Respiratory Medicine Case Reports 16 (2015) 11–14

Contents lists available at ScienceDirect

Respiratory Medicine Case Reports

journal homepage: www.elsevier.com/locate/rmcr

Case report

Cardiopulmonary exercise testing after laryngectomy: A connection conundrum

Shana Overstreet [a], Kalpaj R. Parekh [b], Thomas J. Gross [c, *]

[a] Departments of Respiratory Care, Carver College of Medicine, University of Iowa Health Care, USA
[b] Departments of Cardiothoracic Surgery, Carver College of Medicine, University of Iowa Health Care, USA
[c] Department of Internal Medicine, Division of Pulmonary & Critical Care, Carver College of Medicine, University of Iowa Health Care, USA

ARTICLE INFO

Article history:
Received 4 June 2015
Received in revised form
8 June 2015
Accepted 10 June 2015

Keywords:
Cardiopulmonary exercise test
Laryngectomy
Tracheostomy
Preoperative risk

ABSTRACT

A patient presents with a new bronchogenic carcinoma 5 years after laryngectomy for recurrent laryngeal tumor and 13 years after chemoradiation for concurrent lung cancer with synchronous base-of-tongue tumor. Due to his complex history and perceived limited respiratory reserve, he was felt high risk for the completion pneumonectomy needed for resection of this new tumor. The attending surgeon requested a full cardiopulmonary exercise test for risk assessment prior to surgery. We found that there was no commercially available connector that would allow our CPET equipment to reliably collect respiratory gases from a patient with tracheostomy stoma or tube. We report here a simple coupling devised "in house" that allowed for the performance of an interpretable test leading to a significant change in medical care.

1. Introduction

Cardiopulmonary exercise testing (CPET) uses a patient generated workload to provide objective assessment of the integrated fitness of the cardiac, respiratory, and musculoskeletal systems [1]. In use for decades in the evaluation of enigmatic dyspnea, CPET has received increasing attention as a tool to determine readiness for major cardiovascular and cancer surgeries [2,3]. In addition, there is evidence that achieving certain milestones on CPET testing may help risk stratify patients undergoing evaluation for major thoracic resections [4,5]. A well-performed CPET that provides quality data for analysis requires a cooperative and motivated subject, well-trained technicians and supports staff, and properly calibrated equipment that allows for simultaneous measurement of a host of physiology parameters including collection of all inspired and expired air without leak [6].

Cigarette smoking is associated with an increased incidence of a host of chronic illnesses including coronary artery disease, chronic obstructive lung disease (COPD) and a variety of malignancies. Among the more common, and deadly, of these cancers include neoplasms of the Head and Neck and Bronchogenic Cancer. United by the common exposure to chronic cigarette smoke, patients with Head and Neck cancers and Lung cancers often have coexistent COPD complicating their operative risk for curative resections. In addition, a history of heavy cigarette smoking increases the risk for second tumors even if the primary lesion is successfully treated.

2. Case description

Mr. T is a 67-year-old smoker (150 pack-years) who presented in 2002 with dysphagia. He was found to have a locally advanced base of tongue cancer (T_4N_0) and a right upper lobe lung nodule (T_2N_0), both biopsy-proven to be squamous cell carcinomas. As it was deemed impossible to distinguish a synchronous lung primary tumor from metastasis, he was treated with primary radiotherapy to both locations followed by a full course of cis-platinum doublet adjuvant chemotherapy with a complete response at both sites. He was disease free for 5 years and then lost to follow-up. He continued to smoke and presented in 2010 with hemoptysis. Pan endoscopy revealed a multifocal squamous cell neoplasm in the larynx. He was referred to our institution and underwent total laryngectomy without further adjuvant therapy; there was no apparent new disease in the chest. At this point, he quit smoking. A one-year surveillance positron emission tomography scan (PET) in

* Corresponding author. Division of Pulmonary & Critical Care Medicine, Room C33-GH UIHC, 200 Hawkins Drive Iowa City, IA 52242, USA.
E-mail address: thomas-gross@uiowa.edu (T.J. Gross).

http://dx.doi.org/10.1016/j.rmcr.2015.06.004

2011 revealed no evidence for persistent or recurrent disease. In the fall of 2014, he noted increasing chest congestion and sputum production. There was no evidence for tracheoesophageal fistula, but chest imaging demonstrated a new right lung mass (Fig. 1A). PET scan revealed an FDG-avid lesion involving both the posterior segment of the right upper lobe and crossing the major fissure into the right lower lobe (Fig. 1B); there was no obvious nodal involvement or disease outside the chest. The mass appeared intimately associated with the bronchus intermedius. Bronchoscopy revealed endobronchial tumor in a subsegment of the posterior segment right upper lobe and bulging of the membranous portion of the bronchus intermedius. Endobronchial ultrasound confirmed a large homogeneous soft tissue mass posterior to the airway without an obvious tissue plane between the airway and tumor. Biopsy revealed poorly differentiated squamous cell cancer.

Mr. T. had a long history of chronic bronchitis without frequent exacerbations. He used nebulized combination short acting beta-agonist and anticholinergic bronchodilators two to four times daily. He had a daily cough productive of small amounts of thick white sputum with recent occasional blood streaking. He had not needed supplemental oxygen with any of his prior procedures. His CT scan showed upper lobe predominant centrilobular emphysema and he carried the diagnosis of COPD. Baseline PFT prior to his previous cancer treatments could not be located in an outside system. He noted dyspnea with walking a block on level ground or with any incline; he was able to climb two flights of stairs slowly in Thoracic Surgery Clinic without finger oximetry desaturation, though he did appear short of breath. He had no known heart disease, no chronic edema, and no orthopnea.

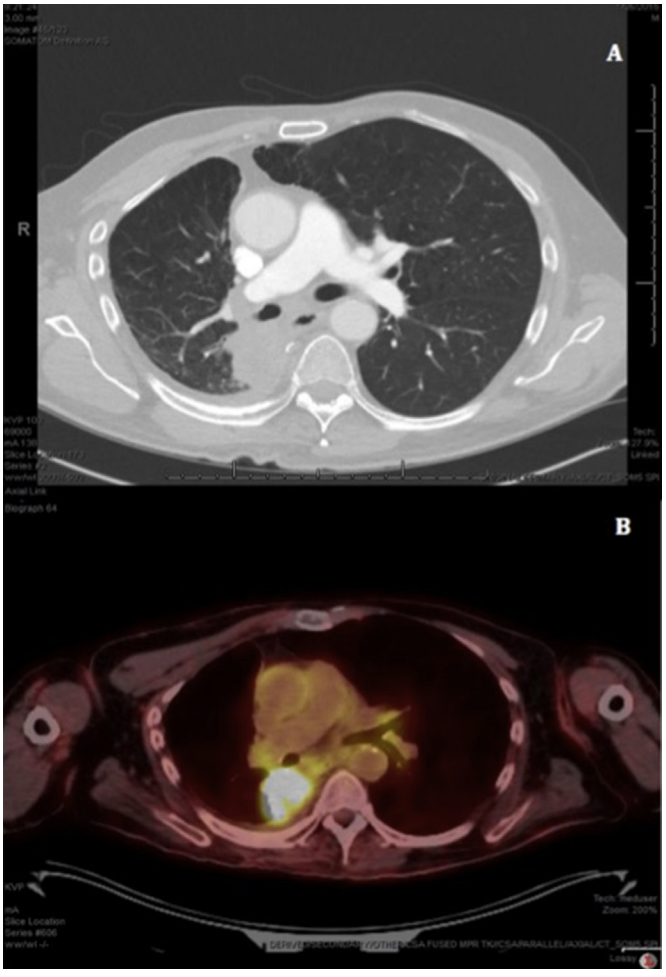

Fig. 1. A) CT imaging showing mass in the posterior RUL. B) PET-CT showing FDG-avid mass posterior to bronchus intermedius.

3. Physiologic testing

Pulmonary function testing was performed using a standard soft rubber adapter than is held against the stoma to achieve a short-term seal for spirometry and diffusion capacity (DLCO) testing. Spirometry revealed a post-bronchodilator FEV_1 of 2.18 L (63% predicted), FVC of 3.24 (69%), and FEV_1/FVC of 0.67. DLCO was reduced at 44% predicted. MVV was reduced at 77 L/min (>35 × FEV1). Flow volume loops were reproducible without evidence for leak on the Volume–Time plot. Quantitative Ventilation/Perfusion scanning (V/Q) revealed 16% perfusion right lung vs. 84% left lung. Resting room air ABG showed $pO_2 = 87$, $pCO_2 = 34$, and $pH = 7.45$.

Based on prior experience, we have found that the standard cycle-based CPET set-up in our lab is not compatible with the stoma interface adapter we use for PFT testing; the leak is large and variable. We contacted the manufacturer of our CPET equipment and were told there was not a readily available connecting device compatible with a stoma. We assumed we could place a tracheostomy tube with inflatable cuff, but similarly, there are no standard parts available to connect the 15 mm outside diameter (OD) tracheostomy tube fitting to the 30 mm OD CPET mass flow sensor. Any connector used would need to provide an airtight seal while flexible enough to allow for the movement inherent in a maximal effort exercise test. Using parts available within the Respiratory Therapy Department, we crafted a connector from the tracheostomy tube to the mass flow using a straight 15 mm–15 mm tube connector and a silicone rubber connector from Servo 900C ventilator parts (part #MCCO.6343420) (Fig. 2 A & B). After discussing options with the patient, a #8 cuffed plastic Shiley tracheostomy tube was placed using 2% lidocaine lubricating jelly. After allowing 15 min to acclimate, the balloon was inflated to the point of eliminating leak with Valsalva during tube occlusion (8–10 cc air). Repeat spirometry revealed nearly identical expired volumes ($FEV_1 = 2.21$, $FVC = 3.42$) and flow volume loop. Using this set up, the patient was able to breath comfortably through the circuit with reproducible breath-to-breath volumes and no evidence of leak.

The patient exercised on a cycle ergometer at a 30-Watt ramp for 4 min and 20 s stopping due to leg fatigue (Fig 3). The test was deemed near maximal as evidenced by achieving 83% of predicted target heart rate (134 bpm), a Respiratory Quotient (RQ) at peak exercise of 1.14, and signs of physical exhaustion. ABG revealed no hypoxemia or hypercarbia at peak exercise, and a drop in serum HCO_3^- of 3 mmol/L. There was no evidence for a ventilatory limitation to this level of exercise with a breathing reserve of 35% (VE max of 50 L/min with MVV of 76), a peak respiratory rate of only 34, and normal tidal volume recruitment (Vt/FVC going from 12% to 55%). Ventilation-perfusion parameters showed an elevated A–a DO_2 of 27 at rest that did not fall with exercise (A–a DO_2 of 32 at peak stress), but no desaturation noted. There was a normal drop in the arterial to end tidal PCO_2 gap and normal fall in VD/VT (41% at rest to 18% at peak VO_2), demonstrating the tube and connectors did not seem to introduce a meaningful dead space load. There was no apparent cardiac limitation with Anaerobic Threshold (AT) occurring normally at 54% of predicted VO_2 max (13 ml/kg), a normal rise in the O_2-pulse (a surrogate for stroke volume recruitment), and no ECG changes to suggest ischemia. At peak exercise, the patient's VO_2 max was 1375 ml/min (65% of predicted) or 15.7 ml/min/kg with patient 4 kg above ideal body weight

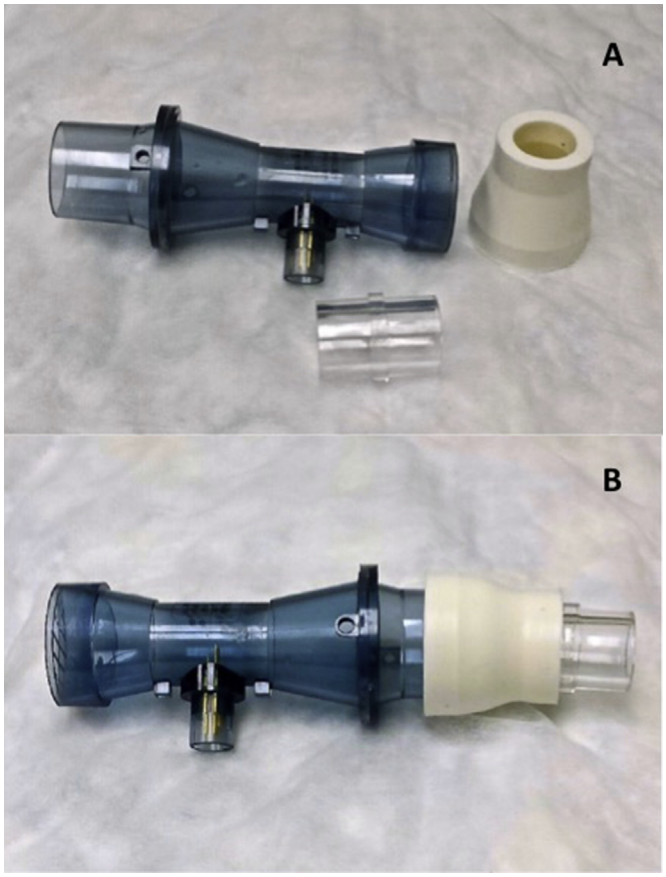

Fig. 2. Solving the connection conundrum. A) Mass flow sensor, flexible foam ventilator connector, and 15-15 mm tube connector; B) assembled connection.

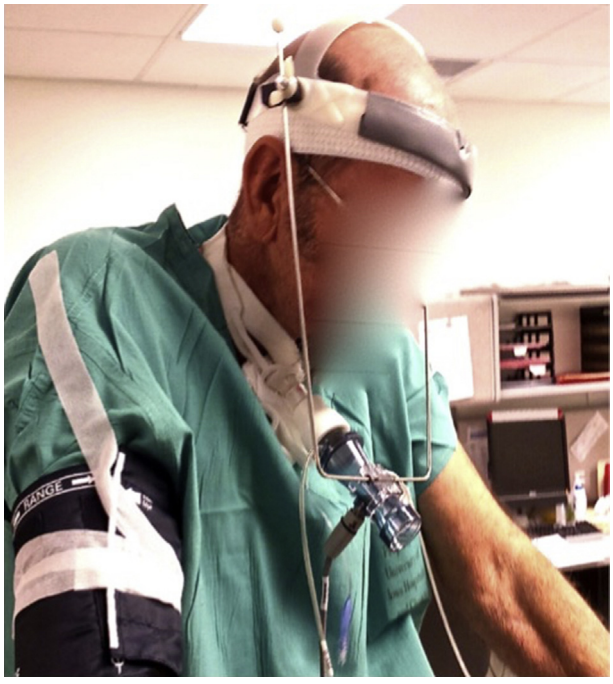

Fig. 3. Patient performing cycle ergometer CPET with connector.

(BMI = 28). We interpreted this study to show a reduced exercise work capacity without clear respiratory or cardiac limitation at a level of work that may have been a submaximal effort. This suggested his true maximal performance may have been a bit higher and these findings likely included a component of lower extremity aerobic deconditioning. Given that he exceeding a VO_2 max of 15 ml/kg, he was enrolled in a 4 week long, three sessions per week, outpatient Pulmonary Rehabilitation program with both objective and subjective improvements in physical endurance. Formal CPET was not repeated and he was offered completion pneumonectomy.

The patient underwent surgery that involved a protracted dissection due to prior definitive external beam radiotherapy. The patient was extubated in the recovery room and rapidly weaned to humidified air. Final pathology revealed a T4 (invasion into mediastinum) N1, Stage 3B tumor with negative margins. From a respiratory standpoint his operation was a success. Unfortunately, in the post-operative period he suffered a large middle cerebral artery stroke and had an extended hospital stay. He was eventually discharged to a long-term rehabilitation facility on humidified room air with plans for adjunctive chemotherapy pending functional recovery status.

4. Discussion

Risk stratification for patients being considered for lung resection surgery remains an inexact science. Consensus guidelines suggest acceptable surgical risk in patients with pre-resection values for FEV1 and DLCO that both exceed 80% predicted without further testing [4,5]. In those with lesser values, various methods to predict post-resection physiology have been proposed. These range from simple calculations of estimated contribution of the planned resected segments to total lung function to the use of quantitative V/Q scanning to estimate post-resection functional lung [5,7]. Consensus guidelines suggest that if the calculated post-operative predicted value for FEV1 and DLCO both exceed 40%, pneumonectomy can be offered with reasonable expectation of good post-surgical functional status. Some groups advocate dropping that to 30% if much of the tissue targeted for resection is emphysematous [5]. For predicted values less than 30% predicted, most guidelines suggest further physiologic testing such as full cardiopulmonary exercise testing [4].

The use of CPET for pre-operative risk assessment is also an evolving science with many suggestions that the measured parameters may be more useful as continuous variable to track response to therapy or deterioration in function rather than as single threshold or “cutoff” indicators. However, there appears to be some utility in predicted post-operative functional status and complications in patients undergoing large vascular surgical repairs, complex advanced cardiac support interventions, or large lung resections [2,5,8]. Even major health care payors support the use of CPET for lung resection preoperative assessment [9]. The oxygen consumption at peak workload (VO_2 max) is the most commonly used parameter. Most guidelines suggest a value that exceeds 15 ml/kg/min supports proceeding with surgery, while values less than 10 ml/kg/min should be considered particularly high risk. The 10–15 ml/kg/min range appears to be something of a “gray” zone and suggests high risk. Some authors propose the use of the VO_2 at the Anaerobic Threshold (AT) as many patients with underlying cardiopulmonary disease have trouble reaching typical criteria for a maximal exercise effort. Suggested prohibitive values fall in the range of 11–12 ml/kg/min at AT [4,5]. Unfortunately, data from large cohort, randomized, controlled trials are lacking and are challenging to design and implement.

Few of the patients included in the series making up the basis for guidelines had prior resections or radiation lung injury, limiting

the extrapolation of these tools to patients like ours. Furthermore, the presence of a tracheostomy renders measure of PFT difficult and subject to error. Therefore, although the V/Q scan predicted a post-resection DLCO in the 35% range, it was felt his physiologic complexity warranted more sophisticated testing. The use of a manually held, occlusive soft rubber adapter is fairly common and yields acceptable flow volume loops and minimizes leak allowing for DLCO measurement as well [10]. Others have devised indwelling adapters that produce good results on spirometry [11]. Certainly, physiologic variables measured in this way can be used as "worse case scenarios" is estimating what function might be with normal upper airway anatomy. While one abstract described using a manual occlusion adapter to obtain reliable CPET data [12], our experience has been that the physical rigor of the test makes a continuous seal difficult and leads to lost data, often right at the peak of exercise where it is most valuable. It does not appear there is a commercially available tool for connecting an endotracheal or tracheostomy tube to standardized exercise equipment that allows for movement. The small sales market make manufacturing such a device unattractive from a business model. We found one report where a customized flexible adapter was constructed on demand for CPET testing with good success [13]. We describe here the results of creatively using parts on hand, at no cost to the patient, which provided the hermetic, flexible seal we needed to facilitate a cycle ergometry to maximal patient effort. While we have a large number of these parts on hand and demand is small, this is not a sustainable solution going forward. The part is still commercially available in limited supply and at rather high relative cost (personal communication; Maquet Medical Systems). We would be interested in how other readers have solved this unusual pulmonary physiologic conundrum.

5. Conclusion

In summary, we describe the successful performance of a full cardiopulmonary exercise test on a laryngectomy patient using a spare tube coupler and silicone rubber ventilator connector. This system provided satisfactory seal and flexibility and low airway resistance and dead space to facilitate CEPT testing that correctly predicted acceptable risk for a completion pneumonectomy.

Acknowledgments

None of the authors have financial disclosures relevant to this case or the testing involved.

References

[1] ATS/ACCP statement on cardiopulmonary exercise testing, Am. J. Resp. Crit. Care Med. 167 (2003) 211–277, http://dx.doi.org/10.1164/rccm.167.2.211.
[2] S.J. Goodyear, H. Yow, M. Saedon, J. Shakespeare, et al., Risk stratification by pre-operative cardiopulmonary exercise testing improves outcomes following elective abdominal aortic aneurysm surgery: a cohort study, Periop Med. 2 (2013) 10, http://dx.doi.org/10.1186/2047-0525-2-10.
[3] L.H. Moyes, C.J. McCaffer, R.C. Carter, G.M. Fullarton, et al., Cardiopulmonary exercise testing as a predictor of complications in oesophagogastric cancer surgery, Ann. R. Coll. Surg. Engl. 95 (2013) 125–130, http://dx.doi.org/10.1308/003588413X13511609954897.
[4] A. Brunelli, R. Charloux, C.T. Bolliger, G. Rocco, et al., ERS/ESTS clinical guidelines on fitness for radical therapy in lung cancer patients, ERJ 34 (2009) 17–41, http://dx.doi.org/10.1183/09031936.00184308.
[5] G.L. Colice, S. Shafazand, J.P. Griffin, R. Keenan, C.T. Bolliger, Physiologic evaluation of the patient with lung cancer being considered for resectional surgery: ACCP evidenced-based clinical practice guidelines, Chest 132 (3 suppl) (2007) 161S–177S, http://dx.doi.org/10.1378/chest.07-1359.
[6] S. Chatterjee, S. Sengupta, M. Nag, et al., Cardiopulmonary exercise testing: a review of techniques and applications, J. Anesth. Clin. Res. 4 (2013) 340, http://dx.doi.org/10.4172/2155-6148.1000340.
[7] B.G. Zeiher, T.J. Gross, J.A. Kern, L.A. Lanza, M.W. Peterson, Predicting post-operative pulmonary function in patients undergoing lung resection, Chest 108 (1995) 68–72, http://dx.doi.org/10.1378/chest.108.1.68.
[8] M.R. Mehra, J. Kobashigawa, R. Starling, et al., Listing criteria for heart transplantation: International Society for heart and lung transplantation guidelines for the care of cardiac transplant candidates, J. Heart Lung Transpl. 25 (2006) 1024–1042, http://dx.doi.org/10.1016/j.healun.2006.06.008.
[9] AETNA Clinical Policy Bulletin: Cardiopulmonary Exercise Testing. Number 0825. Review 03/0215. www.aetna.com/cpb/medical/data/800_899/0825.html.
[10] M.M. Hess, R.A. Schwenk, W. Frank, R. Loddenkemper, Pulmonary function after total laryngectomy, Laryngoscope 109 (1999) 988–994, http://dx.doi.org/10.1097/00005537-199906000-00027.
[11] M.A. Castro, R.A. Dedivitis, A.G. Macedo, Evaluation of a method for assessing pulmonary function in laryngectomees, ACTA Otorhinolaryngol. Ital. 31 (2011) 243–247 doi: 10.1.1.288.5980.
[12] E. Dumoulin, B. Grondin-Beaudoin, C. Labrosse, Y. Poulin, Lung function assessment prior to a lung surgery in patients with permanent tracheostomy, Chest 144 (2013) 102A, http://dx.doi.org/10.1378/chest.1704972.
[13] M. Gwinnutt, S. Ralston, Cardiopulmonary exercise testing (CPET): an unusual challenge, Anaesth. Cases (2014) 0181.