Clinical Medicine 2014 Vol 14, No 2: 122–7

Surgical approaches for lung volume reduction in emphysema

Authors: Samuel J Clark,[A] Zaid Zoumot,[B] Olivia Bamsey,[C] Michael I Polkey,[D] Michael Dusmet,[E] Eric Lim,[F] Simon Jordan[G] and Nicholas S Hopkinson[H]

ABSTRACT

Lung volume reduction surgery (LVRS) for chronic obstructive pulmonary disease (COPD) is recommended in both British and international guidelines because trials have shown improvement in survival in selected patients with poor baseline exercise capacity and upper lobe-predominant emphysema. Despite this, few procedures are carried out, possibly because of historical concerns about high levels of morbidity and mortality associated with the operation. The authors reviewed data on lung volume reduction procedures at their institution between January 2000 and September 2012. There were no deaths within 90 days of unilateral LVRS (n=81), bullectomy (n=20) or intracavity drainage procedures (n=14). These data suggest that concerns about surgical mortality should not discourage LVRS in selected patients with COPD, provided that it is undertaken within a multidisciplinary team environment involving appropriate patient selection.

KEYWORDS: Lung volume reduction surgery, emphysema, under-treatment, risk, mortality

Authors: [A]research nurse, NIHR Respiratory Biomedical Research Unit at Royal Brompton and Harefield NHS Foundation Trust and Imperial College London, UK; [B]consultant respiratory physician, NIHR Respiratory Biomedical Research Unit at Royal Brompton and Harefield NHS Foundation Trust and Imperial College London, UK; [C]research nurse, NIHR Respiratory Biomedical Research Unit at Royal Brompton and Harefield NHS Foundation Trust and Imperial College London, UK; [D]professor of respiratory medicine, NIHR Respiratory Biomedical Research Unit at Royal Brompton and Harefield NHS Foundation Trust and Imperial College London, UK; [E]thoracic surgeon, NIHR Respiratory Biomedical Research Unit at Royal Brompton and Harefield NHS Foundation Trust and Imperial College London, UK; [F]thoracic surgeon, NIHR Respiratory Biomedical Research Unit at Royal Brompton and Harefield NHS Foundation Trust and Imperial College London, UK; [G]thoracic surgeon, NIHR Respiratory Biomedical Research Unit at Royal Brompton and Harefield NHS Foundation Trust and Imperial College London, UK; [H]senior lecturer in respiratory medicine, NIHR Respiratory Biomedical Research Unit at Royal Brompton and Harefield NHS Foundation Trust and Imperial College London, UK

Background

Chronic obstructive pulmonary disease (COPD) is a common and important condition responsible for considerable morbidity and mortality worldwide.[1–5] Guidelines such as the recent national outcomes strategy for COPD,[6] introduced in the British NHS, stress the importance of patients receiving appropriate care, and the use of surgical interventions in carefully selected patients is one element of this. Lung volume reduction surgery (LVRS) involves resecting the most emphysematous part of the lung to allow relatively healthier lung to be ventilated effectively. Operating lung volumes are reduced, which decreases the work of breathing and thus breathlessness. Data from the National Emphysema Treatment Trial (NETT) has shown that, in patients with upper lobe-predominant disease and a reduced exercise capacity, LVRS produces a clear and sustained survival benefit as well as improvements in exercise capacity and quality of life.[7] Therefore the COPD guidelines of the National Institute for Health and Care Excellence (NICE 2010) provide a grade A recommendation that patients with severe COPD who remain limited by breathlessness should be referred for consideration of LVRS.[8]

Although it is 'known' that LVRS improves outcomes in selected patients with emphysema,[7–9] it appears that this knowledge is rarely *acted* on. Data from the UK Society of Cardiothoracic Surgery (SCTS) register (www.scts.org/professionals/audit_outcomes.aspx) show that only 96 procedures in 2009–10 and 90 in 2010–11 were recorded. The reasons for this are unclear but may be due to exaggerated concerns about the morbidity and mortality associated with the procedure. In the NETT study the mortality rate was 5.5% at 90 days post-surgery, and 24% of those undergoing surgery were still inpatients 30 days after the procedure. This is not just a UK issue; in the USA, in 2006, only 105 Medicare beneficiaries underwent LVRS.[7]

The advanced COPD service at the Royal Brompton Hospital includes a multidisciplinary team (MDT) meeting at which patients with emphysema are discussed, involving a thoracic surgeon, respiratory physician and radiology, nursing and physiotherapy input. Conventional LVRS and bullectomy, as well as the Monaldi procedure which involves intracavity drainage of bullous lung disease combined with talc insufflation as a sclerosant, are considered.[10] In addition, patients are assessed for possible participation in trials of experimental interventions such as bronchoscopic valve placement.[11–14] This approach is intended to ensure appropriate patient selection, optimisation of patients

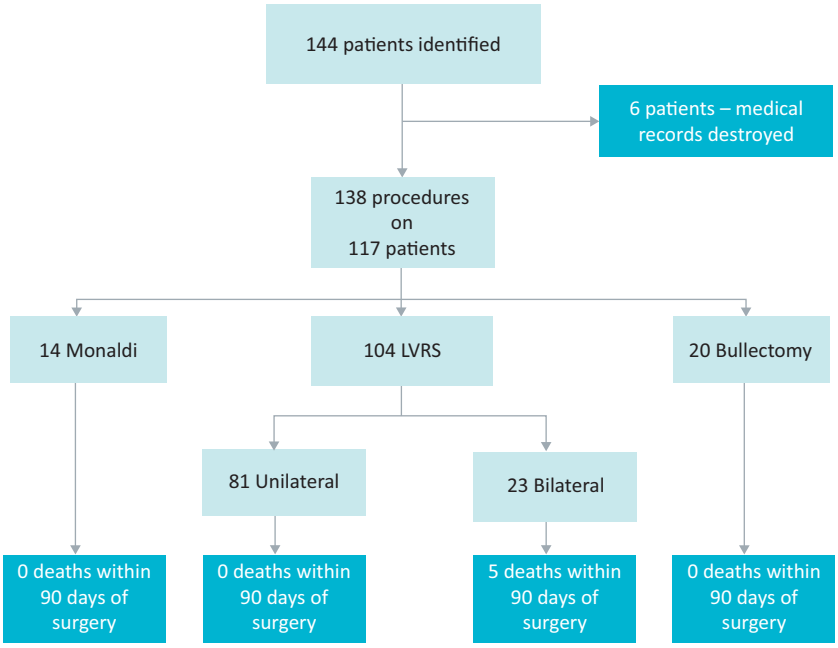

Fig 1. Numbers of patients undergoing lung volume reduction surgery procedures January 2000 to September 2012.
LVRS = lung volume reduction surgery.

preoperatively, and a concentration of experience in this area to ensure that postoperative care is optimal. Decisions are based on factors including pulmonary function test results, the pattern of emphysema on thoracic computed tomography (CT), exercise capacity, the presence of significant co-morbidity and patient preference.

Data on the morbidity and mortality associated with various surgical lung volume procedures should enable clinicians to have a clearer picture when considering them with their patients.

Methods

LVRS, bullectomy and the Monaldi procedures carried out between January 2000 and September 2012 were identified from operating theatre records and hospital coding. Individual case records were then examined and data on survival, complications, and baseline and follow-up lung function collated. The primary outcome was 90-day mortality. The NETT classification of surgical complications post-LVRS was used to allow like-for-like comparisons. Major pulmonary morbidity was defined as incidence of one or more of the following in the 30 days after LVRS: tracheostomy, failure to wean, pneumonia, and at least one postoperative intubation or ventilator use for 3 or more days. Major cardiac morbidity was defined as the incidence of one or more of the following: intraoperative or postoperative (in the 30 days after LVRS) arrhythmia requiring treatment, or myocardial infarction or pulmonary embolus in the 30 days after LVRS.

Most LVRS procedures before 2003 were bilateral, whereas from 2003 (after a morbidity and mortality review) the standard approach in the authors' institution became unilateral LVRS and the two outcomes were compared. Statistical analysis was performed using SPSS version 8.

Results

A total of 144 procedures were identified. The medical notes of six patients operated on in 2000–1 were unavailable (destroyed by water damage), leaving 138 procedures in 117 patients (Fig 1). Mean (standard deviation [SD]) age was 56.5 years (10 years), 78% were males with forced expiratory volume in 1 second (FEV_1) of 36% (16.3%) predicted, carbon monoxide gas transfer factor (TL_{CO}) was 42.2% (16.3%) predicted and residual volume:total lung capacity ratio 0.59 (0.1). There were 104 LVRS procedures (81 unilateral, 23 bilateral), 14 Monaldi procedures and 20 bullectomies. Further details of participant characteristics are broken down by procedure in Table 1.

Mortality

The 90-day mortality rate for unilateral LVRS, bullectomy and intracavity drainage procedures was zero (confidence interval [CI] 0–0.45% for unilateral LVRS). By contrast, for bilateral LVRS the 30-day mortality rate was 17.4% and the 90-day mortality rate 21.7%, with the last death within 90 days occurring in 2003 when the switch to a unilateral approach occurred.

Morbidity

At 30 days after the procedure, 6% of unilateral LVRS, 5% of bullectomy and 7% of Brompton procedure patients remained in hospital compared with 10% after a bilateral LVRS. Median length of stay was 14 days for bilateral LVRS and 10.5 days for unilateral LVRS. Major pulmonary or cardiac complications occurred in 39% and 13% of bilateral LVRS patients, respectively, compared with 11% and 6% for unilateral LVRS (Tables 2 and 3). This compares with rates of 29.8% for

Table 1. Preoperative data for patients undergoing surgery for emphysema.*

Data	Bilateral LVRS (n=23)	Unilateral LVRS (n=81)	Bullectomy (n=20)	Monaldi[9] (n=14)	All patients (n=138)
Age (years)	57.87 (5.23)	57.32 (10.1)	49.15 (12.1)	59.5 (8.0)	56.54 (10.0)
Males (%)	91.3	74.1	75	85.7	78.3
BMI (kg/m^2)	23.96 (4.1)	23.8 (4.3)	24.6 (5.0)	23.4 (4.4)	23.9 (4.3)
Smoke exposure (pack-years)	42.1 (27.6)	39.4 (20.9)	32.6 (22.8)	52.3(36.0)	40.1 (24.2)
FEV_1 (l)	0.80 (0.30)	1.12 (0.60)	1.63 (0.77)	1.05 (0.35)	1.14 (0.61)
FEV_1 (% predicted)	25.9 (12.1)	35.8 (14.8)	51.4 (20.2)	32.5 (8.12)	36.0 (16.3)
FVC (l)	3.04 (0.65)	3.24 (0.94)	3.10 (0.92)	3.08 (1.11)	3.17 (0.91)
FVC (% predicted)	77.2 (18.1)	84.5 (19.4)	77.7 (20.9)	76.9 (23.7)	81.5 (20.0)
FEV_1:FVC	25.0 (7.76)	32.8 (11.0)	52.0 (19.1)	33.1 (9.40)	34.01 (14.0)
RV (%)	263.5 (57.9)	216.9 (55.7)	188.3 (55.8)	223.2 (43.4)	221.7 (58.5)
TLC (% predicted)	138.4 (15.0)	127.7 (18.9)	109.7 (21.1)	125.7 (19.6)	126.9 (20.1)
RV:TLC	65.0 (7.86)	58.4 (10.5)	54.4 (10.1)	61 (10.4)	59.3 (10.4)
TL_{CO} (% predicted)	40.5 (10.2)	39.8 (15.8)	55.0 (20.3)	42.1 (15.8)	42.2 (16.3)
PaO_2 (kPa)	9.3 (1.3)	9.7 (1.2)	10.0 (1.1)	9.5 (0.8)	9.6 (1.2)
$PaCO_2$ (kPa)	5.7 (1.2)	5.0 (0.5)	5.2 (0.6)	5.1 (0.5)	5.2 (0.7)

*Values are mean (standard deviation).
BMI = body mass index; FEV_1 = forced expiratory volume in 1 second; FVC = forced vital capacity; LVRS = lung volume reduction surgery; $PaCO_2$ = partial pressure of carbon dioxide; PaO_2 = partial pressure of oxygen; RV = residual volume; TLC = total lung capacity; TL_{CO} = carbon monoxide gas transfer corrected for haemoglobin.

major pulmonary complications and 20% for major cardiac compilations in the NETT study.

Efficacy

Improvements in lung function parameters were similar after unilateral and bilateral LVRS with a mean increase in FEV_1 of 32% (55%) for bilateral LVRS and 27% (37%) for unilateral (Table 4). Follow-up data for lung function was incomplete because some patients had been discharged back to local hospitals for followup.

Discussion

The main finding was that surgical lung volume reduction procedures currently in use, including unilateral LVRS, bullectomy and the Monaldi procedure, were associated with a zero 90-day surgical mortality, with much lower rates of morbidity with unilateral LVRS than reported previously with bilateral procedures in the NETT study.[7]

Unilateral LVRS produced similar lung function improvements to the bilateral procedure. Although the authors have not undertaken a formal economic analysis, the value of the unilateral procedure is likely to be greater than that in the NETT study which investigated bilateral LVRS. First, the mortality and morbidity are lower. Second, the cost of the intervention is lower because hospital length of stay is shorter. Third, after bilateral LVRS patients would go to intensive care to recover initially, whereas after unilateral surgery they routinely receive level 2 care, which means that inpatient costs are lower. Currently, only bilateral LVRS is reimbursed in the USA but the present data suggest that this may be exposing patients to unnecessary risk, particularly where disease is very asymmetrical.

Given that LVRS is already recommended by NICE for selected patients with COPD,[8] the small number of cases being performed in the UK and elsewhere is a concern because it means that some patients are missing out on an effective treatment. According to the UK Society for Cardiothoracic Surgery (SCTS) register, there were only 57 video-assisted thoracoscopic surgery (VATS) LVRS procedures and 39 open procedures in 2009–10. In 2010–11 there were 57 VATS and 33 open procedures. Data on LVRS procedures were not recorded specifically for previous years. It is difficult to estimate the size of unmet need that this represents precisely, but it is likely to be large. Based on quality outcomes framework data from 2012 (see www.gpcontract.co.uk) there are 1.1 million patients with COPD in the UK. Accurate data on the proportion of individuals with different disease severities are lacking, but, assuming that only 10% of these have severe or very severe disease and that of these 15% meet the criteria for LVRS (based on a US database study),[17] this would still make approximately 16,000 potentially eligible individuals.

The authors speculate that low rates of LVRS may be because clinicians have an exaggerated impression of its morbidity and mortality based on NETT data or senior clinicians' experience at the start of the century, before the high-risk cohort of people with an FEV_1 and a T_{LCO} <20% were identified and excluded

Table 2. Outcomes of surgical groups at the Royal Brompton Hospital during the audit period.

Data	Bilateral LVRS (n=23)	Unilateral LVRS (n=81)	Bullectomy (n=20)	Monaldi (n=14)	All patients (n=138)
Length of stay (days)	21.4 (24.1)	13.8 (11.0)	13.1 (21.2)	19.0 (19.9)	15.3 (16.2)
Returned to theatre (%)	30.4	12.2	10	0	13.8
Discharged with a chest drain (%)	31.6	16.5	10	7.7	16.8
Inpatient after 30 days (%)	10.5	6.2	5	7.1	6.7
Major cardiac complication (%)*	13	6.3	0	0	5.9
Major pulmonary complication (%)†	39.1	11.4	15	30.8	18.4
30-day mortality rate (%)	17.4	0	0	0	2.9
90-day mortality rate (%)	21.7	0	0	0	3.6

*Major pulmonary morbidity is defined as incidence of one or more of the following in the 30 days after LVRS: tracheostomy, failure to wean, pneumonia, at least one postoperative intubation, or ventilator use for 3 or more days.
†Major cardiac morbidity is defined as incidence of one or more of the following: intraoperative or postoperative (in the 30 days after LVRS) arrhythmia requiring treatment or myocardial infarction or pulmonary embolus in the 30 days after LVRS.
LVRS = lung volume reduction surgery.

Table 3 Complications after LVRS – NETT (National Emphysema Treatment Trial) data vs Royal Brompton Hospital (RBH) experience.

Complication*	NETT(n=511)	RBH bilateral LVRS (n=23)	RBH unilateral LVRS (n=79)
None	41.3	30.4	29.6
Arrhythmia	23.5	13.0	6.3
Arrhythmia requiring treatment	18.6	13.0	6.3
Myocardial infarction	1.0	4.3	0
Failure of early extubation	3.9	30.4	3.8
Tracheostomy	8.2	8.7	1.3
Failure to wean	5.1	30.4	3.8
Reoperation for air leak	3.3	0	8.9
Pulmonary embolus	0.8	0	0
Readmission to ICU	11.7	17.4	6.3
Mediastinitis	0.6	0	0
Sternal debridement	0.6	4.3	0
Pneumonia	18.2	26.1	6.3
Urinary retention	3.5	0	2.5
Epidural catheter complications	0.8	4.3	0
Sepsis	2.5	17.4	2.5
Readmission within 72 hours after discharge	2.5	5.2	0
Ventilated >2 days	13.6	N/A	N/A
Required reintubation	21.8	N/A	N/A
Major pulmonary morbidity	29.8	39.1	11.4
Major cardiac morbidity	20	13	6.3
Died within 90 days of operation	5.5	21.7	0

*All values are percentages.
The NETT study categorises both the intraoperative and the postoperative complications after lung volume reduction surgery (LVRS).[15,16] The RBH audit used the same format to categorise surgical complications examining medical notes retrospectively. Two unilateral patients' medical notes were unavailable and were not included in the audit of complications (although both were alive at 90 days).
LVRS = lung volume reduction surgery; N/A = not applicable; NETT = National Emphysema Treatment Trial; RBH = Royal Brompton Hospital.

Table 4. Change in lung function parameters after different lung volume reduction procedures.

Lung function parameter*	Bilateral LVRS (n=14)	Unilateral LVRS (n=44)	Bullectomy (n=6)	Monaldi (n=11)	All patients (n=74)
FEV_1 (% change)	31.5 (55.4)	26.9 (37.4)	80.2 (88.5)	19.3 (33.8)	31.4 (48.3)
FVC (% change)	24.1 (28.9)	12.3 (26.7)	44.9 (75.7)	8.3 (26.7)	17.3 (34.7)
RV:TLC (absolute change)	–12.7 (12.1)	–8.0 (10.3)	–18.2 (17.3)	–12.3 (23.6)	–10.4 (14.0)
T_{LCO} (% change)	2.6 (23.6)	11.3 (31.9)	28.6 (44.8)	–16.4 (20.1)	7.2 (31.9)

*Values are mean (standard deviation).
For all comparisons of bilateral vs unilateral LVRS p>0.05.
FEV_1 = forced expiratory volume in 1 second; FVC = forced vital capacity; LVRS = lung volume reduction surgery; RV = residual volume; TLC = total lung capacity; T_{LCO} = carbon monoxide gas transfer corrected for haemoglobin.

from the procedure. The current data show that this concern is indeed exaggerated.

The second contributory factor may be the lack of standardised care pathways equivalent to those in place to ensure that patients with lung cancer are systematically considered for suitability for resection. The data on survival benefit with LVRS in selected patients should mandate systematic assessment of patients to identify those with the appropriate characteristics – heterogeneous emphysema with a poor exercise capacity.[7] In practice this approach should include routine assessment of pattern of emphysema by CT scan as well as gas transfer measurement in all patients with Medical Research Council (MRC) 4 or 5 dyspnoea and GOLD (**G**lobal Initiative for Chronic **O**bstructive **L**ung **D**isease) III or IV disease, unless there are obvious co-morbidities precluding surgery with review by an MDT, including chest physicians, surgeons and radiologists, as is already the case for the management of lung cancer. Many patients with COPD have a CT scan when admitted to hospital with an acute exacerbation to exclude other causes of breathlessness or chest discomfort, so systematic evaluation of these may be a good place to start.

As well as the use of a unilateral approach, improvements in morbidity since the NETT study was published may also be due to improved surgical techniques and newer staple guns, which minimise leak, as well as improved aftercare including one-way chest drain valves that allow early discharge/shorter hospital stays.

Other lung volume reduction procedures are under development[11–14] and there is emerging evidence that placement of endobronchial valves, where lobar exclusion can be achieved, may lead to a survival benefit.[18] The present data highlight that LVRS is the gold standard approach for lung volume reduction in patients with heterogeneous emphysema and that bronchoscopic therapies will need to prove their worth against it in terms of both efficacy and safety. In addition, bronchoscopic approaches are likely to be more expensive than the UK LVRS tariff.

Low rates of referral for LVRS may be a manifestation of clinical nihilism. It remains conventional to write in reviews of COPD treatment that 'only smoking cessation and oxygen in selected patients improve survival in COPD'. However, the present data should reinforce the benefits of LVRS, reassure clinicians of its safety in appropriately selected patients and support the development of a systematic, multidisciplinary approach to the management of patients with severe emphysema. ■

Acknowledgements

The study was supported by the NIHR Biomedical Research Unit at the Royal Brompton and Harefield NHS Foundation Trust and Imperial College, London.

Contributorship

Nicholas S Hopkinson and Simon Jordan conceived the study; Samuel J Clark, Zaid Zoumot and Olivia Bamsey collected data; Nicholas S Hopkinson, Samuel J Clark, Zaid Zoumot, Michael I Polkey, Michael Dusmet, Eric Lim and Simon Jordan contributed to analysis and interpretation of the data. All authors contributed to and approved the final manuscript. Nicholas S Hopkinson is the guarantor.

References

1 Kelly JL, Bamsey O, Smith C *et al.* Health status assessment in routine clinical practice: the chronic obstructive pulmonary disease assessment test score in outpatients. *Respiration* 2012;84:193–9.
2 Nacul L, Soljak M, Samarasundera E *et al.* COPD in England: a comparison of expected, model-based prevalence and observed prevalence from general practice data. *J Public Health (Oxf)* 2011;33:108–16.
3 Shrikrishna D, Hopkinson NS. Chronic obstructive pulmonary disease: consequences beyond the lung. *Clin Med* 2012;12:71–4.
4 Lozano R, Naghavi M, Foreman K *et al.* Global and regional mortality from 235 causes of death for 20 age groups in 1990 and 2010: a systematic analysis for the Global Burden of Disease Study 2010. *Lancet* 2012;380:2095–128.
5 Boutou AK, Shrikrishna D, Tanner RJ *et al.* Lung function indices for predicting mortality in COPD. *Eur Respir J* 2013;42:616–25.
6 National Health Service. *An outcomes strategy for COPD and asthma: NHS companion document.* London: DH, 2012. www.gov.uk/government/uploads/system/uploads/attachment_data/file/216531/dh_134001.pdf [Accessed 10 March 2014].
7 Criner GJ, Cordova F, Sternberg AL, Martinez FJ. The National Emphysema Treatment Trial (NETT): Part II: Lessons learned about lung volume reduction surgery. *Am J Respir Crit Care Med* 2011;184:881–93.
8 National Institute for Health and Care Excellence. *Chronic obstructive pulmonary disease: Management of chronic obstructive pulmonary disease in adults in primary and secondary care* (partial update). London: NICE, 2010. www.nice.org.uk/nicemedia/live/13029/49397/49397.pdf [Acccessed 24 January 2014].

9 Geddes D, Davies M, Koyama H *et al.* Effect of lung-volume-reduction surgery in patients with severe emphysema. *N Engl J Med* 2000;343:239–45.
10 Venn GE, Williams PR, Goldstraw P. Intracavity drainage for bullous, emphysematous lung disease: experience with the Brompton technique. *Thorax* 1988;43:998–1002.
11 Hopkinson NS, Shah PL, Polkey MI. Endobronchial valves for emphysema. *N Engl J Med* 2011;364:381–2;author reply 383–4.
12 Toma TP, Hopkinson NS, Hillier J *et al.* Bronchoscopic volume reduction with valve implants in patients with severe emphysema. *Lancet* 2003;361:931–3.
13 Shah PL, Slebos DJ, Cardoso PFG *et al.* Bronchoscopic lung-volume reduction with Exhale airway stents for emphysema (EASE trial): randomised, sham-controlled, multicentre trial. *Lancet* 2011;378:997–1005.
14 Shah PL, Zoumot Z, Singh S *et al.* Endobronchial coils for the treatment of severe emphysema with hyperinflation (RESET): a randomised controlled trial. *Lancet* 2013;i:233–40.
15 National Emphysema Treatment Trial Research Group. A randomized trial comparing lung-volume-reduction surgery with medical therapy for severe emphysema. *N Engl J Med* 2003;348:2059–73.
16 Naunheim KS, Wood DE, Krasna MJ *et al.* Predictors of operative mortality and cardiopulmonary morbidity in the National Emphysema Treatment Trial. *J Thorac Cardiovasc Surg* 2006;131:43–53.
17 Akuthota P, Litmanovich D, Zutler M *et al.* An evidence-based estimate on the size of the potential patient pool for lung volume reduction surgery. *Ann Thorac Surg* 2012;94:205–11.
18 Hopkinson NS, Kemp SV, Toma TP *et al.* Atelectasis and survival after bronchoscopic lung volume reduction for COPD. *Eur Respir J* 2011;37:1346–51.

Address for correspondence: Dr NS Hopkinson, Royal Brompton Hospital, Fulham Road, London SW3 6NP. Email: n.hopkinson@ic.ac.uk