pulse}$ no different (**Figure 9**). In only 3 patients, all in the complications group, was an AT not achieved. At the optimized cut-off point of AT = 10.1 $mL.kg^{-1}.min^{-1}$, there were generally fewer issues of morbidity when > 10.1 compared to < 10.1 using POMS defined at day 5. In a multivariable regression model only sex and AT were retained, with higher rates of complications in men than women (OR = 4.19) for the same AT. Overall for a 1.0 mL.kg-1.min-1 increase in AT, there was » 20% reduction in the odds of complications occurring and for a 2.0 increase a » 40% reduction, when adjusted for sex. This study, the first one to be blinded to some degree confirms further the importance of using CPET to assess patients for surgery and to highlight potential issues of morbidity.

Chandrabalan et al (2014) assessed the usefulness of CPET in patients undergoing pancreatic surgery. 100 patients were assessed, all having CPET before surgery. In patients with an AT < 10 $mL.kg^{-1}.min^{-1}$, there were

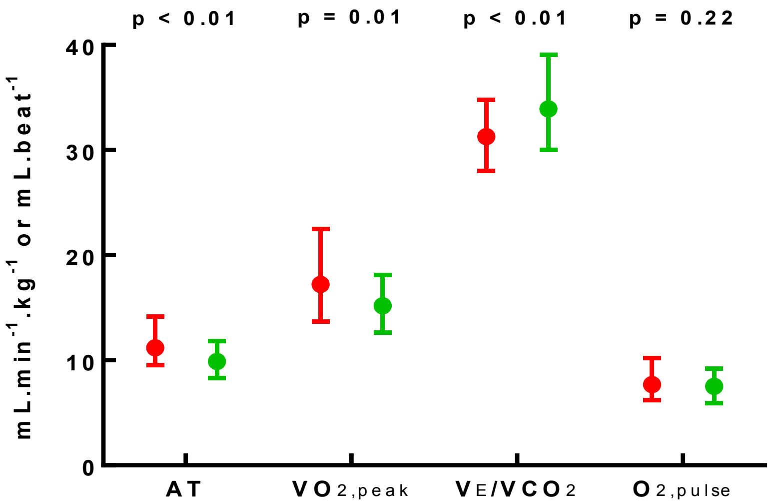


Figure 9 Summary of CPET data comparing those patients with complications (red) and those without complications (green). Data from West et al, 2014.

significantly greater adverse outcomes compared to those patients with an AT > 10 mL.kg^{-1}.min^{-1}. With the same AT cut-off, there was an increased LOS in patients with an AT < 10 mL.kg^{-1}.min^{-1} (20 vs 16 days, $p = 0.001$), In terms of receipt of adjuvant therapy post-surgery, the only index that separated out those who did and those who did not was AT, with the cut-off of 10 mL.kg^{-1}.min^{-1}. CPET therefore proved useful is the pre-operative assessment of patients undergoing major pancreatic surgery.

Bariatric Surgery

McCullough et al (2006) assessed the cardiorespiratory fitness and short-term complications after bariatric surgery in a group of 109 patients with a BMI ranging from 36.0 to 90.0 kg.m^{-2} (mean 48.7 ± 7.2). This was potentially important as these authors had previously reported that cardiorespiratory fitness levels in morbidly obese patients were similar to patients with advanced heart failure (*Gallagher et al, 2004*). The authors noted that there was a graded inverse relationship between a BMI > 25 kg.m^{-2} and $VO_{2,peak}$. The subjects were divided into tertiles, based on $VO_{2,peak}$, which were 13.7 ± 2.1, 17.1 ± 0.80 and 21.3 ± 2.1 mL.kg^{-1}.min^{-1} and at AT – 10.5 ± 2.0, 12.3 ± 1.40 and 14.5 ± 2.2 mL.kg^{-1}.min^{-1}.

There were more complications, longer operating and intubation times, and longer length of stay in patients in the first tertile. There were no complications in those with BMI < 45 kg.m^{-2} or peak VO_2 > 15.8 mL.kg^{-1}.min^{-1}. Multivariate analysis adjusting for age and sex showed that $VO_{2,peak}$ was a significant predictor of complications. Interestingly the authors also reported that 35/109 (32%) had sleep apnoea, although this was just reported within the clinical characteristics of the patients, and no further comment was made, including as to whether any of the patients were treated!

Hepatic Surgery

One of the earliest studies in the hepatic transplant group was by *Epstein et al (2004).* Of 156 patients tested, 59 (38%) underwent hepatic transplantation. Of these, 6 died within 100 days. There were no significant differences in baseline data and resting lung function data, including spirometry and ABG's. Those that died generally had a lower $VO_{2,peak}$ at < 60% predicted and a lower AT%$VO_{2,peak}$ compared to the survivors. Overall, a reduced aerobic capacity was considered a good guide to 100-day mortality post-transplant. The authors suggest that assessment of potential transplant recipients may be important component of a limited resource allocation.

In a further study by *Prentis et al (2012b),* this time in relation to liver transplantation patients, which is important as liver transplantation can have a high mortality rate, especially in the early post-transplant phase. None of the models for predicting outcome, at the time of the study were able to discriminate between survivors and non-survivors in the early post-transplant phase (*Jacob et al, 2005; Burroughs et al, 2006).* 165/182 patients achieved a measurable AT and of these 60 underwent transplantation. AT was a component in an attempt to predict the 90-day mortality, of which 6/60 patients had died within 90-days. In those patients who died before 90-days, the AT was significantly lower (8.4 ± 1.3 vs 12.0 ± 2.4 mL.min^{-1}.kg^{-1}; $p < 0.001$), whilst $VO_{2,peak}$ was not significantly different (12.5 ± 2.4 vs 14.8 ± 4.0 mL.min^{-1}.kg^{-1}; $p = 0.17$). Similarly, other CPET indices were not significantly different. All these measures were adjusted for actual body weight. However, it was noted that in patients with refractory ascites, there was an additional weight issue of the ascites, so the authors adjusted the CPET indices to ideal body weight, based on the Devine formula (*Pai & Paloucek, 2000*). Using ROC analysis, the optimal value for AT to predict survival was 9.0 mL.min^{-1}.kg^{-1}. It was noted that an AT > 11.0 was helpful in determining the critical care LOS, but not for total hospital LOS.

Junejo et al (2012) highlights the issue of undertaking liver resection in an increasingly older population who are likely to have greater comorbidities. The age range of the group of 94 patients who underwent surgery and had CPET was 24 – 85 years (median 71). The group median (range) for the key indices were: AT - 11.2 (7.4 – 21) mL.min^{-1}.kg^{-1}, V_E/VCO_2 - 32.0 (23.0 – 45.0), $VO_{2,peak}$ – 16.1 (9.5 - 28.1) mL.min^{-1}.kg^{-1} and $O_{2\ Pulse}$ – 9.0 (3.0 – 28.1) mL.beat^{-1}. AT was the only marker related to post-operative in-hospital mortality (5 deaths noted), with ROC analysis giving a cut-off of 9.9 mL.min^{-1}.kg^{-1}. In terms of complications, a cut-off of V_E/VCO_2 of 34.5, from ROC analysis, was deemed a reasonable rule-in test. The relative risk of cardiopulmonary morbidity at this cut-off was 2.17 (1.36 – 3.44). Multivariable regression showed age (years) and the V_E/VCO_2 as the two key predictors with OR's of 1.07 and 3.45 respectively. In terms of predicting LOS, an AT < 9.9 $mL.min^{-1}.kg^{-1}$ was associated with an increased, unplanned ICU stay.

Survival of patients who had CPET, and divided by the AT cut-off of 9.9 $mL.min^{-1}.kg^{-1}$ are shown in **Figure 10**. The authors concluded that CPET was useful in this group of patients, not least as it allows patients to make an informed decision about the peri-operative risks.

Kaibori et al (2013) assessed the usefulness of patients undergoing hepatectomy for hepatocellular carcinoma (HCC). Sixty-one patients were studied. Post-operative complications were classified according to the Clavien-Dindo system. All surviving patients were followed up 3-monthly for a median of 24 months post-operatively. The Child-Pugh class was assessed at regular intervals (*Child & Turcotte, 1964).*

In relation to CPET variables,

a $VO_{2,peak}$ ≥16.5 $mL.min^{-1}.kg^{-1}$ showed better survival at both 1 year (87.1% vs 78.6%) and at 3-years (50.3% vs 10.8%) compared to those with a value < 16.5 $mL.min^{-1}.kg^{-1}$. Survival was also better where the AT ≥ 11.5 $mL.min^{-1}.kg^{-1}$ at 1-year (90.3% vs 75%) and at 3-years (42.3% vs 33.4%) compared to those with an AT < 11.5 $mL.min^{-1}.kg^{-1}$. In terms of maintenance of the Child-Pugh class, AT was one of the factors from a univariate analysis (**Figure 11**). The authors concluded that hepatectomy can be safely performed in patients with an AT ≥ 11.5 $mL.min^{-1}.kg^{-1}$ and that this is a marker of better survival.

Bernal et al (2014) assessed CPET and survival with and without transplantation in patients with chronic liver disease. In a large group of 399 patients, 223 underwent transplantation. The patients were monitored and the primary outcome measure was mortality at 1-year, either post CPET in those who did not transplantation and 1-year in those after their transplant. In the transplant group, LOS in ITU and total LOS were assessed.

In those patients with ascites, significantly lower $VO_{2,peak}$ (14.3 vs 17.5, $p < 0.001$) and AT (9.5 vs 11.4, $p < 0.001$) were observed. It was also noted that in patients with diabetes, $VO_{2,peak}$ vales were significantly lower, but this was not similarly observed for AT. In the transplant patients, survivors at 1-year had a higher AT (10.3 vs 9.3, $p < 0.05$) and a higher $VO_{2,peak}$ (17.4 vs 13.8, $p < 0.001$). The LOS was longer in those patients with an AT < 9.2 $mL.min^{-1}.kg^{-1}$ (21 vs 15 days), and in those patients with a $VO_{2,peak}$ < 13.4 $mL.min^{-1}.kg^{-1}$ the ITU LOS was longer (4 days vs 3 days).

Comparing transplant to non-transplant patients, mortality rates were lower in the transplant patients at

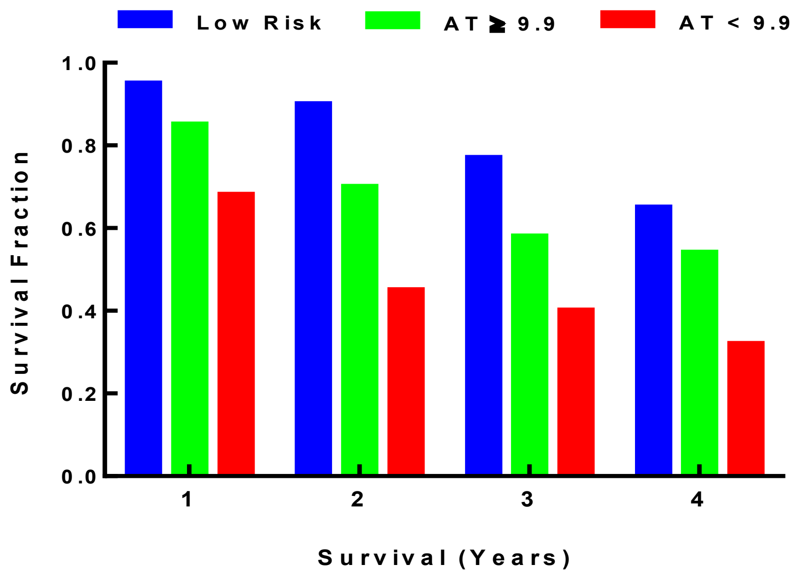


Figure 10 The survival fraction of patients deemed low risk compared to those who had an AT above and below 9.9 $mL.min^{-1}.kg^{-1}$. Data from Junejo et al 2012.

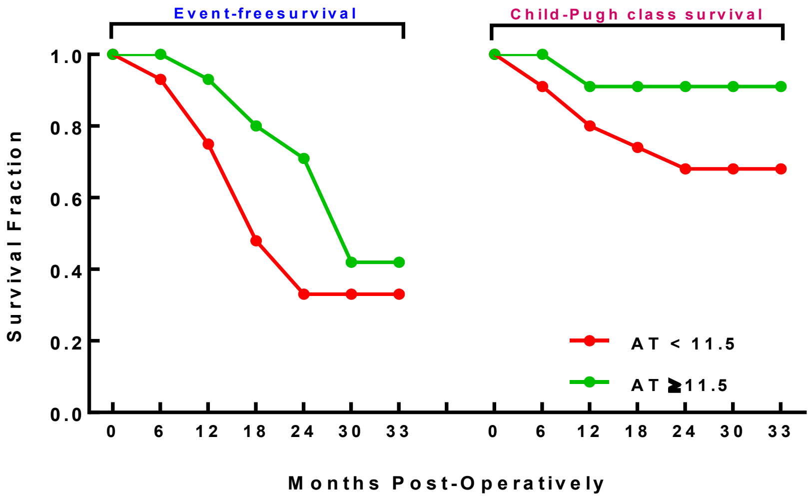


Figure 11 Comparison of event-free survival and maintenance of Child-Pugh class after hepatectomy in patients with pre-operative AT ≥11.5 $mL.min^{-1}.kg^{-1}$ and <11.5 $mL.min^{-1}.kg^{-1}$. Data from Kaibori et al, 2013

90-days (1.8% vs 11.3%) and at 1 year (4.9% vs 34.6%). Non-survivors had lower values of AT and $VO_{2,peak}$ compared to survivors. The authors conclude that CPET is important to assess patients, which is modifiable to support and improve survival even if transplant is not anticipated.

Neviere et al (2014) assessed the prognostic implications of preoperative CPET testing and exercise oscillatory ventilation (EOV) in patients undergoing liver transplant. EOV is characterized by waxing and waning of tidal volume leading to an oscillatory kinetics of breathing with a period of 45 – 90 s. Mechanisms of ventilation instability leading to EOV include prolonged circulatory time, abnormal response of central and peripheral controllers that drive ventilation and the impairment of the efficiency of gas exchange system to damp out changes in arterial gas tensions. In patients with heart failure, EOV has been attributed to prolonged circulatory time due to reduced cardiac output (*Dhakal et al, 2012*). In patients with neurological disorders such as hepatic encephalopathy, prolonged circulatory time may not be responsible for EOV as normal or even hyperdynamic circulatory status is typically present in advanced liver diseases (*Cherniak et al, 2005*). Instead, in these clinical conditions, ventilation instability has been related to overstimulation of the ventilatory control centre that will then present as periodic breathing – Cheyne-Stokes pattern (*Cherniak et al, 2005*). Overstimulation of the ventilatory drive has been reported in severe cirrhotic patients and related to increased chemoreceptor sensitivity in response to elevated catecholamine and progesterone plasma concentrations (*Lustik et al, 1997; Passino et al, 2012*).

Transplantation was undertaken in 263 patients. Comparing those patients who died (n = 20) to those who survived, resting lung function was no different. Peak VO_2 was significantly higher in the survivors (18.6 vs 17.1 $mL.min^{-1}.kg^{-1}$, $p = 0.02$) as was this index expressed as %predicted (64% vs 55%, $p = 0.04$). The only other index of significance was EOV, which was observed in 6/20 non-survivors, and only 21/243 of the survivors. In patients where EOV observed and died, the $VO_{2,peak}$, peak workload, $V_E/VCO_{2,\ peak}$ and $O_{2,pulse}$ were all significantly different.

EOV was independently associated with 1-year all-cause mortality, whereas $VO_{2,peak}$ best predicted the primary composite end-point of all-cause 1-year mortality and/or LOS and early in-hospital mortality. Multivariable analysis showed that EOV and $VO_{2,peak}$ were independent predictors of mortality.

The authors conclude that CPET is useful and that the use of EOV and a reduced $VO_{2,peak}$ may identify transplant candidates who are at high risk.

Lung Cancer

Colman et al (1982) assessed 59 patients before thoracotomy and observed that when compared to FEV_1 and VC, CPET added little to predicting postoperative complications, and noted only a weak correlation with the results of pulmonary function tests. This rather negative study, given many of the reported complications, perhaps reflected more a set of technical difficulties rather than actual complications, and which could not be reasonably predicted pre-operatively. Additionally, the authors did not adjust VO_2 for body mass.

Smith et al (1984) reported in 22 patients that there was a minimal risk of postoperative complications after thoracotomy where the $VO_{2,peak}$ was 20 $mL.min^{-1}.kg^{-1}$. However, there were postoperative complications observed in those patients who were unable to exceed a $VO_{2,peak}$ of 15 $mL.min^{-1}.kg^{-1}$. The authors concluded that CPET testing, in patients undergoing thoracotomy was a useful adjunct in the preoperative risk assessment for such patients.

Bechard and Wetstein (1987) selected patients for lung cancer resection on the basis of their FEV_1, with > 1.7 Litres for pneumonectomy, > 1.2 Litres for lobectomy and > 0.9 Litres for wedge resection. In patients with a $VO_{2,peak}$ < 10 $mL.min^{-1}.kg^{-1}$, the mortality was 29% and morbidity 43%, whereas with a value between 10 and 20 $mL.min^{-1}.kg^{-1}$ there was no mortality and 10.7% morbidity. Patients > 20 $mL.min^{-1}.kg^{-1}$ had no morbidity or mortality. These results are similar to those of *Smith et al (1984)* and were as predicted by the work of *Vacanti et al (1970)*, who showed a relationship between physical status and postoperative mortality.

Ussetti et al (1988) did not show any obvious relationship between $VO_{2,peak}$ and postoperative complications. However, there was no clear and systematic examination of a range of alternative methodology in risk stratification, such as < 10 $mL.min^{-1}.kg^{-1}$

or > 15 $mL.min^{-1}.kg^{-1}$.

Olsen et al (1989) assessed CPET performance using submaximal exercise testing, but with invasive catheterisation to measure pressures and cardiac output. Exercise was repeated measurements of 25W and 40W on a cycle ergometer. In those patients described as tolerant, i.e. survived > 60 days the VO_2/kg at 40W was 11.3 ± 2.1 $mL.min^{-1}.kg^{-1}$, compared to this who were deemed intolerant (dead within 60 days) with a VO_2/kg of 7.8 ± 1.5 ($p < 0.001$). Most of their patients had COPD, and it was therefore felt that exercising at this submaximal level was helpful in uncovering issues before surgery.

Markos et al (1989) undertook a comprehensive study in patients requiring lung resection. They were aware of the conflicting reports regarding the usefulness of CPET, and the uncertainties that they raise. CPET, apart from the change in SaO_2 did not appear to contribute much to the overall outcome. In patients who did not survive 90 days post-surgery, 2/3 had a value of $VO_{2,peak}$ of > 10 $mL.min^{-1}.kg^{-1}$, but it was noted that 2/9 who had no or minor complications similarly had values of < 10 $mL.min^{-1}.kg^{-1}$ (*Holden et al, 1992*).

Boysen et al (1990) was aware of the controversy over the issues of predicting post-thoracotomy complications. Of 70 patients, 17 were studied using a treadmill protocol to obtain the $VO_{2,peak}$ and associated variables. 2/17 patients had post-operative cardiopulmonary complications and 6/17 had non-cardiopulmonary complications. None of the exercise indices were related to complications, but this may be as a result of such small numbers.

Morice et al (1992) assessed 37 patients who were deemed inoperable due to one or more criteria – FEV_1% ≤ 40%, ppoFEV_1% ≤ 33% or a P_aCO_2 >6 kPa. 8/37 patients had a $VO_{2,peak}$ ≤ 15 $mL.min^{-1}.kg^{-1}$ and proceeded to surgery, whilst those who did not achieve this had non-surgical management. In the 8 patients who had resection, despite poor resting lung function, their overall lung function showed severe airflow obstruction. No relationship was observed between resting and exercise data. None of the 8 patients died and all left hospital within 22 days of surgery. The authors conclude that CPET is a useful addition to resting lung testing in the selection of patients undergoing lung resection.

Nakagawa et al (1992) assessed graded exercise performance, and as with *Olsen et al (1989)* this was done within cardiac catheterisation. Measures of blood lactate were obtained and the index of VO_2/BSA at a lactate of 20 $mg.dl^{-1}$ (La20) as well as the O_2 delivery per body surface area (O_2D/BSA = CI x C_aO_2) at the same lactate level. The patients were divided into 3 groups; 1 – no complications, 2 – nonfatal complications and 3 – fatal complications.

The only indices that distinguished between groups 1+2 vs 3 were the O_2D/BSA at La20 and the VO_2/BSA (**Figure 12**). The authors concluded that the VO_2/BSA at La20 should be > 400 $mL.min^{-1}.m^{-2}$ and the O_2D/BSA should be

> 500 mL.min^{-1}.m^{-2} in patients proceeding to thoracotomy.

Epstein et al (1993) assessed whether CPET could predict complications after pulmonary resection, as previous studies had not provided a clear-cut conclusion (*Colman et al, 1982; Smith et al, 1984; Bechard & Wetstein, 1987; Ussetti et al, 1988; Markos et al, 1989*). The authors devised a cardiopulmonary risk index (CPRI) which combined a cardiac risk score and a pulmonary risk score, the latter of which included estimates of FEV_1 and $PaCO_2$ > 6.0 kPa. By combining the two subscores, a total score ranging from a minimum of 1 to a maximum of 10. Indices of $VO_{2,peak}$ were adjusted for body mass (mL.min^{-1}.kg^{-1}) and also body surface area (BSA: mL.min^{-1}.m^{-2}). A cut-off of > 4 was observed to be indicative of increased risk of complications, whilst a $VO_{2,peak}$ adjusted for BSA of < 500 mL.min^{-1}.m^{-2} was associated with a 6 times greater risk of cardiopulmonary complications. There was a relationship between a low $VO_{2,peak}$ and a raised CPRI, which suggests that simply using the CPRI might obviate the need for CPET testing, although that at this time point would need further investigation.

In the study of *Pierce et al (1994),* it was noted that in the 9 patients who died, 3/9 had a value > 20, with values for the whole group (n = 52) ranging from 12.4 to 24.7 (mean 18.4 ± 3.1) mL.min^{-1}.kg^{-1}. The $VO_{2,peak}$ did not, in this group, predict complications from the surgery.

Bolliger et al (1995) attempted to predict postoperative complications in lung resection patients by assessing their $VO_{2,peak}$ in 80 patients. The patients were divided into those who had complications (16/80, 20%) and those who did not (64/80, 80%). In the patients who had complications, 3/16 died (19% or 4% overall mortality). The $VO_{2,peak}$% was significantly greater in the group without complications (84 ± 19% vs 61 ± 11%) and proved the more appropriate marker of complications within 30-days. If the $VO_{2,peak}$ > 75% the probability of not having complications was 0.9, whereas when the $VO_{2,peak}$ < 43%, the probability fell to 0.1.

Pate et al (1996) assessed resting lung function, stair climbing and CPET and concluded in a small study of lung resection patients (n = 12), that an FEV_1 > 1.6 L (40% predicted), a ppoFEV_1 > 700 mL and a $VO_{2,peak}$ > 10 mL.kg^{-1}.min^{-1} would allow patients to undergo resection safely.

Larsen et al (1997) prospectively assessed 97 patients undergoing pneumonectomy or lobectomy, who were included based on an FEV_1 > 2.0 L or a ppoFEV_1 > 1.0 L. These authors noted that there were significant differences for $VO_{2,peak}$ between those patients with any complication, but not so in patients with cardiopulmonary complications. Similarly the FEV_1 tended to be higher in those patients without complications. The authors provided a calculation based on the $VO_{2,peak}$% and FEV_1 which allows an estimation of

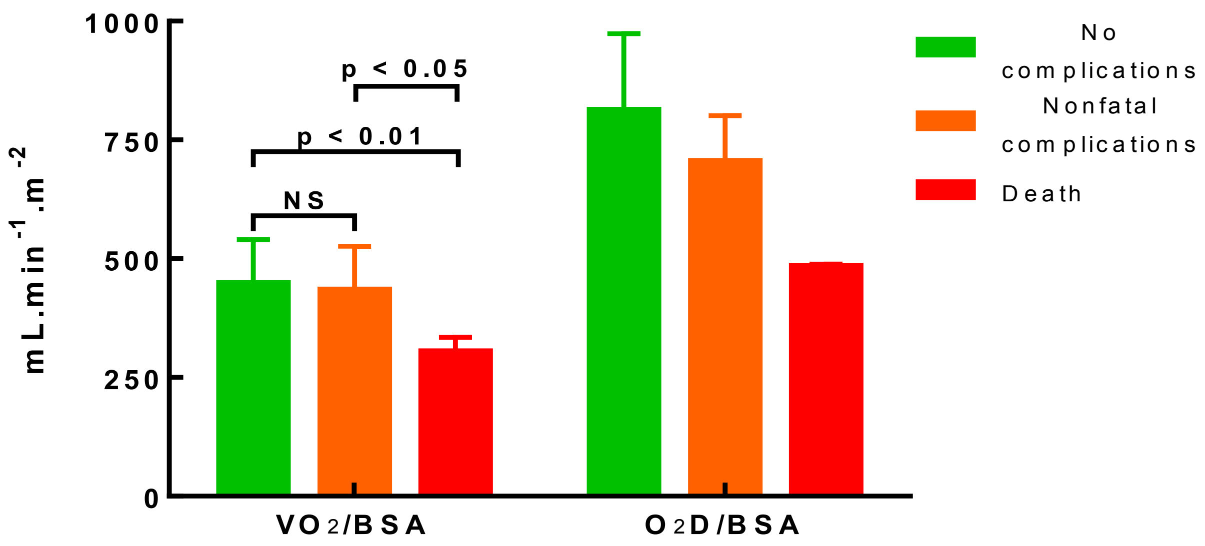


Figure 12. Comparison of two indices of exercise in lung cancer patients obtained at a blood lactate of 20 mg.dl^{-1} in three groups of patients as defined. The levels of significance shown apply to both indices. Data from Nakagawa et al (1992).

the risk of developing complications (**Figure 13**).

Brutsche et al (2000) further assessed the issue of predicting operative risks using CPET in patients with lung cancer. In patients with complications the $VO_{2,peak}$/kg% was significantly lower than in patients with no complications (80 ± 17% vs 99 ± 21%; $p < 0.0001$) and, along with the estimated extent of lung tissue resection, were the only two independent predictors of postoperative complications. The relationship of these two variables permitted a range of probabilities to be estimated (**Figure 14**) and within the limitations of this study provide an estimate of potential difficulties that may arise from the proposed surgery. The approach is slightly different to that used by *Larsen et al (1997),* and it would be interesting to compare such approaches using new data, or by modelling the data to assess outcomes.

period. There were significant improvements in resting lung function (**Figure 15**). In line with the observed changes in resting lung function, exercise capacity similarly significantly improved. From the observed data, the authors were able to conclude that the recovery in exercise capacity following surgery was a combination of both circulatory and ventilatory limitations. Ventilatory limitations may, in part, have been due to the surgical injury to the chest wall immediately following surgery.

Villani & Busia (2004) assessed which test – spirometry, blood gases, lung scanning or CPET testing was the best predictor of postoperative morbidity and mortality in patients undergoing pneumonectomy. 47/150 patients had complications postoperatively and 4 (2.7%) died within one month. Those patients with complications has a lower $ppoFEV_1$%, a lower $VO_{2,peak}$ and in particular

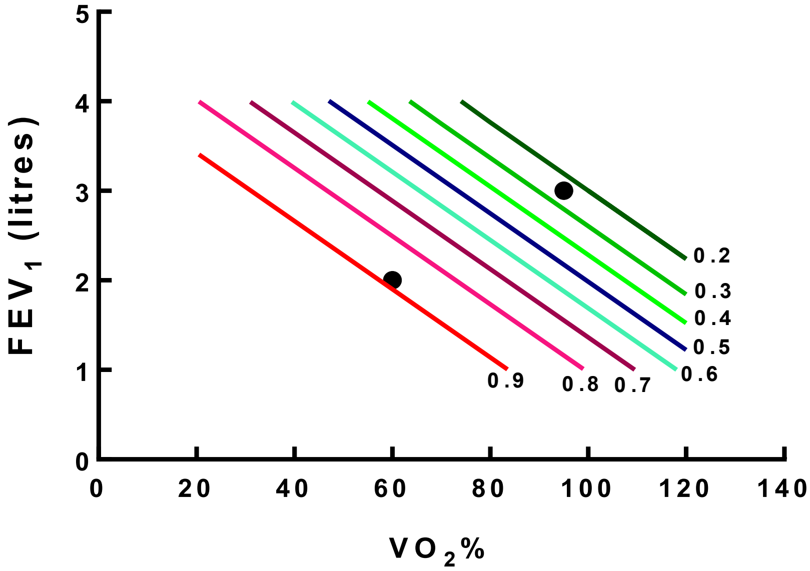


Figure 13. The relationship between absolute FEV_1 and $VO_{2,peak}$%. The isopleths are the risk (R) of developing of any complications between 0.2 (Low risk) and 0.9 (High risk). The risks were calculated for FEV_1's from 1.0 to 4.0 litres and $VO_{2,peak}$% from 20 to 120%, using the equation from Larsen et al (1997) - $\ln(R/(1\text{-}R)) = 7.911 - 0.052VO_{2,peak}\% - 1.365FEV_1$. In the two patjent examples shown then for an FEV_1 of 2.0 litres and achieving a $VO_{2,peak}$ of 60% predicted, the risk is 0.88 (High risk), whilst for an FEV_1 of 3 litres and achieving a $VO_{2,peak}$ of 95% predicted, the risk is 0.245 (Low risk).

Miyoshi et al (2000) assessed the effects of surgery on exercise performance before and within and at 14 days post-surgery. Whilst not using CPET to risk assess, this study does provide an interesting insight into the recovery, not only of resting lung function, but also exercise function in the immediate post-operative

those patients with a $VO_{2,peak}$ of < 50% predicted.

In patients with advanced lung and breast cancer, *Jones et al (2007)* assessed the safety and feasibility of CPET. In 85 patients who underwent CPET, three patients (3.5%) were found to have positive ECG changes suggestive of ischaemia, whereas asymptomatic,

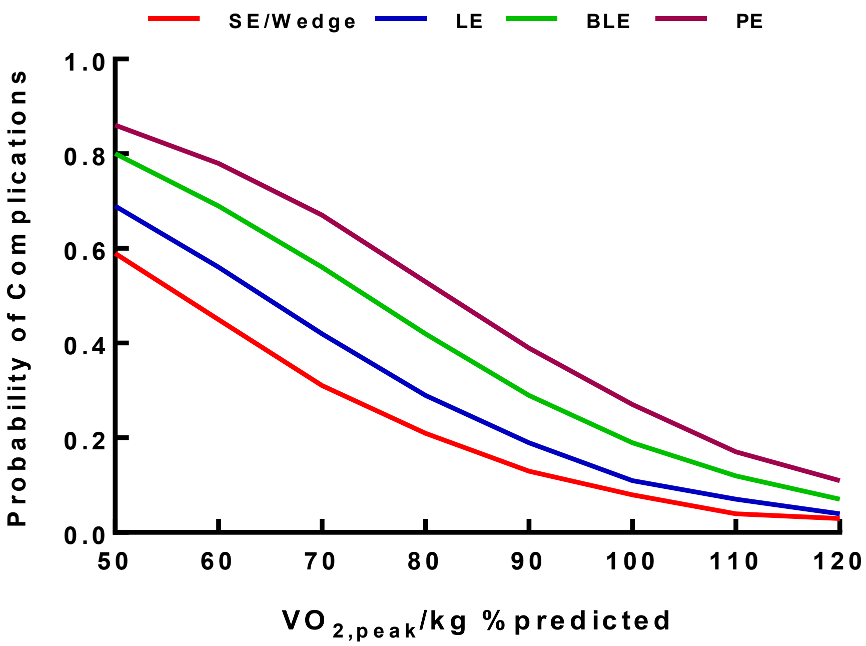


Figure 14 Probabilities of postoperative complications based on exercise tests and lung resection according to stepwise logistic regression analysis. These were calculated independent of the localization assuming 50, 31, 20 and 5% tissue removed for pneumonectomy (PE), bilobectomy (BLE), lobectomy (LE) and segmentectomy/wedge resection (SE/wedge) respectively. Based on data from Brutsche et al (2000).

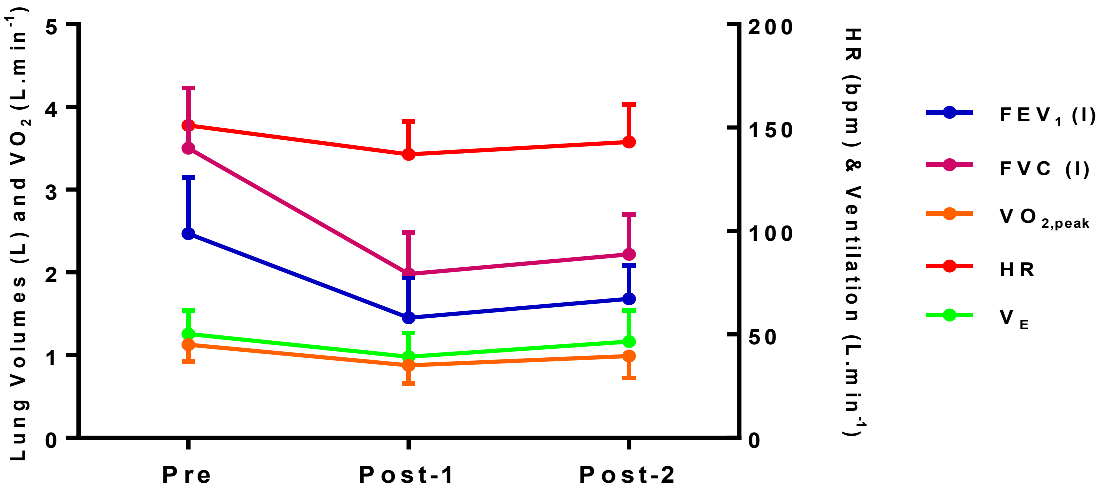


Figure 15 Changes in resting lung function and exercise variables compared to pre-operative values. Post-1 were measured within 14 days of surgery (9 ± 2 days) and Post-2 after 14 days (mean 26 ± 12 days). Data are mean ± 1SD. Data from Miyoshi et al, 2000.

nonsignificant changes in ST segment developed in 12 patients with NSCLC (26.0%) and 17 patients with breast cancer (43.6%); in two patients adverse events developed during the test.

Baser et al (2006) assessed a cohort of 206 patients with NSCLC. In general, and following the guidance regarding CPET testing with abnormal FEV_1% and DL_{co}% showed that CPET highlighted in a subgroup of 12 patients overall poor $VO_{2,peak}$.

Brunelli et al (2009) performed cycle ergometry on 204 patients undergoing lobectomy or pneumonectomy. Logistic regression demonstrated that $VO_{2,peak}$ was an independent predictor of pulmonary complications. The conclusions from this study are important –

1. If the FEV_1% and DL_{co}% are both > 80%, CPET adds very little to the outcome

2. If the FEV_1% or DL_{co}% are < 80%, but both are >

40%, then CPET should be performed, and where for a $VO_{2,peak}$ < 12 $mL.kg^{-1}.min^{-1}$, there was an increase in mortality.

3. Where the $ppoFEV_1$% $ppoDL_{co}$% or both are < 40%, lung resection may be considered if the $VO_{2,peak}$ is > 12 $mL.kg^{-1}.min^{-1}$.

4. Where the $ppoFEV_1$ < 30% or the PPP < 1650 (*Pierce et al, 1994; Figure 1*), good surgical outcome is possible where the $VO_{2,peak}$ is > 12 $mL.kg^{-1}.min^{-1}$. Where there is concern about operability, then CPET should be performed.

5. In patients with coronary artery disease (CAD), CPET should be performed to ensure that operability and perioperative management are appropriate.

6. CPET should be performed in patients with severe comorbidities to determine whether sufficient aerobic reserve exists to undertake lung-sparing procedure.

The importance of this study cannot be understated as this demonstrates the limitations of the guidelines of the time (*Colice et al, 2007; Lim et al, 2001*) and should lead to improvements in the pathway management of patients requiring lung resection.

Bobbio et al (2009) assessed the usefulness of CPET testing in patients undergoing lung resection on 71 patients. 54/71 patients had not complications, leaving 19/71 who did. It was noted that in the group with pulmonary complications, FEV_1%, $VO_{2,peak}$/kg and V_E% was significantly reduced, which in terms of the latter is perhaps not surprising since the FEV_1 x 40 may be used to estimate $V_{E,max}$. In patients who had cardiac and/or pulmonary complications, the DL_{co}% was the one index that showed a significant difference. There is one interesting methodological issue with this study, which was highlighted in the post-paper discussion. In patients with a $VO_{2,peak}$ of between 10 to 15 $mL.kg^{-1}.min^{-1}$ (n = 9; 13%) each patient undertook a 4-week period of pulmonary rehabilitation (*Bobbio et al, 2008*), although no data is presented on the actual improvements in $VO_{2,peak}$.

Jones et al (2010) investigated the association between $VO_{2,peak}$ and survival in patients with stage I to stage III lung cancer. The patients were grouped according to $VO_{2,peak}$/kg as < 13.9, 14 – 17.3 and > 17.4 $mL.kg^{-1}.min^{-1}$. The 5-year survival rate in those patients with a $VO_{2,peak}$ < 13.9 was 30%, rising to 34% and 36% in those patients with > 17.4. The adjusted hazard ratio (HR) were 0.79 and 0.76 for the middle and higher groups. Mean survival for the group was 30, 34 and 36 months respectively. Separating out the group into resected and non-resected patients, the 5-year survival was 37, 37 and 40 months respectively in the resected group and 11.4, 23.1 and 19.5 in the non-resected group. The authors concluded that $VO_{2,peak}$ was a strong, independent predictor of survival in NSCLC patients.

Brunelli et al (2012b) moved away from AT and $VO_{2,peak}$ in the assessment of respiratory complications and death predictions in patients having lung resection. They observed that of 225 patients, 51 (23%) had cardiopulmonary morbidity and 5 (2.2%) died. Of the 25 patients who had respiratory complications, compared to those without, the V_E/VCO2 slope was higher (34.8 ± 5.5 vs 30.9 ± 6.1, p = 0.001). The $VO_{2,peak}$/kg and $VO_{2,peak}$%, FEV_1% and DL_{co}% were not significantly different. It was suggested that this index - V_E/VCO_2 slope might be a better predictor of respiratory complications and death than $VO_{2,peak}$. It is known that the use of V_E/VCO_2 is a better predictor for poorer outcomes in patients with chronic heart failure (*Corrà et al, 2004*). A high V_E/VCO_2 reflects ventilatory inefficiency and it is perhaps not surprising that in patients with COPD who are undergoing lung resection surgery a higher value is associated with increased mortality but not with cardiopulmonary morbidity (*Torchio et al, 2010*). In this study it was noted that when using the cut -off value of > 35, there was a 3-fold increase in the incidence of respiratory complications and a 12-fold increase in mortality. This cut-off of > 35 has been noted to be predictive of an adverse outcome in patients who have chronic heart failure (*Corrà et al, 2002; Ferguson et al, 2008).* The V_E/VCO_2 slope appears to be a guide to underlying ventilatory alterations that may become more evident during exercise and may indeed be a more useful or additional indicator for risk-stratification, which is independent of $VO_{2,peak}$.

Brunelli et al (2014) assessed $VO_{2,max}$ in patients with Stage I NSCLC. In those patients with a $VO_{2,max}$ < 60% survival at 48 months was 40% compared to 73% with a $VO_{2,max}$ > 60% (p = 0.0004). Overall survival showed that age > 70 years (HR = 2.3) and $VO_{2,max}$ < 60% (HR = 2.4) were both independent prognostic factors associated with survival. Cancer specific survival was also greater when the $VO_{2,max}$ > 60% (81% vs 61%). The authors suggest that perhaps a presurgical rehabilitation programme aimed at improving overall exercise tolerance may be helpful in the long-term prognosis of these patients.

Unable to achieve AT!

Lai et al (2013) reviewed a very important aspect of the assessment and reporting of CPET results – what happens when the patient is unable to perform a CPET test, or fails to attain an AT? This is actually a really important, but obvious question as there will be a group of patients who simply are unable to complete the test as required, for whatever reason. Furthermore, as highlighted by the authors, many previous studies have not included patients who were unable to complete the test or in whom the AT was not attained (*Older et al, 1993; Older et al, 1999; Wilson et al, 2010; Swart & Carlisle, 2012; Carlisle et al, 2012; Challand et al, 2012*). The authors included all patients who agreed to be assessed, and who were deemed as being "fit" with an AT > 11.0 $mL.min^{-1}.kg^{-1}$, "Unfit" with an AT < 11.0 $mL.min^{-1}.kg^{-1}$ and "Unable/No AT". Overall the patients deemed "Unable/No AT" had longer hospital stays compared to "Unfit" and "Fit" patients (14.0 vs 9.9 vs 7.1 days) and similarly an increased mortality at 30-days, 90-days and 2 years (42% vs 20% vs 11%). Overall the authors suggest that where patients are classified as "Unable/No AT" they had poorer outcomes after major colorectal surgery. However, this is based on data from 26 patients only, compared to 174 deemed fit and 69 deemed unfit, but actually probably represents the overall proportions of patients observed in clinical practice. Indeed, with reference to the *Hennis et al (2012)* study, 11/106 (10.4%) patients did not achieve an AT.

The 4% Desaturation – meaning?

One question many people ask about is the 4% desaturation that is observed on exercise, and why this may be important.

In the study of *Pierce et al (1994),* it was noted that during cycle ergometry 7/52 (13.5%) of patients had a fall in SaO_2 of > 4%, whilst in the same group, using a step test 16/51 (31.4%) had a fall in SaO_2 > 4%. This suggests that there are differences in the responses to the different exercise test methodology, producing slightly differing end-points.

Brunelli et al (2008b) reviewed this and applied this to his data in relation to maximal stair climbing. A decrease in exercise O_2 desaturation (EOD) and its association with outcomes after lung resection was unclear, based on a number of previous studies (*Morice et al, 1992; Kearney et al, 1994; Rao et al, 1995; Ninan et al, 1997; Varela et al, 2001*). In analysing 536 patients who underwent surgery, 128 (24%) had postoperative complications. Of these 128, it was observed that 27 (21%) had an EOD > 4%, as compared to the 48 (12%) of the non-complications group. An alternative analysis was to determine the number of patients in whom the SpO_2 was > 90%. For this latter index, there was no difference between the two groups.

The interesting observation is that the EOD > 4% was a marker of adverse outcome particularly in patients with underlying cardiac disease, where the morbidity was up to 51%. The combination of an EOD > 4% and the inability to stair climb > 12 m was clearly a strong marker of postoperative complications. Add to this the cardiac co-morbidity and you have a morbidity of 80% and a mortality of 40%. Based on their analysis, the authors recommended that all patients experiencing an exercise EOD > 4% should be referred for CPET to assess $VO_{2,peak}$ before surgery, to define the mechanisms impairing their oxygen transport system, i.e. whether this is cardiac, pulmonary or pulmonary vascular.

Nakagawa et al (2014) assessed patients using two criteria – 1) SpO_2 < 91% and 2) a $DSpO_2$ > 4%. These two criteria separated out a group of patients who required more home oxygen set-ups and had greater cardiopulmonary mortality at 30 and at 90 days.

So why may an EOD > 4% occur during exercise? This may be explained by one or a combination of a number of potential factors –

1. Alveolar ventilation does not increase to the same relative degree as VO_2
2. Cardiac output response to exercise is subnormal

possibly where there is coexisting ischaemic heart disease or pulmonary hypertension. The mixed venous PO_2 is very low, and, in the presence of ventilation/perfusion inequality, this will decrease the P_aO_2

3. Exercise could lead to ventilation/perfusion mismatching, probably due to the temporary accumulation of interstitial fluid in the lungs caused by an increase in hydrostatic vascular pressure in both the pulmonary artery and vein *(Wagner, 1992).*

Whilst it is possible to estimate $VO_{2,peak}$ using a stair-climb test, the question it raises is how accurate or how closely approximating is the estimated value to actual value, and should there by a cut-off value below which we know that patients will not do well post-surgery?

In the paper by *Ito et al (2015),* they used two cut-offs of 1) walking 5 flights of stairs and 2) no > 4% EOD for patients to have a lobectomy. In those who failed one or the other cut-offs, the patients had sublobar resection. Patients having a lobectomy had better overall outcomes of survival.

Conclusions

Exercise testing is a useful tool to assess patients where there is concern regarding the fitness of a patient for the proposed surgery. Most studies have focused on patients undergoing lung resection of lung cancer. The body of evidence currently suggests that if a patient has a $VO_{2,peak}$ of < 10 $mL.min^{-1}.kg^{-1}$ then there is an increased risk of complications and death. Where the $VO_{2,peak}$ of > 20 $mL.min^{-1}.kg^{-1}$, patients will be able to tolerate surgery with an acceptable level of morbidity and mortality (Figure 16).

Comparison studies between the various modalities of exercise testing show the expected variations between tests that one would expect. There are advantages to non-laboratory field walking tests. In the clinical setting 6MWT, SCT and SWT can be performed quickly, simply (with little expertise required) and relatively cheaply (little equipment required). The results of the various studies outlined above show that all three field exercise tests are quick (< 16 min), safe (no adverse events) and require only one trained clinician. This means, when set-up properly, they can be relatively easily performed by trained clinicians in their own setting, such as an oncology ward, inpatient rehabilitation class or community rehabilitation setting to assess, re-assess or monitor patients. In a research study the ability to perform measurement with few costs, training of researchers and with little time burden for participants (and potential drop-outs) is extremely advantageous to seeking funding, and perhaps getting studies approved by research ethics committees.

Bringing this all together, and incorporating all of the test modalities – SCT, SWT, 6MWT and CPET, would allow clear guidelines to be provided to those undertaking the assessment of patients. In lung cancer patients, the well established guidelines (Brunelli et al, 2013) could be inclusive of all such tests (Figure 16).

In other cancers, as outlined in this review similar indices are used to assess outcomes for surgery. The choice of indices within a specific surgical group should be assessed on the basis of the evidence from the studies reviewed in this article. There is much data available and knowing the type of surgery, the level of impairment before surgery should allow better risk stratification of patients. To some extent, based on this stratification, resources required post surgery can also be determined with some idea of projected LOS and the need for critical care access in high risk patients.

Whilst the field develops more, and with the undertaking of more high quality research, better definitions of outcomes will be become available.

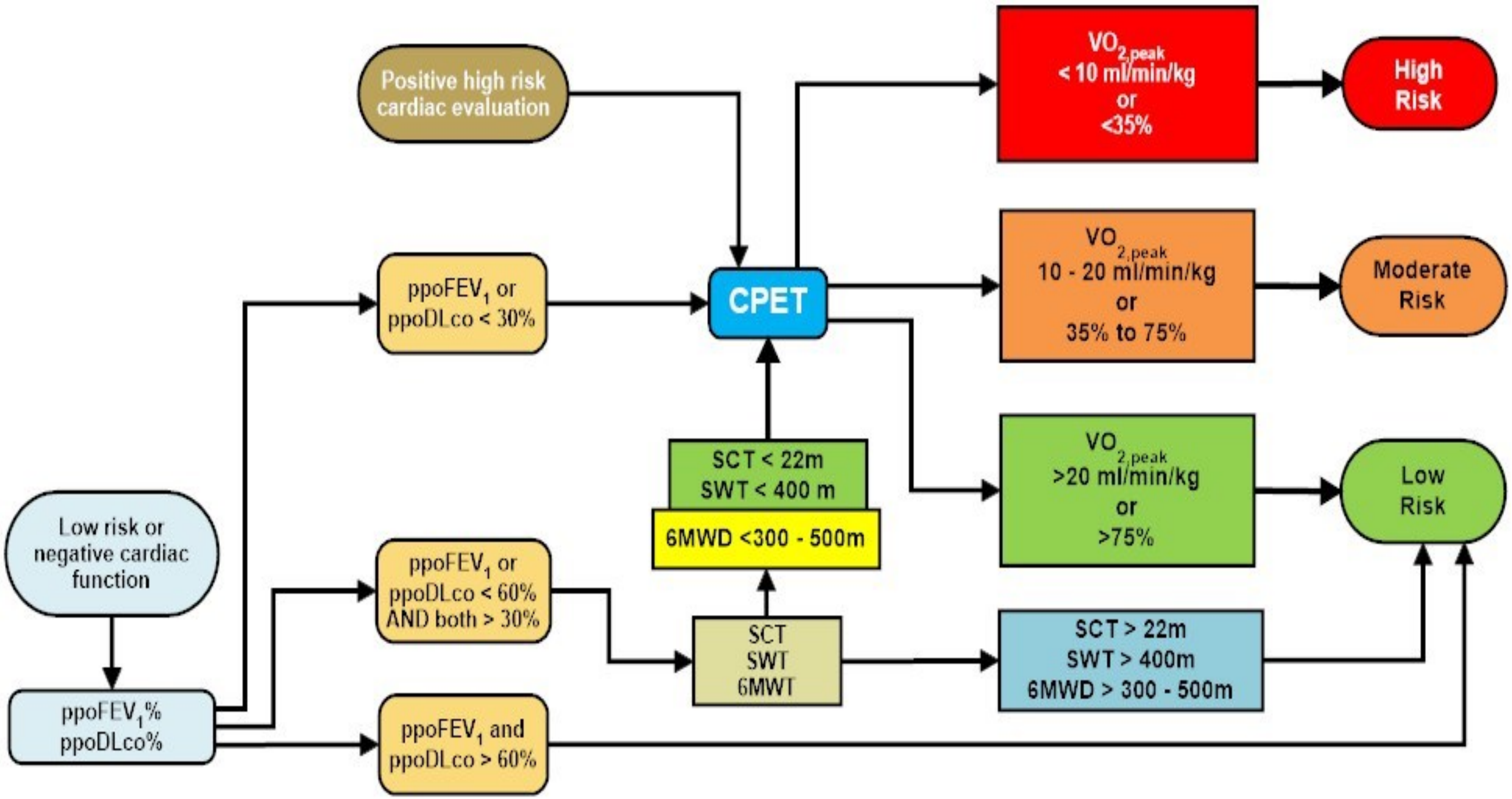


Figure 16. Physiological assessment of patients undergoing lung resection surgery (Brunelli et al 2013), with a suggested modification of adding the outcomes of the 6MWT (Ha et al, 2016). The algorithm permits patients to be assessed for fitness of surgery including pneumonectomy, lobectomy etc. Readers are advised to obtain a copy of the Brunelli paper which provides a full explanation of the risk stratification and the methodology behind this algorithm.

References

Ainsworth BE, Haskell WL, Herrmann SD, Meckes N, Bassett Jr DR, Tudor-Locke C, Greer JL, Vezina J, Whitt-Glover MC, Leon AS, (2011) Compendium of Physical Activities: a second update of codes and MET values. Medicine and Science in Sports and Exercise, 43: 1575 - 1581. https://sites.google.com/site/compendiumofphysicalactivities/

American Thoracic Society & American College of Chest Physicians (2003). ATS/ACCP statement on cardiopulmonary exercise testing. Am J Respir Crit Care Med. 167: 211 – 277.

Arena R, Sietsema KE (2011). Cardiopulmonary exercise testing in the clinical evaluation of patients with heart and lung disease. Circulation. 123: 668 – 680.

Attia RR, Murphy JD, Snider M, Lappas DG, Darling RC, Lowenstein E (1976). Myocardial ischemia due to infrarenal aortic cross-clamping during aortic surgery in patients with severe coronary artery disease. Circulation 53: 961 – 965.

Baser S, Shannon VR, Eapen GA, Jimenez CA, Onn A, Keus L, Lin E, Morice RC (2006). Pulmonary dysfunction as a major cause of inoperability among patients with non-small-cell lung cancer. Clin Lung Cancer. 7: 344 - 349.

Bassett DR, Howley ET (2000). Limiting factors for maximum oxygen uptake and determinants of endurance performance. Med Sci Sports and Exerc 32: 70 – 84.

Baxendale BR, Baker DM, Hutchinson A, Chuter TA, Wenham PW, Hopkinson BR (1996). Haemodynamic and metabolic response to endovascular repair of infra-renal aortic aneurysms. Br J Anaesth 77: 581 – 585.

Benzo RP, Sciurba FC (2010). Oxygen Consumption, Shuttle Walking Test and the Evaluation of Lung Resection. Respiration 80: 19 – 23.

Bechard D, Wetstein L, (1987). Assessment of exercise oxygen consumption as a preoperative criterion for lung resection. Ann Thorac Surg 44: 344 - 349.

Biccard BM (2005). Relationship between the inability to climb two flights of stairs and outcome after major non-cardiac surgery: implications for the pre-operative assessment of functional capacity. Anaesthesia, 60: 588 – 593.

Bernal W, Martin-Mateos R, Lipcsey M, Tallis C, Woodsford K, McPhail MJ, Willars C, Auzinger G, Sizer E, Heneghan M, Cottam S, Heaton N, Wendon J (2014). Aerobic capacity during cardiopulmonary exercise testing and survival with and without liver transplantation for patients with chronic liver disease. Liver Transpl. 20: 54 - 62.

Bernasconi M, Koegelenberg CFN, von Groote-Bidlingmaier F, Maree D, Barnard BJ, Diacon AH, Bolliger CT, (2012). Speed of Ascent During Stair Climbing Identifies Operable Lung Resection Candidates. Respiration, 84: 117 – 122.

Biccard BM (2004). Peri-operative b-blockade and haemodynamic optimisation in patients with coronary artery disease and decreasing exercise capacity presenting for major noncardiac surgery. Anaesthesia 59: 60 – 68.

Biccard BM (2005). Relationship between the inability to climb two flights of stairs and outcome after major non-cardiac surgery: implications for the pre-operative assessment of functional capacity. Anaesthesia, 60: 588 – 593.

Bobbio A, Chetta A, Ampollini L, Primomo GL, Internullo E, Carbognani P, Rusca M, Olivieri D (2008). Preoperative pulmonary rehabilitation in patients undergoing lung resection for non-small cell lung cancer. Eur J Cardiothorac Surg 33: 95 - 98.

Bobbio A, Chetta A, Internullo E, Ampollini L, Carbognani P, Bettati S, Rusca M, Olivieri D (2009). Preoperative pulmonary rehabilitation in patients undergoing lung resection for non-small cell lung cancer. Eur J Cardiothorac Surg 35: 419 - 422.

Bokemeyer C, Oechsle K, Hartmann JT (2005). Anaemia in cancer patients: pathophysiology, incidence and treatment. Eur J Clin Invest. 35 (suppl 3): 26 – 31.

Bolliger CT, Jordan P, Soler M, Stulz P, Gradel E, Skarvan K, et al (1995). Exercise capacity as a predictor of postoperative complications in lung resection candidates. Am J Respir Crit Care Med 151: 1472 – 1480.

Bolton JWR, Weisman DS, Haynes JL, et al, (1987). Stair climbing as an indicator of pulmonary function. Chest, 92: 783 – 788.

Booth S, Adams L (2001). The shuttle walking test: a reproducible method for evaluating the impact of shortness of breath on functional capacity in patients with advanced cancer. Thorax 56: 146 - 150.

Boysen PG, Clark CA, Block AJ (1990). Graded exercise testing and post-thoracotomy complications. J Cardiothorac Anesth. 4: 68 - 72.

Brunelli A, Monteverde M, Salati M, Borri A, Al Refai M, Fianchini A, (2001). Stair-Climbing Test to Evaluate Maximum Aerobic Capacity Early After Lung Resection. Ann Thorac Surg, 72: 1705 – 1710.

Brunelli A, Al Refai M, Monteverde M, Borri A, Salati M, Fianchini A (2002b). Stair Climbing Test Predicts Cardiopulmonary Complications After Lung Resection. Chest 121: 1106 – 1110.

Brunelli A, Al Refai M, Xiumé F, Salati M, Sciarra V, Socci L, Sabbatini A, (2008a). Performance at Symptom-Limited Stair-Climbing Test is Associated with Increased Cardiopulmonary Complications, Mortality, and Costs after Major Lung Resection. Ann Thorac Surg 86: 240 – 248.

Brunelli A, Al Refai M, Xiumé F, Salati M, Marasco R, Sciarra V, Socci L, Sabbatini A, (2008b). Oxygen desaturation during maximal stair-climbing test and postoperative complications after major lung resections. Eur J Cardio-thoracic Surg, 33; 77 – 82.

Brunelli A, Charloux A, Bolliger CT, Rocco G, Sculier JP, Varela G, Licker M, Ferguson MK, Faivre-Finn C, Huber RM, Clini EM, Win T, De Ruysscher D, Goldman L, (2009). European Respiratory Society and European Society of Thoracic Surgeons joint task force on fitness for radical therapy: ERS/ESTS clinical guidelines on fitness for radical therapy in lung cancer patients (surgery and chemoradiotherapy). Eur Respir J, 34: 17 –41.

Brunelli A, Belardinelli R, Refai M, Salati M, Socci L, Pompili C, et al (2010). Peak oxygen consumption during cardiopulmonary exercise test improves risk stratification in candidates to major lung resection. Chest, 135: 1260 – 1267.

Brunelli A, Pompili C, Berardi R, Mazzanti P, Onofri A, Salati M, Cascinu S, Sabbatini A, (2012a). Performance at Preoperative Stair-Climbing Test is Associated with Prognosis after Pulmonary Resection in Stage I Non-Small Cell Lung Cancer. Ann Thorac Surg 93: 1796 – 1801.

Brunelli A, Pompili C, Salati M, Refai M, Berardi R, Mazzanti P, Tiberi M (2014). Preoperative maximum oxygen consumption is associated with prognosis after pulmonary resection in stage I non-small cell lung cancer. Ann Thorac Surg. 98: 238 - 242.

Brutsche MH, Spiliopoulos A, Bolliger CT, Licker M, Frey JG, Tschopp JM (2000). Exercise capacity and extent of resection as predictors of surgical risk in lung cancer. Eur Respir J 15: 828 – 832.

Bruyneel M, Van den Broecke S, Libert W, Ninane V, (2013). Real-time attended home-polysomnography with telematic data transmission. Int J Med Inform, 82: 696 - 701.

Challand C, Struthers R, Sneyd JR, et al (2012). Randomized controlled trial of intraoperative goal-directed fluid therapy in aerobically fit and unfit patients having major colorectal surgery. Br J Anaesth 108: 53 – 62.

Chandrabalan VV, McMillan DC, Carter R, Kinsella J, McKay CJ, Carter CR, Dickson EJ (2014).Pre-operative cardiopulmonary exercise testing predicts adverse post-operative events and non-progression to adjuvant therapy after major pancreatic surgery. HPB (Oxford). 15: 899 - 907.

Charloux A, Brunelli A, Bolliger CT, Rocco G, Sculier JP, Varela G, Licker M, Ferguson MK, Faivre-Finn C, Huber RM, Clini EM, Win T, De Ruysscher D, Goldman L, (2009). Lung function evaluation before surgery in lung cancer patients: how are recent advances put into practice? A survey among members of the European Society of Thoracic Surgeons and of the Thoracic Oncology Section of the European Respiratory Society. Interact Cardiovasc Thorac Surg, 9: 925 – 931.

Cherniack NS, Longobardo G, Evangelista CJ (2005). Causes of Cheyne-Stokes respiration. Neurocrit Care 3: 271 – 279.

Child CG, Turcotte JG (1964). Surgery and portal hypertension. In: The liver and portal hypertension. Edited by CG Child. Philadelphia: Saunders: 50 - 64.

Christensen JF, Jones LW, Andersen JL, et al (2014). Muscle dysfunction in cancer patients. Ann Oncol. 25: 947 – 958.

Clavien PA, Barkun J, de Oliveira ML et al (2009). The Clavien-Dindo classification of surgical complications: five-year experience. Ann. Surg. 250: 187 – 196.

Colice GL, Shafazand S, Griffin JP, Keenan R, Bolliger CT (2007). Physiologic evaluation of the patient with lung cancer being considered for resectional surgery: ACCP evidenced-based clinical practice guidelines (2nd edition). Chest. 132 (suppl): 161S – 177S.

Colman NC, Schraufnagel DE, Rivington RN, Pardy RL (1982). Exercise testing in evaluation of patients for lung resection. Am Rev Respir Dis 125: 604 - 606.

Colson M, Baglin J, Bolsin S, Grocott MP (2012). Cardiopulmonary exercise testing predicts 5 yr survival after major surgery. Br J Anaesth. 109: 735 - 741.

Corrà U, Mezzani A, Bosimini E, Giannuzzi P (2004). Cardiopulmonary exercise testing and prognosis in chronic heart failure: a prognosticating algorithm for the individual patient. Chest 126: 942 – 950.

Dajczman E, Kasymjanova G, Kreisman H, et al (2008). Should patient-rated performance status affect treatment decisions in advanced lung cancer? J Thorac Oncol. 3: 1133 – 1136.

Dhakal BP, Murphy RM, Lewis GD (2012). Exercise oscillatory ventilation in heart failure. Trends Cardiovasc Med 22: 185 – 191.

Dindo D, Demartines N, Clavien PA (2004). Classification of surgical complications: a new proposal with evaluation in a cohort of 6336 patients and results of a survey. Ann. Surg. 240: 205 – 213.

Eagle KA, Berger PB, Calkins H, et al (2002). ACC/AHA guideline update for perioperative cardiovascular evaluation for noncardiac surgery-executive summary. A report of the American College of Cardiology/American Heart Association Task Force on Practice Guidelines (Committee to update the 1996 guidelines on perioperative cardiovascular evaluation for noncardiac surgery). Anesthesia and Analgesia 94: 1052 – 1064.

Epstein SK, Faling W, Daly BD, Celli BR (1993). Predicting complications after pulmonary resection: pre-operative exercise testing versus a multifactorial cardiopulmonary risk index. Chest 104: 694 - 700.

Fleg JL, Pina IL, Balady GJ, et al (2000). Assessment of functional capacity in clinical and research applications. An advisory from the Committee on Exercise, Rehabilitation and Prevention, Council on Clinical Cardiology, American Heart Association. Circulation 102: 1591 – 1597.

Forshaw MJ, Strauss DC, Davies AR, Wilson D, Lams B, Pearce A, Botha AJ, Mason RC (2008). Is cardiopulmonary exercise testing a useful test before esophagectomy? Ann Thorac Surg. 85: 294 - 299.

Gallagher MJ, Franklin BA, deJong A, et al (2004). Cardiorespiratory fitness levels in obesity approximate those of heart failure patients: implications for exercise prescription. Circulation 110: 822A

Girish M, Trayner Jr E, Dammann O, Pinto-Plata V, Celli B, (2001). Symptom-Limited Stair Climbing as a Predictor of Postoperative Cardiopulmonary Complications After High-Risk Surgery. Chest 120: 1147 – 1151.

Gitt AK, Wasserman K, Kilkowski C, et al, (2002). Exercise anaerobic threshold and ventilatory efficiency identify heart failure patients for high risk of early death. Circulation 106: 3079 – 3084.

Hennis PJ, Meale PM, Hurst RA, O'Doherty AF, Otto J, Kuper M, Harper N, Sufi PA, Heath D, Montgomery HE,

Grocott MPW (2012). Cardiopulmonary exercise testing predicts postoperative outcome in patients undergoing gastric bypass surgery. Brit J Anaesth 109: 566 – 571.

Hightower CE, Riedel BJ, Feig BW, Morris GS, Ensor JE Jr, Woodruff VD, Daley-Norman MD, Sun XG (2010). A pilot study evaluating predictors of postoperative outcomes after major abdominal surgery: Physiological capacity compared with the ASA physical status classification system. Br J Anaesth. 104: 465 - 471.

Hlatky MA, Boineau RE, Higginbotham MB, et al (1989). A brief self-administered questionnaire to determine functional capacity (The Duke Activity Status Index). American Journal of Cardiology 64: 651 – 654.

Jacob M, Lewsey JD, Sharpin C, Gimson A, Rela M, van der Meulen JH (2005). Systematic review and validation of prognostic models in liver transplantation. Liver Transpl 11: 814 - 825.

Jones LW, Eves ND, Mackey JR, et al (2007). Safety and feasibility of cardiopulmonary exercise testing in patients with advanced cancer. Lung Cancer 55: 225 – 232.

Jones LW, Eves ND, Peterson BL, et al, (2008). Safety and feasibility of aerobic training on cardiopulmonary function and quality of life in postsurgical non-small cell lung cancer patients: a pilot study. Cancer 113: 3430 – 3439.

Jones LW, Watson D, Herndon JE 2nd, et al (2010). Peak oxygen consumption and long-term all-cause mortality in non small cell lung cancer. Cancer 116: 4825 – 4832.

Jones L, Hornsby WE, Goetzinger A, Forbes LM, Sherrard EL, Quist M, et al (2012). Prognostic significance of functional capacity and exercise behavior in patients with metastatic non-small cell lung cancer. Lung Cancer 76: 248 – 252.

Junejo MA, Mason JM, Sheen AJ, Moore J, Foster P, Atkinson D, et al (2012). Cardiopulmonary exercise testing for preoperative risk assessment before hepatic resection. Brit J Surg, 99: 1097 – 1104.

Kaibori M, Ishizaki M, Matsui K, Nakatake R, Sakaguchi T, Habu D, Yoshiuchi S, Kimura Y, Kon AH. (2013). Assessment of preoperative exercise capacity in hepatocellular carcinoma patients with chronic liver injury undergoing hepatectomy. BMC Gastroenterology 13: 119

Kasymjanova G, Correa JA, Kreisman H, et al, (2009). Prognostic value of the six-minute walk in advanced non-small cell lung cancer. J Thorac Oncol, 4:602–7.

Kavanagh T, Mertens DJ, Hamm LF, et al (2003). Peak oxygen intake and cardiac mortality in women referred for cardiac rehabilitation. J Am Coll Cardiol. 42: 2139 - 2143.

Lai CW, Minto G, Challand CP, Hosie KB, Sneyd JR, Creanor S, Struthers RA (2013) Patients' inability to perform a preoperative cardiopulmonary exercise test or demonstrate an anaerobic threshold is associated with inferior outcomes after major colorectal surgery. Brit J Anaesthesia 111: 607 – 611.

Larsen KR, Svendsen UG, Milman N, Brenøe J, Petersen BN (1997). Exercise testing in the preoperative evaluation of patients with bronchogenic carcinoma. Eur Respir J. 10: 1559 - 1565.

Lee L, Schwartzman K, Carli F, Zavorsky GS, Li C, Charlebois P, Stein B, Liberman AS, Fried GM, Feldman LS (2013). The association of the distance walked in 6 min with pre-operative peak oxygen consumption and complications 1 month after colorectal resection. Anaesthesia. 68:811 - 816.

Lim E, Baldwin D, Beckles M, et al (2010). Guidelines on the radical management of patients with lung cancer. Thorax. 65 (suppl 3): iii1 – iii27.

Lustik SJ, Chhibber AK, Kolano JW, et al (1997). The hyperventilation of cirrhosis: Progesterone and estradiol effects. Hepatology 5: 55–58.

Marjanski T, Wnuk D, Bosakowski D, et al (2015) Patients who do not reach a distance of 500 m during the 6-min walk test have an increased risk of postoperative complications and prolonged hospital stay after lobectomy. Eur J Cardiothorac Surg. 47: e213 – e219.

Morales FJ, Martinez A, Mendez M, Agarrado A, Ortega F, Fernandez-Guerra J, Montemayor T, Burgos J (1999). A shuttle walk test for assessment of functional capacity in chronic heart failure. Am Heart J 138: 291 - 298.

Morales FJ, Montemayor T, Martinez A (2000). Shuttle versus six-minute walk test in the prediction of outcome in chronic heart failure. Int J Cardiol 76: 101 - 105.

Morice RC, Peters EJ, Ryan MB, et al, (1992) Exercise testing in the evaluation of patients at high risk for complications from lung resection. Chest, 101: 356 - 361.

Morris CK, Ueshima K, Kawaguchi T, Hideg A, Froelicher VF, (1991). The prognostic value of exercise capacity: a review of the literature. Am Heart J, 122: 1423 – 1431.

Moyes LH, McCaffer CJ, Carter RC, Fullarton GM, Mackay CK, Forshaw MJ (2013). Cardiopulmonary exercise testing as a predictor of complications in oesophagogastric cancer surgery. Ann R Coll Surg Engl. 95: 125 - 130.

Miyoshi S, Yoshimasu T, Hirai T, Hirai I, Maebeya S, Bessho T, Naito Y (2000). Exercise capacity of thoracotomy patients in the early postoperative period. Chest. 118: 384 - 390.

Nagamatsu Y, Shima I, Yamana H, Fujita H, Shirouzu K, Ishitake T (2001). Preoperative evaluation of cardiopulmonary reserve with the use of expired gas analysis during exercise testing in patients with squamous cell carcinoma of the thoracic esophagus. J Thorac Cardiovasc Surg. 121: 1064 - 1068.

Nakagawa T, Chiba N, Saito M, et al (2014). Clinical relevance of decreased oxygen saturation during 6-min walk test in preoperative physiologic assessment for lung cancer surgery. Gen Thorac Cardiovasc Surg. 62: 620 – 626.

Nakagawa K, Nakahara K, Miyoshi S and Kawashima Y (1992). Oxygen transport during incremental exercise load as a predictor of operative risk in lung cancer patients. Chest 101: 1369 - 1375.

Neviere R, Edme JL, Montaigne D, Boleslawski E, Pruvot FR, Dharancy S (2014). Prognostic implications of preoperative aerobic capacity and exercise oscillatory ventilation after liver transplantation. Am J Transplant. 14: 88 - 95.

Nikolić I, Majerić-Kogler V, Plavec D, Maloča I, Slobodnjak Z, (2008). Stairs Climbing Test with Pulse Oximetry as Predictor of Early Postoperative Complications in Functionally Impaired Patients with Lung Cancer and Elective Lung Surgery: Prospective Trial of Consecutive Series of Patient. Croat Med J. 49: 50 – 57.

Nugent AM, Riley M, Megarry J, O'Reilly MJ, MacMahon J, Lowry R (1998). Cardiopulmonary exercise testing in the pre-operative assessment of patients for repair of abdominal aortic aneurysm. Ir J Med Sci 167: 238 - 241.

Older P, Smith R, Courtney P, Hone R (1993). Preoperative evaluation of cardiac failure and ischemia in elderly patients by cardiopulmonary exercise testing. Chest 104: 701 – 704

Older P, Hall A, Hader R (1999). Cardiopulmonary exercise testing as a screening test for perioperative management of major surgery in the elderly. Chest 116: 355 – 362.

Olsen GN, Weiman DS, Bolton JW, Gass GD, McLain WC, Schoonover GA (1989). Submaximal invasive exercise testing and quantitative lung scanning in the evaluation for tolerance of lung resection. Chest 95: 267 – 273.

Olsen GN, Bolton JWR, Weisman DS, Hornung CA (1991). Stair climbing as an exercise test to predict the postoperative complications of lung resection: two years' experience. Chest 99: 587 – 590.

Pai MP, Paloucek FP (2000). The origin of the ''ideal'' body weight equations. Ann Pharmacother 34: 1066 - 1069.

Passino C, Giannoni A, Mannucci F, et al (2012). Abnormal hyperventilation in patients with hepatic cirrhosis: Role of enhanced chemosensitivity to carbon dioxide. Int J Cardiol 154: 22 – 26.

Pate P, Tenholder MF, Griffin JP, et al (1996). Preoperative assessment of the high-risk patient for lung resection. Ann Thorac Surg 61: 1494 – 1500.

Pearson S, Hassen T, Spark JI, Cabot J, Cowled P, Fitridge R (2005). Endovascular repair of abdominal aortic aneurysm reduces intraoperative cortisol and perioperative morbidity. J Vasc Surg 41: 919 – 925.

Pollock M, Roa J, Benditt J, Celli B (1993). Estimation of ventilatory reserve by stair climbing. A study in patients with chronic airflow obstruction. Chest 104: 1378 – 1383.

Prentis JM, Manas DM, Trenell MI, Hudson M, Jones DJ, Snowden CP (2012b). Submaximal cardiopulmonary exercise testing predicts 90-day survival after liver transplantation. Liver Transpl 18: 152 - 159.

Rao V, Todd TRJ, Kuus A, Buth KJ, Pearson FG (1995). Exercise oximetry versus spirometry in the assessment of risk prior to lung resection. Ann Thorac Surg 60: 603 - 609.

Reddy S, Contreras CM, Singletary B, Bradford TM, Waldrop MG, Mims AH, Smedley WA, Swords JA, Wang TN, Heslin MJ (2016). Timed Stair Climbing Is the Single Strongest Predictor of Perioperative Complications in Patients Undergoing Abdominal Surgery. J Am Coll Surg. 222: 559 - 566.

Reilly DF, McNeely J, Doerner D, et al (1999). Self-reported exercise tolerance and the risk of serious perioperative complications. Archives of Internal Medicine 159: 2185 – 2192.

Reilly DF, McNeely J, Doerner D, et al (1999). Self-reported exercise tolerance and the risk of serious perioperative complications. Archives of Internal Medicine 159: 2185 – 2192.

Salatash K, Sternbergh WC, York JM, Money SR (2001). Comparison of open transabdominal AAA repair with endovascular AAA repair in reduction of the postoperative stress response. Ann Vasc Surg 15: 53 – 59.

Sculier JP, Chansky K, Crowley JJ, et al (2008). The impact of additional prognostic factors on survival and their relationship with the anatomical extent of disease expressed by the 6th Edition of the TNM Classification of Malignant Tumours and the proposals for the 7th Edition. J Thorac Oncol. 3: 457 – 466.

Silverstein PR, Caldera DL, Cullen DJ, Davison JK, Darling RC, Emerson CW (1979). Avoiding the hemodynamic consequences of aortic cross-clamping and unclamping. Anesthesiology 50: 462 – 466.

Singh SJ, Morgan MD, Scott S, Walters D, Hardman AE (1992). Development of a shuttle walking test of disability in patients with chronic airways obstruction. Thorax 47: 1019 - 1024.

Singh SJ, Morgan MD, Hardman AE, Rowe C, Bardsley PA (1994). Comparison of oxygen uptake during a conventional treadmill test and the shuttle walking test in chronic airflow limitation. Eur Respir J. 7: 2016 - 2020.

Smith TP, Kinasewitz GT, Tucker WY, Spillers WP, George RB, (1984). Exercise capacity as a predictor of post-thoracotomy morbidity. Am Rev Respir Dis 129: 730 - 734.

Spurway NC (1992). Aerobic exercise, anaerobic exercise and the lactate threshold. British Medical Bulletin 48: 569 – 591.

Struthers R, Erasmus P, Holmes K, Warman P, Collingwood A, Sneyd JR (2008). Assessing fitness for surgery: a comparison of questionnaire, incremental shuttle walk, and cardiopulmonary exercise testing in general surgical patients. Br J Anaesth 101: 774 - 780.

Sun XG, Hansen JE, Beshai JF, Wasserman K (2010). Oscillatory breathing and exercise gas exchange abnormalities prognosticate early mortality and morbidity in heart failure. J Am Coll Cardiol. 55: 1814 - 1823.

Sun XG, Hansen JE, Stringer WW (2012). Oxygen uptake efficiency plateau best predicts early death in heart failure. Chest. 141: 1284 - 1294.

Swart M, Carlisle JB (2012). Case-controlled study of critical care or surgical ward care after elective open colorectal surgery. Br J Surg 99: 295 – 299.

Swinburn CR, Wakefield JM, Jones PW (1985). Performance, ventilation, and oxygen consumption in three different types of exercise test in patients with chronic obstructive lung disease. Thorax 40: 581 – 586.

Thompson AR, Peters N, Lovegrove RE, Ledwidge S, Kitching A, Magee TR, et al (2011). Cardiopulmonary exercise testing provides a predictive tool for early and late outcomes in abdominal aortic aneurysm patients. Ann R Coll Surg Engl 93: 474 - 481.

Ting SM, Iqbal H, Hamborg T, Imray CH, Hewins S, Banerjee P, Bland R, Higgins R, Zehnder D (2013). Reduced functional measure of cardiovascular reserve predicts admission to critical care unit following kidney transplantation. PLoS One. 8: e64335.

Ting SM, Iqbal H, Kanji H, Hamborg T, Aldridge N, Krishnan N, Imray CH, Banerjee P, Bland R, Higgins R, Zehnder D (2014). Functional cardiovascular reserve predicts survival pre-kidney and post-kidney transplantation. J Am Soc Nephrol. 25: 187 - 195.

Tolchard S, Angell J, Pyke M, Lewis S, Dodds N, Darweish A, White P, Gillatt D (2015). Cardiopulmonary reserve as determined by cardiopulmonary exercise testing correlates with length of stay and predicts complications after radical cystectomy. BJU Int. 115: 554 - 561.

Ussetti P, Roca J, Agustı AGN, Rodriguez-Roisin R, Heras M, Catala M, et al (1988). Failure of exercise tolerance and hemodynamic studies to predict early post-thoracotomy morbidity and mortality. Am Rev Respir Dis A94

Vacanti C, van Houten R, Hill R (1970). A statistical analysis of the relationship of physical status to postoperative mortality in 68,388 cases. Anesth Analg (Cleve) 49: 564 – 566.

Van Norstrand D, Kjeslberg MO, Humphrey EW, (1968). Preresectional evaluation of risk from pneumonectomy. Surg Gynecol Obstet, 127: 306 – 312.

Varela G, Cordovilla R, Jimenez MF, Novoa N, (2001). Utility of standardized exercise oximetry to predict cardiopulmonary morbidity after lung resection. Eur J Cardiothorac Surg, 19: 351 - 354.

Villani F, Busia A (2004). Preoperative evaluation of patients submitted to pneumonectomy for lung carcinoma: role of exercise testing. Tumori. 90: 405 - 409.

Wagner PD, (1992). Ventilation-perfusion matching during exercise. Chest 101: 192S - 198S.

Wasserman K, Hansen JE, Sue DY, Stringer WW, Sietsema KE, Sun X-G, Whipp BJ (2012). Principles of Exercise Testing and Interpretation: Including Pathophysiology and Clinical Applications, Lippincott Williams and Wilkins, Philadelphia.

Waxman K (1987). Hemodynamic and metabolic changes during and following operation. Crit Care Clin 3: 241 – 250.

Wiklund RA, Stein HD, Rosenbaum SH, (2001). Activities of daily living and cardiovascular complications following elective, noncardiac surgery. Yale J Biol Med, 74: 75 – 87.

Wilson RJT, Davies S, Yates D, Redman J, Stone M (2010). Impaired functional capacity is associated with all-cause mortality after major elective intra-abdominal surgery. Br J Anaesth 105: 297 – 303.

Win T, Jackson A, Groves AM, Sharples LD, Charman SC, Laroche CM (2006). Comparison of shuttle walk with measured peak oxygen consumption in patients with operable lung cancer. Thorax 61: 57 - 60.

Matt Rutter
Alan Moore
Brendan Cooper

ON THE BLOWER

This edition of 'On the blower' has a past and future feel. Alan is continuing his series of looking forward to new emerging products and where we might be headed to with the diagnostic tests of the future, while Vitalograph have kindly supplied a historical look back at spirometry and how their company came to be involved.

Changes to the manufacturer liaison committee

It is with regret that I announce that Tom Kelly has had to step away from the Manufacturers Liaison Committee (MLC). In his short term, he managed to have a positive impact for both the ARTP and manufacturers. We are continuing in his footsteps to update our processes and ensure everyone benefits from the close relationship that the ARTP has with the manufacturers. Although Tom has left, he will not be completely absent as he has taken up a new role with Philips Respironics and of course we wish him all the best.

As a result of this I have stepped up from the role of deputy, albeit a lot sooner than I expected, so bear with me while I find my feet. It has already been a steep learning curve.

Manufacturers Survey

As many of you aware, the manufacturers survey was sent out having been presented at the National Strategy Day. Please take the time to read the email and complete the survey as both the ARTP and the manufacturers rely on your feedback. With only a few weeks until the 1st of January deadline, time is running out. This years survey has the added bonus that one lucky individual from the first 100 responders could win free conference registration.

MR

ON THE BLOWER

Carrying on from my new technology theme in the last issue I intend over the next couple of issues to bring details of new technologies in the spirometry field. For this issue I will concentrate on a recent effort from Scandinavia, Air Smart

AIR SMART OR NOT SO SMART?

Air Smart is a new concept in spirometer design from Swedish company Pond Healthcare Innovation AB. Well, what is so different about this spirometer? Quite a lot actually but, my goodness, as you will see from the picture on the right, there doesn't appear to be a lot to it.

It is nicely packaged in a swish box – medical companies are swiftly learning from companies like Apple that packaging creates a lasting impression.

The turbine sensor with the cardboard mouthpiece looks a bit familiar though and, yes it is. Pond Healthcare have not set out to reinvent the wheel. They have chosen to use the FlowMIR single patient use disposable turbine from MIR which has been around now for a few years and, to date, over 9 million of them have been sold. The cost of a FlowMIR is around the £1 mark or less if you buy in larger quantities.

If you look carefully at the picture again you will see what looks like a headphone jack plug and you'd be correct. So, where does that headphone jack plug into? Quite simply, your iPhone or some Android devices (but not all Android devices). Well, it did plug into all iPhones but, thanks to Apple Innovation, the iPhone 7 does not have a headphone socket as they want to flog you very expensive and useless Wireless Headphones. I will digress for a moment from medical technology but bluetooth simply cannot carry the required frequency spectrum to give anywhere near as good a sound as wired headphones. So, Wireless Beats sound even worse than Wired Beats.

I understand however that every iPhone 7 now comes with a Lightning connector to 3.5mm headphone jack adaptor. Pond Healthcare's web site does seem to need a little updating and presently the device states compatibility from iPhone 4s through iPhone 6s so prospective purchasers need to check carefully.

The software comes from the usual App stores and is called 'Air Smart Spirometer'. It is a free App with no in-App purchases. The current version for iPhone or iPad is 1.13 which gives you FEV_1, FVC, FEV_1/FVC and PEF. Earlier versions for some bizarre reason didn't give PEF. So, no Relaxed VC, no LLN or Standardised Residuals, just good old % Predicted and the reference set inbuilt in the App is NHANES III which is fine for the American market but not for any other world sector. The manual states that it displays

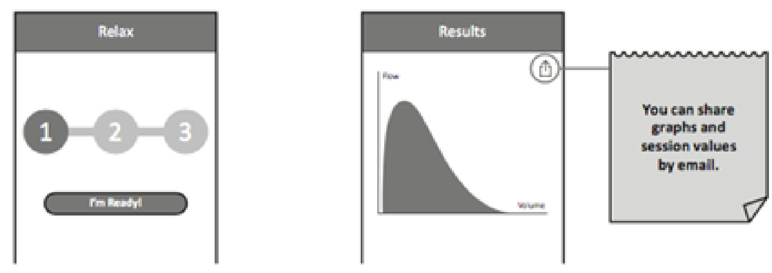
all FV curves performed. Maximum recording time per trial is 15 seconds; which is the minimum recording time recommended for a forced breath by the ATS-ERS 2005 standard. Perversely if you do not expire for at least 6 seconds the device will automatically display an error message and ask you to repeat the measurement. The interpretation algorithm provided by Pond Healthcare is outdated.

Is this a gimmick device or is it intended to be a serious player? How does it work? Well, it uses the microphone feature in the headphone socket and the pulses are read in as a pulsed audio signal which is then decoded by the software. Yes, it is intended as a serious device but for patients to monitor their own spirometry.

Yes, it is intended as a serious device but for patients to monitor their own spirometry.

Pond Healthcare state that the device is 'CE certified as a Class II Medical Device and developed according to the ISO-26782 standards', which is the ISO standard for spirometers. It costs €68 which is about £56 at current exchange rates. The transducer is of the traditional infra-red beam interruption type and is powered by an indwelling CR2 Lithium battery.

Are there any snags with the device? Pond Healthcare claim that they have already sold over 20,000 units which is considerable. But here comes the rub. Very cleverly when you look at the specification, Pond Healthcare reckon the product life is only 2 years or around 1000 tests. The reason for this is that, very craftily, you cannot change the CR2 Lithium battery. As the manual states *'If your device is more than 2 years old or has been used over a thousand times, the battery could be drained. You can purchase a*



When the first test is completed, rest for 15 to 30 seconds before tapping *I'm ready!*

Once you have performed all the tests included in the session, the final results will be displayed.

new spirometer at www.smartspirometry.com'. So, there you have it; a short life span at a low cost device. 1000 tests actually means 1000 trials which equates as we know to a rather smaller number of patient tests. Very clever indeed and this use of life limiting features is starting to appear on a good number of previously low cost medical devices. Indeed in the software setup you can select the number of trials permissible from 1 to 5 per event.

Does the device meet the requirements of the ATS-ERS 2005 standard? Well, actually it doesn't as a minimum of 8 trials have to be permitted and it must also measure relaxed VC. Funnily enough, the ISO standard for spirometers, ISO-26782, lets manufacturers off the hook in some respects and that is why there are now a whole host of cheap spirometers which don't measure everything required.

Pond Healthcare advise that the device compares favourably to the MIR MiniSPIR:

'To validate Air Smart Spirometer performance, we connected the device in parallel to an ERS/ATS approved spirometer (MiniSpir®). In this set up, both devices received the same air flow at the same time. The obtained results for FVC and FEV_1 was plotted on a graph and the correlation coefficient (r) was calculated. The correlation between Air Smart Spirometer and MiniSpir® was excellent with R2 values of 0.999 for FEV_1 and 0.991 for FVC.'

It is a real shame that Pond Healthcare has not evaluated the performance of the device as recommended in the ATS-ERS 2005 standard. The method used is simply not acceptable as a solid piece of science.

For every 10 devices sold the company will donate one to a needy cause.

For those tempted to rush out and buy one for testing patients in more remote locations, there are huge information governance issues here as the data can be shared publicly. Indeed that is regarded by Pond Healthcare as a key feature. Perhaps Sweden is more liberal with medical data than we are in the UK. Further information can be found at www.smartspirometry.com.

ON THE BLOWER

As the old saying goes, 'Caveat Emptor'. What we have here is innovative is of technology let down badly by a lack of knowledge from the manufacturing company about the basics of spirometry. Things will improve, no doubt, with Version 2 if this version continues to sell well. We live in an increasingly consumer world and these low cost 'medical devices' are good earners.

AM

Well we were all impressed with Alan's glimpse of the future in his last "Beam me up, Scottie" article. With it being 50 years next year since its launch, I recently decided to watch a DVD of Stanley Kubrick's **"2001: Space Odyssey"**. For those not familiar with this masterpiece of science fiction it shows the step-changes in the evolution of man as *"tool user"* to *"computer designer"* to conquer the Universe. Many of the film's concepts and ideas were later used in Star Wars, Star Trek and even Red Dwarf! One of the scenes in the middle of the film is a key character travelling on a Concorde-like Space Shuttle (which has happened) to a manned orbiting space station (which has sort of happened) but a shot down the cabin of this "plane" shows flat screen monitors in every seat back! (normal for long haul now!). A bit later on in the film, two astronauts are working at a desk , both with flat computer tablets! This was 1967! Whilst many projections into the future get things badly wrong, just every now and then they are truly prophetic. I wonder how many visions of respiratory physiology have come to fruition? **For the next edition of On The Blower we are looking to ARTP members to write what they anticipate to be the lung function and sleep physiology service of the future.** Why not be imaginative over Christmas and write your thoughts and extrapolations down and send them in for this special article. Whilst this may be an opportunity to have some fun exaggerating current issues, it may also be good to see if we can look back in ten years and see if a few of them come to reality. **"2051: Spacer Physiology"**, perhaps.

BC

The next article was provided by Vitalograph, from a recent publication in the Journal of Occupational Health & Wellbeing. For more details on the Vitalograph story booklet, please contact Vitalograph.

MR

History of Spirometry—The Vitalograph Story

A new publication on lung function screening by a leading manufacturer of spirometry equipment traces its history from Roman times to the latest hand-held technology. Noel O'Reilly reports in the Journal of Occupational Health & Wellbeing.

Spirometry – the use of devices to measure lung capacity – is a frequent topic among occupational health (OH) practitioners. Online forums host conversations about the standards, guidance and evidence base for practice, the legal requirements for recording results, the level and frequency of training needed to use the equipment and the need to screen workers for new kinds of workplace exposures.

Now, one of the leading spirometry equipment suppliers has published a booklet on the history of lung function testing, including, of course, its own part in the story.

"The Vitalograph Story"[*] covers the company's first 50 years, but also touches on earlier pioneers.

It might surprise you to discover that Greek philosopher and physician Claudius Galen performed an experiment on human ventilation around 150AD, when he persuaded a child to breathe in and out of a bladder. But it was the physician John Hutchinson who built the first spirometer in 1846, an inverted bell floating on water. Hutchinson coined the phrase "vital capacity", which is well known to OH practitioners and OH journal editors. Water-seal spirometers are still used today.

[*]Ed. This article does not indicate that ARTP condones all views expressed in the book. The reader is pointed towards an independent and unbiased review of the many other spirometers available from other companies 'Spirometry then & now.', Gibson GJ, ERS Breathe 2005; **1**: 206-16.

ON THE BLOWER

The founders of Garthur, the company that was to become Vitalograph, were Dietmar Garbe and Margaret Gardiner. They became distributors of German medical device companies in the UK in the 1950s.

Their specialisation in cardio-respiratory diagnostics and therapy began when they started distributing iron lungs and ventilators to help polio victims breathe. One of the colourful incidents in the book relates to how, in 1961, a ventilator device was sent from Buckingham Palace to the London Hospital to save Elizabeth Taylor from double pneumonia, which she caught while filming the movie *"Cleopatra"*.

The current managing director is Bernard Garbe, whose parents were inspired to start the company partly because Bernard suffered from asthma. In 1962, they were asked by the Medical Research Council Pneumoconiosis Panel to develop a simple mobile spirometer to screen coal miners for "black lung". The invention that followed made it possible to undertake spirometry in occupational health and primary care settings, and set the scene for generations of OH nurses and doctors to carry out lung function screening ever since.

The company only began manufacturing the equipment after failing to find an existing medical devices company to produce it under licence. The portability of the new spirometer, and its ease of use and relatively simple calibration, meant its use grew rapidly. Physicians and technicians were able to instantly assess results and inform the patient, which had not been possible with the more cumbersome spirometers in laboratories.

The company exported equipment to Germany, Ireland and the US – there is a Vitalograph office in Kansas City.

As technology developed, so did the spirometer, with the introduction of electronics in the 1970s, before the widespread use of computers. The use of computer software followed in 1980. In the early 1980s, Japanese companies began to innovate with flow-measuring spirometers, which led Vitalograph to develop its own version after rejecting many forms of flow-measuring technology. The booklet discusses the issue of accuracy in flow-sensing spirometers and the failure of some equipment to pass the test of the international spirometry standard ISO 26782:2009.

Innovations followed throughout the 1980s through to the new century, including the first global, centralised data clinical trial in 2003. In 2009, the company launched a hand-held spirometer and electronic diary, including automatic synchronisation with a database, customised questionnaires, and remote data transmission by mobile phone or a land line.

This, and other technology, means that lung function screening can move out of the office to other locations.

The company has branched out beyond spirometry to electrocardiographs, audiometry, pulse oximetry, chronic obstructive pulmonary disease (COPD) assessment, blood pressure measurement and other forms of testing.

ON THE BLOWER

From around the companies

RemServe have a new product called ***SoClean***.

An Automated Cleaning Cycle, sanitises by safely creating a dry sealed flow pathway of activated oxygen (O_3) through CPAP, Bilevel and similar devices, including humidifiers, hoses and mask. It fits all popular mask types, CPAP and NIV machines.

SoClean eliminates 99.9% of CPAP bacteria, viruses, and mould safely and naturally with no water or chemicals. The activated oxygen disinfects equipment and naturally breaks down to regular oxygen within two hours. Additionally, any excess activated oxygen passes through a filter which converts it back to regular oxygen before release.

The same sanitising technology is safely used on produce and drinking water.

http://socleansolutions.co.uk/how-does-it-work/clinical-tests

http://www.socleansolutions.co.uk/wp-content/uploads/2015/09/soclean2_manual_UK.pdf

ResMed (UK) Ltd has recently welcomed **Emma Cooke** (*Clinical Applications Specialist*) and **Phil Stephens** (*Account Manager*) to the North West territories, whilst being busy bringing new products to market.

December 2016 will see the start of the roll-out of the highly anticipated enhancement to ***AirView*** in the form of 'Action Groups' – designed to help manage your patient population more efficiently, as well as some new interesting insights into ***myAir***, ResMed's patient engagement application and how it can improve patient compliance. All this follows the successful launch of the ***AirFit 20*** series of Masks in November which have already started to make a huge impression with clinicians and patients alike. The new ***InfinitySeal*** cushion used in the ***AirFit F20*** and ***N20*** helps deliver the fit range of 96.5% and 99.4% respectively, and are in fact the most tested masks ever launched by ResMed.

ResMed will once again be supporting the annual conference in Belfast this January, so we invite everyone who is attending to come along to take a closer look at our new products for real or by using our Virtual Reality headsets!

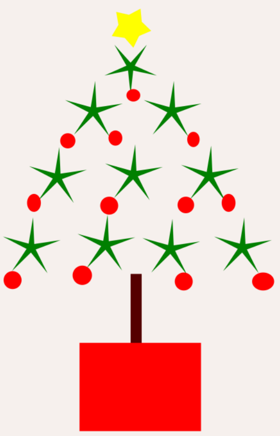
nSpire Health have launched ***Iris™*** Integrated Respiratory Information System (IRIS), which brings relevant respiratory data together in one place, empowering respiratory professionals to efficiently analyse and optimally diagnose and manage respiratory disease.

Iris™ Decision a component of ***Iris™*** is a modular respiratory care workstation designed to provide actionable, streamlined information to consultants and physiologists in order to better care for their patients. The Interpretation Module is the first released component.

The ***Iris™ Decision Interpretation Module*** uses the power of Iris to present all relevant clinical and diagnostic respiratory data together in one place for enhanced interpretations with high confidence of accuracy. View relevant data from multiple sources including PFT, Spirometry, pre/post test questionnaires, and test results from other respiratory devices to provide an interpretation based on the complete picture of your patient's health. Interpretation workflow is simplified, allowing you to quickly review, interpret, digitally sign, and send test results from any source to the EMR/HIS using a single interface.

Also launched are the next generation of the *HDpft* systems the *KoKo® Px* lung function systems and *KoKo® Sx* spirometers. They are designed with the user and patient experience in mind, making them easier to use, faster and more reliable. *KoKo* combines the latest gas analysing and flow sensing technologies with robust reporting capabilities and an intuitive user interface, seamlessly integrated with *Iris™* delivering unparalleled workflow and EMR/HIS interoperability.

MR



At CareFusion, we have always been united in our vision to improve the safety and lower the cost of healthcare for generations to come. We are passionate about healthcare and helping those that deliver it.

With that in mind CareFusion/BD and Apax Partners are pleased to announce the launch of our joint venture as a stand-alone, global respiratory company, Vyaire Medical. Vyaire Medical will continue with our vision by becoming the world's largest pure-play "breathing company". This pure respiratory "startup" company comes with a 65-year proven track record of pioneering, innovating, and advancing respiratory diagnostics, ventilation, and anesthesia delivery & patient monitoring.

Vyaire Medical, comprises all of CareFusion's Respiratory Solutions business lines, including Ventilation, Respiratory Diagnostics, Vital Signs and AirLife. From industry-pioneering brands like Jaeger, Micro Medical and Sensormedics to respected industry leaders like AirLife,® Vital Signs,® Viasys, and many others.

Vyaire Medical has more than 5,000 employees globally, all focused on a shared purpose of closely collaborating with healthcare providers and institutions to deliver world-class products, support, and services that contribute to the overall health and wellness of society.

As a singular, highly focused Respiratory company, Vyaire Medical is fully dedicated to bringing new respiratory and anaesthesia innovations and unparalleled customer service to you and the patients you serve. We will continue to focus on the needs of healthcare providers, investing in product innovation to bring new ideas and concepts to market that improve patient outcomes and address unmet clinical needs.

We are excited by the future of Vyaire Medical and the possibilities this new company creates. We remain committed to delivering the high quality products and service that you have come to expect from CareFusion and we look forward to continuing to serve you.

You will continue to be supported by our UK team of 14 individuals, including a dedicated clinical application and IT/Connectivity specialist and a team of clinical physiologist account managers, all committed to the UK Respiratory Diagnostics division and focused on providing best in class service for our customers.

Association of Respiratory Technicians & Physiologists

FROM THE ARCHIVE:

ARTP members can view archive issues of Inspire/ Breath at: http://artp.org.uk/en/members-area/inspire-journal/inspire-archive/index.cfm

ISSUE No. 4: March 1977

NEWSLETTER

Editors: DCS Hutchinson
MF Clay

Chest Unit
King's College Hospital Medical School
Denmark Hill, London, SE5 6RX

Association of Respiratory Technicians & Physiologists

CHRONIC AIRFLOW OBSTRUCTION

The Hammersmith Survey

What are the main causes of chronic airflow obstruction?

What proportion of smokers develop severe chronic lung disease?

Is there any point in trying to persuade people to give up smoking?

- Just three questions among many one could ask on this subject.

There are no short cuts in trying to find the answers as one soon becomes aware when studying the results of many years of painstaking work by Professor Charles Fletcher and his colleagues at the Hammersmith Hospital*. The authors describe a follow-up study of 792 men over an eight year period, with a mass of information including clinical symptoms, smoking habits and measurements of lung function. The men, all volunteers, were in full-time work either in a large office or in an engineering works.

Cigarette smoking, as one perhaps might have expected, far outweighed other factors as a cause of chronic airflow obstruction in the group. In fact not a single man among 103 life-time non-smokers developed significant airflow obstruction, and of particular interest is the fact that about 80% of the smokers themselves completely got away with it as well.

So it looks as if a minority of people have a special susceptibility to cigarette smoke, the rate of decline of their FEV over the years being twice as great as in their luckier work-mates. There is no suggestion of course that this group is any more or less likely to develop other cigarette-related diseases such as lung cancer or coronary artery disease.

Is it any good giving up smoking once lung damage has developed? The answer is YES! The rate of deterioration goes back to the level found in non-smokers although little of the damage can be reversed.

This large study was naturally a team effort with technicians, statisticians and clinicians all playing a part. From the technical point of view, the 792 men attended six monthly for 8 years and 5 measurements of FEV were obtained at each attendance, making a grand total of ^3,360! (The number of inches in a mil, you will have noticed).

The FEV's were measured by nurses and technicians, and it is worth noting the attention to detail that went into this aspect. The accuracy of the spirometers was checked every day; 21 different observers took part during the study, and "before each new observer;s observations were accepted, he or she and an established observer made independent duplicate recordings of FEV and obtained answers to the routine questionnaires on 40 subjects ….. And any technical errors thus disclosed were discussed with the new observer and corrected".

It would take some time to assimilate all the information in this book, particularly the statistical sections! Each chapter is, however, provided with a good summary and a final chapter setting out the main conclusions rounds it all off. The price isn't too bad for these days.

* The natural history of chronic bronchitis and emphysema: by Charles Fletcher, Richard Peto, Cecily Tinker and Frank E. Speizer.

Pub. Oxford University Press 1976. Price £9.00

O-O-o-O-o-O-o

Manufacturers haven't exactly been falling over themselves to place advertisements in this Newsletter so we decided to put in one of our own:

Quality Assured Spirometry

September 12th 2016 saw the launch of a competency assessment framework *'Quality Assured Spirometry'*. This document sets the minimum competency standards for practitioners performing spirometry. The ARTP spirometry qualifications are now the recognised competency assessment qualifications for all practitioners performing spirometry. The ARTP will also be responsible for holding the national register of spirometry accredited practitioners at all levels. The document can be accessed via the link http://www.pcc-cic.org.uk/news/improving-quality-diagnostic-spirometry-adults. The framework will be phased in commencing 1st April 2017 with full implementation by 31.3.2021.

This document has been brought about by a collaboration between ARTP, Education for Health, ARNS, Asthma UK, BLF, BTS and PCRS and has been endorsed by NHS England.

This is a really important day for Respiratory Physiology and the ARTP as we continue to promote quality standards in the measurement of spirometry. We are looking to further support this initiative with additional spirometry education resources such as the soon to be published Spirometry Handbook and online educational resources.

Joanna Shakespeare
Chair ARTP Education

ARTP Standards welcomes the publication of the competency framework for diagnostic spirometry in adults, which is a direct result of the All Parliamentary Group (APPG) Report on premature mortality from respiratory disease (2014). The document looks to implement many of the recommendations of the APPG, which includes a common curriculum, quality training, and assessment of healthcare professionals against defined standards and the creation of a national register.

ARTP Standards endorses this initiative which contributes to quality assured, accurate spirometry performed to a national standard that ultimately aid accurate diagnosis of respiratory disease.

Ian Cliff
Chair ARTP Standards

Joint News Release

Representatives of the Registration Council for Clinical Physiologists (RCCP) Council and its professional body members met with the Board members of the Academy of Healthcare Science (AHCS) on the 16th November 2016.

The aims of the board to board meeting were to consider areas of mutual interest and to see where the organisations might work together and in doing so look at where there may be benefit to patient safety, public confidence and provide clarity for the professionals, profession, employers and educators.

Building on earlier discussions, at the conclusion of a successful meeting, both organisations requested that the CEOs work together on developing plans and options which will create a robust, integrated regulatory framework focused on maintaining and improving standards for all registrants of the relevant professions and specialisms. This will involve a number of facilitated workshops and focussed discussions.

The Boards will meet again in the new year to formalise and agree the way forward.

- The AHCS, Academy for Health Care Science is the uniting voice of the diverse UK Healthcare Science workforce, working alongside a diverse range of professional bodies to bring together a wide range of scientific disciplines: AHCS takes a proactive role in the identification of issues of concern to patients and the profession and supports the highest standards of patient care. It provides an Accredited Register, equivalence and the Certificate of Attainment and Certificate of Equivalence for the scientist training programme.
- The RCCP campaigns for patients safety and holds a voluntary register for the disciplines of Audiologists (including Hearing Therapists), Cardiac Physiologists, Gastro-intestinal Physiologists, Neurophysiologists, Respiratory Physiologists and Sleep Physiologists.
- For further information please contact:
  Janet Monkman, CEO of AHCS on 07592 803609 janet.monkman@ahcs.ac.uk or
  Paul Sharpe CEO of RCCP on 07973 545146 or chief exec@rccp.co.uk

ARTP | Association for Respiratory Technology & Physiology

Rationale for a move to payment by treatment function code

For a number of years we have been striving to achieve appropriate coding, recognition of activity and attraction of income for the important work we do in respiratory and sleep physiology. Under the expert guidance of Dr Martin Allen, Consultant Respiratory and Sleep Consultant and lead of the Respiratory Expert Working Group at The Information Centre, we are in a far better position than many of our physiological diagnostic colleagues. However, there is still some work to do and in collaboration with the casemix office we are working on unbundling respiratory and sleep physiological tariffs from respiratory medicine consultations. While this work progresses there is an opportunity for greater recognition of the work we do via the utilisation of our dedicated treatment function code. In the below document Dr Allen expertly outlines the rationale behind this change.

https://gallery.mailchimp.com/09570500787e3840eed674993/files/Rationale_for_TFC_final_MA_JC.pdf

I urge you all to follow this guidance, get in contact with your finance teams and ensure you are all being appropriately recognised for the outstanding work you all do.

Dr. Karl Sylvester
ARTP Chair

ARTP Association for Respiratory Technology & Physiology

UK Inhaler Group

Blue inhalers save lives – standard colour needed to prevent asthma deaths

Patients' lives could be put at risk if pharmaceutical companies stray away from the widely recognised colour coding of inhalers used to treat asthma.

That's according to UK Inhaler Group (UKIG), which has published the findings of its survey of 3,000 healthcare professionals and patients. The survey sought to determine the importance of coloured labelling on inhalers used in the treatment of asthma and COPD (Chronic Obstructive Pulmonary Disease). Now the group is calling for an official colour-code system for inhalers to prevent possible confusion over which inhaler to use in emergencies, which it says could put patients' lives at risk.

The survey of 2,127 patients with asthma and COPD and 596 healthcare professionals, is published 3 Nov in npj Primary Care Respiratory Medicine.

'Reliever' inhalers, the ones used in an emergency for instant relief, are traditionally coloured blue. The survey revealed 89 per cent of patients and 95 per cent of healthcare professionals frequently refer to the colour when discussing reliever medication.

However, this remains an unofficial colour-coding system. With the increase in inhaler types available, there is concern that blue may be used for inhalers not designed for emergency relief, and other colours used for quick relief medications. UKIG is concerned this could mean patients reach for the wrong inhaler in an emergency.

Comments from patients who took part in the survey included:

"My seven year old knows the blue one is for when I am having an attack. It's useful to tell people I need the blue one and quicker therefore to get the medicine I need."

"I am visually impaired and rely very much on the colour of my inhalers. It's also great to be able to say to my kids please fetch my blue inhaler for example and know they get the right one."

Lead Author Monica Fletcher, CEO of UK charity Education for Health and Chair of the UKIG, said: *"In an acute emergency, inhalers that work rapidly to open up the airways are lifesaving, particularly for asthma.*

"With a range of inhalers and new treatments available, it is vitally important for not only patients but their families and carers such as schoolteachers to know which one to use in an emergency. Our survey revealed that it is important to know what medications people take, but definition by colour is by far the preferred way to do this and could save lives."

Over the last two years two pharmaceutical companies that had planned to change the proposed colour of new inhalers and break this 'unofficial convention' decided not to after considerable lobbying from the group. UKIG is calling for all interested parties to agree a formal industry-wide approach to colour coding so that in the future it would not be possible for a blue inhaler to obtain a licence unless it is a reliever and inhalers not for rapid symptom relief will not be licensed if they are blue. Fletcher added: *"These results highlight the importance of colour and add to the debate about the need to formalise the colour coding of inhaled therapies. In particular, they show the need for using the colour blue for inhalers for rapid relief of symptoms.*

"We believe this survey should provide the impetus for all interested parties to discuss and agree a formal industry-

wide approach to colour coding of inhaled therapies for the benefit of patients, carers and healthcare professionals."

Dr Duncan Keeley, GP in Thame and policy lead for the Primary Care Respiratory Society UK, said clear communication is important if clinicians and patients are going to work together to ensure the patient's lung condition is as well controlled as possible.

He explained: *"With so many different compounds in inhalers, and patients often having more than one inhaler, referring to inhalers by their colour is obviously very helpful. And it also helps the people around the patient to know that the blue inhaler is the one that needs to be used in an emergency. So this is about safety - in a real emergency, when someone is struggling for breath, it is important that there is no room for confusion about which inhaler will have a rapid effect to relieve symptoms."*

Toby Capstick, Lead Respiratory Pharmacist at Leeds Teaching Hospitals NHS Trust said: *"There are a wide range of inhalers available for the treatment of asthma and COPD. Our survey has shown that patients rely on the colour of their inhalers to identify them rather than their names, which may be difficult to remember or pronounce.*
"There was a strong opinion across patients and healthcare professionals that the blue colour is important to identify reliever inhalers, so that they and friends or family can retrieve them in an emergency. However, there are also concerns that if blue colouring is used for preventer inhalers, which are taken regularly to control asthma and COPD, that this could cause patients to accidentally overuse their preventer inhalers potentially resulting in significant side effects.".

Useful background information:

- Is the 'blue' colour convention for inhaled reliever medications important? A UK-based survey of healthcare professionals and patients with airways disease, npj Primary Care Respiratory Medicine (2016) 26, 16081; doi:10.1038/npjpcrm.2016.81; published online 03 Nov 2016 http://www.nature.com/articles/npjpcrm201681
- UK Inhaler Group is a coalition of not-for-profit organisations and professional societies with a common interest in promoting the correct use of inhaled therapies. http://www.respiratoryfutures.org.uk/programmes/uk-inhaler-group/
- Education for Health is a leading UK-based educational charity, working to transform the lives of people living with long term health conditions. http://www.educationforhealth.org

Further information

please contact Jules Gaughan, Project Manager, UK Inhaler Group
jules@ukinhalergroup.org +44 (0)7817398351

COMMUNICATIONS

ARTP Association for Respiratory Technology & Physiology

ARTP held the annual Nation Strategy Day in October. The slides from the presentations are now available for ARTP members only from the website.

National Strategy Day 2016

Monday 17th October

Ricoh Arena, Phoenix Way, Coventry CV6 6GE

The ARTP National Strategy Day for Leaders in Respiratory/Sleep Physiology is a must attend for those leading services nationwide.

National Strategy Day 2016 - Draft Program

Below are PDF documents containing presentations given on the day (where we have the presenters permission to share):

Sessions 1 & 2

- 01 - Coding - Casemix Mixing Up the Cases - Dr. Martin Allen
- 02 - Latest in Sleep Technology - Sara Parsons
- 03 - E-Learning for the ARTP - Rhys Jefferies
- 04 - Continuing Professional Development - Natalie O'Reilly
- 05 - Impact of Quality Assured Spirometry Document - Dr. Vicky Moore
- 06a - The STP Experience In-Service Perspective - Darren Ramsay

Sessions 3 & 4

- 01 - ARTP Manufacturers Survey - Matt Rutter
- 02 - IQIPS Building on the Success - Joanna Shakespeare
- 03 - Ethics Committees - Are They Really Scary - Dr. Adrian Kendrick
- 04 - Administration of Prescription Medicines and Healthcare Scientists - Julie Lloyd
- 05 - Regulation and Registration - Janet Monkman & Paul Sharpe

ARTP Upcoming Courses

Basic Sleep Course

1st February 2017
Jury's Inn, Birmingham

This course is ideal for band 3-6 staff that may be part of an existing basic sleep service, or band 6 and above who wish to start a new service and want to cover all the basics.

This one day course will focus on the theory and practical aspects of sleep breathing disorders and will cover the physiology and pathophysiology of sleep breathing disorders, related diagnostics and their treatments.

The course will refer to ARTP SLEEP Guidelines on diagnosis and therapy and will also draw upon current and established evidence base.

To register, please click HERE

Masterclass

6th and 7th March 2017
Hilton Belfast

This course is aimed at A4C Bands 3-5 level staff as a stand alone assessment of professional competence. The course is designed to support the ARTP Practitioner and Associate professional examinations providing the candidate with all the underpinning knowledge required for these examinations.

To register, please click HERE

ARTP Association for Respiratory Technology & Physiology

Hospital treatment for children experiencing severe asthma attacks is 'very effective' - but better education and review is needed on discharge to reduce re-admission – new audit

Please see below details of a new audit published by the British Thoracic Society (BTS) investigating treatment during hospitalisation in children experiencing severe asthma attacks. ARTP are reassured by some of the outcomes of this audit, in particular the appropriateness of first line treatment in most children with acute asthma. We are pleased to see that evidence is provided of areas that can be improved. These include reducing environmental smoke exposure in these vulnerable children, ensuring each child has an asthma plan in place and inhaler technique is checked on every clinic visit. We strongly encourage all healthcare professionals working with children with asthma to read this audit and to consider smoking cessation advice for parents and carers, along with more checks regarding asthma care plans and inhaler technique.

Paul Burns
Chair, ARTP Paediatrics Committee

Children admitted to hospital with severe asthma attacks generally receive 'very effective and efficient' treatment and care - but a greater level of asthma education and review is need on discharge from hospital, to help prevent future attacks and readmission to hospital - according to a new national audit published Tuesday 29 November 2016 by the British Thoracic Society (BTS).

The BTS National Paediatric Asthma Audit reviewed over 5,500 sets of data in 153 hospitals and healthcare settings across the UK in November 2015, probing the quality of emergency care and outcomes for children (over the age of one) admitted to hospital with severe asthma attacks.

Positive areas highlighted in the audit include the following:

- Medical care of children with acute wheezing and asthma continues to be highly efficient and effective.
- Most children receive appropriate 'first line' rescue treatment and care.
- Hospital stays are short – more than seven in ten children were in hospital for one day or less - with a substantial proportion receiving care entirely within the emergency department.
- Second line treatment used for children with more severe attacks such as intravenous therapies or ventilation, and the use of the paediatric intensive care unit, were only required in a very small proportion of children.

Key areas of concern highlighted in the audit include the following:

- Exposure to environmental tobacco smoke (ETS) was reported in nearly a third (32%) of children. The audit authors believe this level is worrying as tobacco smoke is known to be a key trigger for asthma attacks that require hospital admission. A significant proportion of hospitals did not provide data on this question, suggesting that clinical teams may need to pay greater attention to asking about exposure to tobacco smoke.

The authors point to the need for healthcare professionals to always discuss the issue of environmental tobacco smoke with parents or carers and, where appropriate, provide education about the role of tobacco smoke in worsening asthma, and the pivotal need to minimise exposure in children. Smoking cessation support should also be given as appropriate.

- Chest X-rays and antibiotics were used more frequently than evidence suggests is appropriate.
- Most aspects of discharge from hospital are less than optimal with fewer than six in ten (56%) children and families/carers being given a personal asthma action plan. Furthermore, only four in ten (42%) of children were reported to have had their asthma inhaler technique assessed.

The provision of, and adherence to, action plans has been shown to improve an individual's control of their asthma and reduce the number of 'attacks' needing admission to hospital. Experts believe inadequate discharge procedures could be contributing to the current hospital re-admission rate of 15%.

- Contrary to national guidance, only 24% of families/carers and their children were advised to visit their GP within two working days after discharge from hospital.

Commenting on the report, Dr James Paton, Reader in Paediatric Respiratory Medicine, University of Glasgow, who led the Audit, said:

"The good news is that first line rescue care and treatment for children suffering from acute wheezing and asthma is generally working extremely well in hospitals. This is very welcome.

"Overall, children are receiving the right treatments, and admission to paediatric intensive care is only needed in a very small proportion of cases. Hospital stays are generally very short with a substantial number of children receiving care entirely within the emergency department. This all points to good practice and adherence to national guidance.

"However, there are some 'red flags' highlighted in the report. It's very worrying that a third of children were potentially exposed to tobacco smoke at home, although more data is needed here. When discharging children, health professionals should take the opportunity to talk about the issue with their parents or carers - and offer smoking cessation support as appropriate.

"Above all, it is paramount that children, families and carers leave hospital with a personal asthma action plan that provides guidance and practical tools on managing and monitoring asthma effectively. For many people, asthma is a long-term condition and should be treated as such. Provision of a proper long-term action plan at the hospital discharge stage can help prevent further 'attacks' and readmission in the future.

At present this isn't happening in the majority of cases. We should be doing better."

Association for Respiratory Technology & Physiology

UK hospitals fail to meet national standards in either helping patients quit smoking or providing smoke-free environments – major new report

ARTP read with great interest the recent audit conducted by the British Thoracic Society (BTS) on smoking cessation policies and practice within NHS hospitals. We agree that a more proactive use of time while patients attend our hospitals to aid them to stop smoking needs to be introduced. It is disappointing to see so many areas where opportunities have been missed to address the issue of smoking cessation. However, this report highlights the areas for improvement and NHS Trusts I am sure will see this as a call to action. ARTP fully supports the Societies pledge to use the report findings to call for all hospitals to deliver NICE Guidelines and to request that the Care Quality Commission (CQC) hold Hospital Boards accountable for the delivery of smoke-free and smoking cessation hospital policies. The report gives clear guidance on other activities Trusts should be adopting to deliver the help patients need to stop smoking. We hope we will see a signifiant improvement in Trusts commitment to smoking cessation for the benefit of patients, their relatives and friends.

Dr. Karl Sylvester
Chair, ARTP

According to a major new report launched Wednesday 7th December 2016, NHS hospitals across UK are falling *'woefully short'* of national standards on helping patients who smoke to quit and enforcing smoke-free premises.

Experts presenting the findings at the British Thoracic Society (BTS) Winter Meeting, will state that many NHS hospitals are missing out on a *'golden opportunity'* to provide what is often the most effective front-line treatment for smoking patients who are sick – support and medication to help them quit tobacco.

The BTS Report *'Smoking cessation: policy and practice in NHS hospitals'* is unique in its scope and size; reviewing the smoking cessation & smoke-free policies and practices of 146 hospitals across UK between April and May 2016 - including the analysis of 14,750 patient records.

The main findings of the report are as follows:

- Over 7 in 10 (72%) hospital patients who smoked were not asked if they'd like to stop
- Only 1 in 13 (7.7%) hospital patients who smoked were referred for hospital-based or community treatment for their tobacco addiction
- Over 1 in 4 (27%) hospital patients were not even asked if they smoke
- Only 1 in 10 hospitals completely enforce their fully smoke-free premises. Rates of enforcement were even lower for hospitals which provided areas where smoking was allowed. The report highlights the importance of a smoke-free NHS – to trigger and support quit smoking attempts for patients and reduce second hand smoke exposure for children, staff and the public
- Provision of nicotine replacement therapies and other smoking cessation treatments were 'poor' in hospital pharmacy formularies

- Only 26% of hospitals had an identified consultant 'lead' overseeing their smoke-free and smoking cessation plans
- 50% of frontline healthcare staff in hospitals were not offered training in smoking cessation

In the study, 25% of hospital patients were recorded as being 'current smokers' – which is higher than rates in the general adult population (19%) Other studies have shown that approximately 1.1 million smokers are admitted to NHS hospitals a year.

The Society is using the report findings to call for all hospitals to deliver NICE Guidelines in this area (PH48) and that national regulators such as the Care Quality Commission (CQC) hold Hospital Boards accountable for the delivery of smoke-free and smoking cessation hospital policies.

The report also highlights a number of key activities that all NHS hospitals should deliver to help more of their patients quit smoking:

1. Offer a prescription for Nicotine Replacement Therapy to all patients who smoke to help them cope with their tobacco dependence whilst in hospital
2. Refer all patients who smoke in hospital to specialised stop smoking support services to explore the option of quitting smoking. Patients can opt out if they like – but the NHS should try to offer the most effective treatment and support whatever the illness – and with many smoking-related conditions such as chronic obstructive pulmonary disease (COPD), support and medication to help people quit smoking are the best front line treatments
3. Employ an appropriately skilled senior clinician within the hospital to oversee, drive forward, and be accountable for the hospital's smoking cessation service
4. Employ smoking cessation practitioners in every hospital – this was recommended by NICE in 2013 but the report shows patchy delivery across the country
5. Hospital Board involvement in delivering plans is key. Delivering smoke-free hospital grounds - as part of a wider smoking cessation policy - requires Hospital Boards to work together including the chief executive, director of human resources, director of facilities and the medical and nursing directors – in partnership with the the 'smoking cessation lead' at the hospital

The Society is also encouraging more health professionals to become BTS 'Stop Smoking Champions' in their hospital. There are over 160 at present and they deliver a range of vital activities to champion stop smoking service provision. For further information, contact stopsmokingchampions@brit-thoracic.org.uk or to see a video about the initiative go to:
https://www.brit-thoracic.org.uk/standards-of-care/quality-improvement/smoking-cessation/bts-stop-smoking-champions/

The Commissioning for Quality and Innovation (CQUIN) payment framework enables NHS commissioners to reward excellence by linking a proportion of NHS providers' income to the achievement of local quality improvement goals. There is a new national CQUIN indicator *'Preventing ill health from risky behaviours – alcohol and tobacco'*, which asks Hospital Trusts to identify and record the smoking status of all inpatients and to provide smokers with very brief advice and an offer of medication and referral. The scheme applies to acute Trusts in 2018/19 and to community and mental health trusts in both 2017/18 and 2018/19.

Dr Sanjay Agrawal, Consultant Lung Specialist & Chair of the British Thoracic Society's Tobacco Group, who led the audit said:

'Our report shows that many NHS hospitals are woefully failing to meet national guidance on delivering smoking cessation services and smoke-free premises. This is a dangerous situation that is costing the country dear in both health and economic terms. We must do better.

Critically, hospitals are missing out on a golden opportunity to help supply often THE most effective treatment for illnesses that smokers are admitted with – support and treatment for their tobacco dependence. If patients in other disease areas were not offered, by default, the most effective way to treat their condition – there would probably be an uproar. Nevertheless, this happens all too frequently with people with smoking-related illnesses.

Many hospital boards need to sort out their leadership, plans and resources on this issue – so they can deliver some simple but life-changing steps: identify patients who smoke, ask them if they'd like to quit - and give effective treatment and support to help them stop.'

Dr Lisa Davies, Consultant Respiratory Physician at Aintree University Hospital and Chair of the British Thoracic Society Board, said:

'Being admitted to hospital should be a real window of opportunity for smokers to quit – given that smoking should be prohibited on the premises, tobacco use may be linked to their health condition, and expert stop smoking advice and therapies are potentially 'on tap.' This report shows, however, that we need to fund, plan and deliver smoking cessation work in hospitals far better – so we can fully deliver on this opportunity for our patients.

At a wider level, there is a real fight going on for the future of stop smoking support services in this country. Local authorities, facing overall budget reductions, have cut funding for community-based stop smoking services – meaning that people who need support may have nowhere to go.

The NHS must urgently work together, alongside local authorities, to plan and fund these vital services - to ensure no-one who needs treatment and support to stop smoking falls through the net.'

2017 Course Dates and Locations

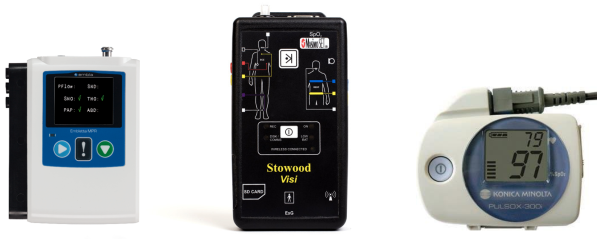
Course Name	Dates	Location
Basic Sleep	1st February	Birmingham
Master Class	27th-28th February	Belfast
Respiratory Muscle	7th April	Bristol
Practical Blood Gas Sampling	28th April	Birmingham
Lung Function Reporting	15th-16th May	Birmingham
Occupational Asthma	May	Birmingham
Research	9th June	**Bristol**
Advanced Sleep	20th-21st June	Birmingham
Basic Sleep	18th September	Birmingham
Cardio Pulmonary	9th-11th October	**Manchester**
Master Class	9th-10th October	Birmingham
NIV	19th-20th October	**Bristol**
Practical Blood Gas Sampling	November	Birmingham

For up to date information on course dates and exact locations, please visit www.artp.org.uk

Please note that course details may be subject to change


GVS
FILTER TECHNOLOGY
Pure. Clear. Safe.
spirguard
ELECTROSTATIC SPIROMETRY FILTER
HUMI-TRAQ
ECO MAXI
ECO SLIMLINE
ECO MAXIPLEAT
www.gvs.com


Black Shadow Component Card v1.0



JOIN ARTP

MEMBERSHIP BENEFITS

The ARTP ...

- is the sole professional organisation in the UK for practitioners working in respiratory physiology and technology.
- develops training strategies, training materials, organises and runs its own national training course and meetings for members.
- holds a major national annual conference. (preferential rates for members).
- provides the only national professional examinations for practitioners in; (1) spirometry and (2) respiratory function testing.
- produces 'Inspire' - the official journal of the ARTP.
- circulates national job vacancies.
- publishes guidelines and standards for good practice.
- funds grants to enable members to attend important national / international meetings and courses.
- works closely with lung function equipment manufacturers and respiratory pharmaceutical companies.
- works in conjunction with the British Thoracic Society to produce national guidelines and standards for good practice in the performance of respiratory measurement.
- works closely with the NHS Executive & the Department of Health in formulating policy and in the strategic direction of the profession.
- is a founder member of the Conference of Clinical Scientist's Organisation's (CCSO) and is a member of the Association of Clinical Scientist's.
- is a founder member of the Institute of Physiological Sciences (IPS) and the Federation of Healthcare Scientists (FedHCS).
- has close involvement with Assembly 9 of the European Respiratory Society.
- Free European Society membership.

GRANTS AVAILABLE

ARTP currently offer grants for attendance at the following meetings:

Meeting	Grant available	Number available	Application Deadline
ARTP Conference	Registration only	5	tbc
BTS Summer Meeting	Up to £300	5	tbc
ERS Congress	Up to £1000	5	tbc

ARTP MEETINGS

Year	Date AGM	Venue	Town/City
1975		Inaugural Meeting King College Hospital	London
1976	12/06/1976	“General Meeting" Brompton Hospital	London
1977		NO MEETING?	
1978		Spring Meeting, Derbyshire Royal Infirmary	Derby
1978		AGM. Charing Cross Hospital	London
1979		Spring:	
1979		AGM;	
1980		Spring: Harefield Hospital	London
1980	04/10/1980	AGM, Walsgrave Hospital	Coventry
1981	04/04/1981	Spring: Hope Hospital	Manchester
1981	10/10/1981	AGM. Derbyshire Royal Infirmary	Derby
1982		Spring:	
1982	16/10/1982	AGM: Harefield Hospital	London
1983	16/04/1983	Spring: Royal Liverpool Hospital	Liverpool
1983	08/10/I 983	AGM: Kings College Hospital	London
1984	06/04/1984	Spring: Stoke Mandeville Hospital	Aylesbury
1984	06/10/1984	AGM: Lodge Moor Hospital	Sheffield
1985	20/04/1985	Spring Leeds General Infirmary	Leeds
1985	05/10/1985	AGM 10th Anniversary Papworth Hospital	Cambridge
1986		Spring	
1986	31/10/1986	AGM:York District Hospital	York
1987	04/04/1987	Spring: City Hospital	Edinburgh
1987	31/10/1987	AGM: Manor Hospital	Walsall
1988		Spring ??? With BTS?	Newcastle
1988	14/10/1988	AGM:City Hospital	Edinburgh
1989		Spring Meeting, St Thomas’ Hospital	London
1990	08/12/1990	AGM. Kensington Town Hall	London
1991	30/11/1991	AGM: Queen Mary Westerfield Hall	London
1992		Spring	Stirling
1992	21/11/1992	AGM: B’ham General Hospital	Birmingham
1993		NO MEETING	
1994	18/02/1994	Spring:North Staffs Hospital	Stoke on Trent
1994	26/11/1994	AGM: Stirling University	Stirling
1995		Summer:QMC	Nottingham
1995	24/11/1995	AGM: Pontefract General Infirmary	Pontefract
1996	04/07/1996	Summer:University of Warwick	Warwick
1996	22/11/1996	AGM: Park Hotel Fazakerley	Liverpool
1997	03/07/1997	Univ of Loughborough	Loughborough
1998	22/01/1998	AGM:ICC "25th Anniversary"	Birmingham
1999		AGM:Racecourse/Moat House	Doncaster
2000	10/02/2000	AGM:Hanover International	Daventry
2001	22/02/2001	AGM:Hilton	Blackpool
2002	17/01/2002	AGM:Hilton	Blackpool
2003	16/01/2003	AGM:Moat House	Stratford upon Avon
2004	28/01/2004.	AGM:ICC	Telford
2005	24/02/2005	AGM-Moat House 30th Anniversary	Glasgow
2006	26/01/2006	AGM Hilton Metropole	Brighton
2007		AGM-Moat House	Glasgow
2008		AGM Hinckley Island Roundabout	Hinckley
2009		AGM Hinckley Island Roundabout	Hinckley
2010	28/01/2010	AGM Park Inn Hotel	Heathrow
2011	03/03/2011	AGM Marriott Hotel	Glasgow
2012	26/01/2012	AGM Hinckley Island Roundabout	Hinckley
2013	07/02/2013	AGM Hinckley Island Roundabout	Hinckley
2014	30/01/2014	AGM:Hilton	Blackpool
2015	22/01/2015	AGM:Hilton	Blackpool
2016	14/01/2016	AGM Russell Hotel 40th Anniversary	London