Two-Year Improvement in Multidimensional Body Mass Index, Airflow Obstruction, Dyspnea, and Exercise Capacity Index After Nonresectional Lung Volume Reduction Surgery in Awake Patients

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Two-Year Improvement in Multidimensional Body Mass Index, Airflow Obstruction, Dyspnea, and Exercise Capacity Index After Nonresectional Lung Volume Reduction Surgery in Awake Patients

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Background. **This study analyzed the comprehensive 2-year outcome of nonresectional lung volume reduction surgery (LVRS) in awake patients, including calculation of the multidimensional BODE index (body mass index, degree of airflow obstruction assessed by spirometry, modified Medical Research Council dyspnea grade, and 6-minute walking distance), which has proved a useful predictor of survival in patients with chronic obstructive pulmonary disease.**

Methods. **The study cohort included 42 patients undergoing LVRS while awake within a staged bilateral program entailing unilateral LVRS, followed by contralateral treatment performed at the reappearance of disabling symptoms. Outcome measures included hospital stay, procedure-related costs, calculation of the multidimensional BODE index, actuarial survival, and freedom from contralateral LVRS. Results were compared with those of a control group undergoing resectional LVRS under general anesthesia.**

Results. **The groups were well matched in demographics and baseline measures. There was no operative mortality. Median hospital stay was significantly shorter in the awake group (6 days versus 9 days, $p < 0.0001$); median procedure-related costs were significantly lower in the awake group (€5220 versus €8580; $p < 0.0001$). At intergroup comparisons of awake versus control group of clinical results, the BODE index improved postoperatively in both groups (-2.24 ± 1.0 versus -1.95 ± 1.0, intergroup $p = 0.35$) and remained improved for up to 2 years (-1.95 ± 1.3 versus -1.37 ± 1.4, intergroup $p = 0.1$); 2-year survival and freedom from contralateral LVRS rates were 87% versus 91% ($p = 0.52$) and 74% versus 73% ($p = 0.71$), respectively.**

Conclusions. **A significant improvement in the BODE index, satisfactory survival, and high rate of freedom from contralateral LVRS occurred both in the awake and control group, although the awake procedure proved more cost-effective.**

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There is increasing scientific evidence that resectional lung volume reduction surgery (LVRS) can induce long-lasting clinical improvements in selected patients with upper-lobe predominant emphysema and that clinical benefit and survival are better than those achieved with maximized medical treatment [1–5]. The most widely used surgical techniques entail unilateral [6–8] or bilateral staple resection of the most emphysematous lung tissue performed under general anesthesia through open or thoracoscopic approaches.

Unfortunately, even the use of video-assisted thoracoscopic surgery (VATS) [9] did not modify the considerable procedure-related morbidity, which can be mainly attributed to general anesthesia and surgical trauma deriving from resection of emphysematous lung tissue. After resectional LVRS, expected mortality is 5.5% and pulmonary morbidity is 30% [10]. Time spent for postoperative recovering is often prolonged, and about 30% of patients are still hospitalized or in rehabilitation facilities 1 month after LVRS [11]. As a result, the cost-effectiveness of LVRS continues to be questioned.

In recent years, new surgical and bronchoscopic lung volume reduction techniques have been proposed in an attempt to reduce the typical shortcomings of resectional LVRS [12–15]. We have developed a nonresectional LVRS technique in awake patients that respects the basic concepts of resectional LVRS but adds some theoretic advantages and can be performed solely with thoracic epidural anesthesia.

After an initial pilot study to assess feasibility and early results [16], we have now analyzed the comprehensive 2-year outcome of nonresectional LVRS in awake patients, including the multidimensional body mass index, airflow obstruction, dyspnea, and exercise capacity (BODE) index, which has proved a useful predictor of survival [17] in patients with chronic obstructive pulmonary disease (COPD) and has recently shown to improve significantly after LVRS [18].

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Material and Methods

This analysis included 42 patients undergoing unilateral awake LVRS at the Tor Vergata University School of Medicine between January 2001 and March 2005. This time span was chosen to assure a minimum follow-up of 2 years to adequately assess clinical outcome, need of contralateral treatment, and survival in the patient cohort. All patients gave written informed consent for the procedure, and the Tor Vergata Ethical Committee approved the study. Eligibility criteria for LVRS have been already described [19] and included the finding of severe emphysema with radiologic evidence of distinct heterogeneity of disease within the lung associated with severe disability, despite maximized medical care, postbronchodilator forced expiratory volume in 1 second (FEV_1) less than 40% predicted, and residual volume (RV) of more than 180% predicted. All patients were former smokers and had quit smoking at least 4 months before the operation. No patient was homozygous for α1-antitrypsin deficiency.

Unilateral LVRS was done within our standard treatment strategy entailing initial unilateral LVRS performed on the most diseased lung, followed by eventual contralateral treatment delayed until the clinical benefit achieved with the first procedure was lost, as indicated by deterioration of FEV_1, dyspnea index, exercise capacity back to baseline values, or a combination of these. Contraindications for awake LVRS included any of the following: radiologic evidence of extensive pleural adhesions with pleural scarring and calcifications, a contraindication for thoracic epidural anesthesia (including patient refusal or noncompliance), unfavorable anatomy, previous surgery of the cervical or upper thoracic spine, compromised coagulation (thromboplastin time $< 80\%$, prothrombin time > 40 seconds, or platelet count $< 100/nL$), or a bleeding disorder.

Static lung volumes were determined by plethysmography, and diffusing capacity for carbon monoxide was assessed by the single-breath technique. Pulmonary function tests were performed before and after administration of two puffs of aerosolized salbutamol.

Exercise tolerance was assessed by standard 6-minute walk test (SMWT) and maximal incremental treadmill test. Dyspnea was rated according to the modified Medical Research Council Score. Quality of life was assessed with the self-administered Medical Outcomes Study 36-Item Short-Form Health Survey questionnaire (SF-36).

Outcome measures included satisfaction with anesthesia scored into 4 grades (from 1 = unsatisfactory to 4 = excellent), hospital stay, calculation of the multidimensional BODE index, which integrates measures of body mass index (BMI), degree of airflow obstruction indicated by FEV_1, modified Medical Research Council dyspnea index, and exercise capacity assessed by the SMWT; actuarial survival, and freedom from contralateral LVRS.

Table 1. Variables and Point Values Assigned for the Computation of the Multidimensional Body Mass Index, Airflow Obstruction, Dyspnea, and Exercise Capacity Index [17]

	Points on BODE Index			
Variable	0	1	2	3
FEV_1 (% predicted)	≥65	50–64	36–49	≤35
SMWT distance (m)	≥350	250–349	150–249	≤149
MMRC dyspnea scale	0–1	2	3	4
Body mass index	>21	≤21		

BODE = body mass index, airflow obstruction, dyspnea, and exercise capacity; FEV_1 = forced expiratory volume in 1 second; MMRC = modified Medical Research Council; SMWT = 6-minute walking test.

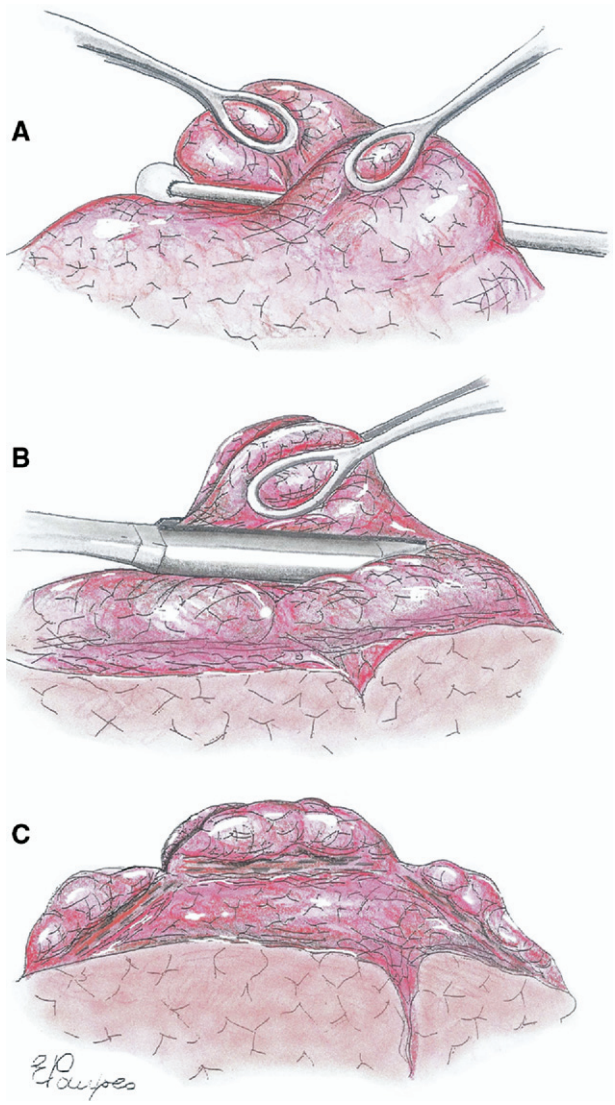

Fig 1. Main operative steps of awake nonresectional lung volume reduction surgery. (A) The most emphysematous lung region targeted for plication is depressed by a cotton swab while the lung edges are grasped by two ring forceps. (B) Afterwards, both lung edges are grasped by a single ring forceps, and a "no knife" endoscopic stapler is fired at the base of the plicated area. (C) The same maneuver is repeated three times along a single ideal line to create a linear but interrupted suture line crossing the lung apex from the ventral segment of the upper lobe back to the dorsal one.

The BODE index was calculated according to the criteria proposed by Celli and colleagues [17], which entails assignment of a score from 0 to 3 for dyspnea index, FEV_1 and SMWT, and values of 0 and 1 for BMI. The points for each variable were totaled so that the BODE index ranged from 0 to 10 points, with higher scores indicating a more severe disability (Table 1).

Also calculated were procedure-related costs, including devices, routine laboratory assessment, dressing materials, medications, surgical instrumentation operative time-related costs, and hospital stay. All outcome measures, except the anesthesia satisfaction score, were compared with those of an equivalent control group consisting of the last 42 patients undergoing unilateral resectional LVRS under general anesthesia.

Anesthesia and Surgical Technique

Anesthesia and surgical technique have been already described in detail [16]. Briefly, thoracic epidural anesthesia was initiated to achieve somatosensory and motor block at the T1 to T8 level while preserving diaphragmatic respiration. The thoracic epidural catheter was inserted at the T4 level. In the operating room, patients received a continuous infusion of 0.5% ropivacaine and 1.66-μg/mL sufentanil into the epidural space. During the procedure, patients breathed oxygen through a Venturi face mask to keep oxygen saturation above 90%. During wound closure, the anesthetic regimen was changed to 0.16% ropivacaine and 1-μg/mL sufentanil at 2 to 5 mL/h.

In patients undergoing resectional LVRS with general anesthesia, a thoracic epidural catheter was inserted between T5 and T8 and a continuous infusion of ropivacaine was initiated. General anesthesia was induced with intravenous propofol (1.5 to 2 mg/kg), fentanyl (0.1 mg), and vecuronium (0.1 mg/Kg) and maintained using a continuous infusion of propofol, fentanyl, and vecuronium. A left-sided double-lumen tube was routinely used. In all patients, the epidural catheter was removed 48 hours after the procedure.

All operations were done with VATS. The patient was placed in full lateral decubitus position. A four-trocars access was used for a 30° 10-mm camera and instrumentation. Whenever severe lung hyperinflation persisted despite induction of the surgical pneumothorax, thus jeopardizing adequate visualization, an endopaddle lung retractor was used to increase the operating space. Carbon dioxide insufflation was not used. The most emphysematous target areas were visualized and depressed with a cotton swab while the redundant lung edges were gently grasped by two ring forceps. Both lung edges were then grasped together with a single ring forceps, and a 45-mm, "no knife" endostapler (Endopath 45NK, Ethicon Endosurgery, Pomezia, Italy) was applied on the plicated lung region, starting at the apex of the upper lung lobe and continuing, applying two other cartridges in the ventral and dorsal side of the targeted area to perform a linear, interrupted suture line (Fig 1).

In the control group, staple resection of target areas was performed in the standard manner, excising a reversed U-shaped single strip of emphysematous lung tissue to reduce the upper lobe by about 50%. No suture line buttress was used in either group.

Whenever conversion to general anesthesia was deemed necessary, this was done after insertion of a chest tube and one-layer closure of the thoracic incisions, placement of the patient in supine position, intravenous induction of anesthesia with propofol, and double-lumen tube intubation for single-lung ventilation.

Table 2. Perioperative Data

Assessment	Awake Group		Control Group		Intergroup *P* Value
	Median	IQR	Median	IQR	
Anesthesia time (min)	35	30–40	40	34–45	0.02
Surgery time (min)	30	27–38	50	45–60	<0.0001
Weaning time (min)	—	—	45	40–65	—
In-operating room time (min)[a]	134	123–150	375	330–420	<0.0001
Anesthesia satisfaction (score)	4	3–4	—	—	—
End-operative					
Po_2/Fio_2	180	175–190	184	167–200	0.58
Pco_2 (mm Hg)	55	49–60	40	39–44	<0.0001
Postoperative[b]					
Po_2/Fio_2	205	180–300	162	136–186	<0.0001
Pco_2 (mm Hg)	42	39–44	47	45–55	<0.0001
Hospital stay (days)	6	4–7	9	8–11	<0.0001
Global cost (€)	5220	4680–5880	8580	7980–11280	<0.0001

[a] Includes anesthesia time, surgery time, weaning time, and time spent in the recovery room. [b] Postoperative assessment was performed 24 hours after the operation.

Fio_2 = fraction of inspired oxygen volume; IRQ = interquartile range; Pco_2 = carbon dioxide tension; Po_2 = oxygen tension.

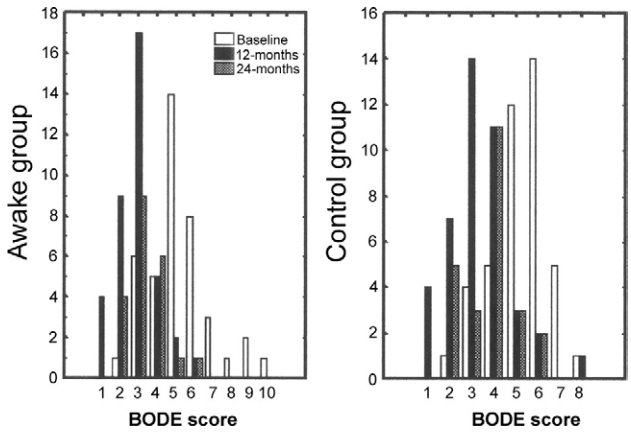

Fig 2. Distribution of preoperative and postoperative BODE index (body mass index, airflow obstruction, dyspnea, and exercise capacity) in awake and control patients. (Baseline, clear bars; 12 months, black bars; 24 months, patterned bars.)

Statistical Analysis

Group descriptive statistics are presented as median with interquartile range. Owing to the small sample size, nonparametric Wilcoxon rank sum and Mann-Whitney tests were used for paired and unpaired data, respectively. Frequencies were compared with the Fisher exact test. Survival and risk of contralateral treatment were assessed by the Kaplan-Meier method, and intergroup differences were assessed by the log-rank test. The outcome variables were analyzed on an intention-to-treat basis. All reported p values are two-sided. No interim analysis was done during the course of the study.

Results

There was no difference between the awake and control group in median age (64.5 years versus 66 years, $p = 0.63$) and sex ratio (female/male, 3:39 versus 4:38, $p > 0.99$).

Conversion to general anesthesia was necessary in 2 patients in the awake group because of panic attack in 1 and hypercapnia exceeding 80 mm Hg in another. No patients in either group required conversion to thoracotomy.

Partial failure of epidural analgesia occurred in 3 patients, who required an additional perioperative local injection of anesthetic. During the operation, intermittent in-expiratory lung motion was easily controlled by the endopaddle, and in no instances did the maintained diaphragmatic motion jeopardize surgical maneuvers.

Perioperative results are detailed in Table 2, which shows that anesthesia time, operative time and global in-operating room time were shorter in the awake group. Oxygenation remained satisfactory throughout the procedure in both groups, although end-operative partial pressure of carbon dioxide (Pco_2) was significantly higher in the awake group. However, postoperative partial pressure of oxygen/fraction of inspired oxygen and Pco_2 measured 24 hours after surgery were better in the awake group.

Satisfaction with the epidural anesthesia was scored as excellent by 31 patients, good by 9, and satisfactory by 2. All patients in the awake group were allowed to drink,

Table 3. Clinical Results

	Baseline, Median (IQR)		12 Months, Median (IQR)		24 Months, Median (IQR)	
Indicator	Awake Group	Control Group	Awake Group	Control Group	Awake Group	Control Group
BODE score	5.0 (4.0–6.0)	5.0 (5.0–6.0)	3.0[a] (2.0–3.0)	3.0[a] (2.0–4.0)	3.0[b] (3.0–4.0)	4.0[b] (3.0–4.0)
Body mass index	23 (22–24)	23 (21–25)	23[b] (22–25)	23 (22–25)	24.6[c] (23–27)	25[b] (22–26)
FEV_1 (L)	0.84 (0.7–1.0)	0.82 (0.69–0.98)	1.17[a] (1.0–1.37)	1.12[a] (0.96–1.3)	1.05[a] (0.93–1.24)	0.96[a] (0.85–1.10)
FEV_1 (%)	31 (26–37)	27 (24–35)	40[a] (38–51)	39.5[a] (32–46)	37[a] (32–45)	34[a] (29–39)
FVC (L)	2.5 (2.0–2.9)	2.62 (2.10–2.88)	2.9[a] (2.6–3.25)	3.0[a] (2.35–3.23)	2.8[b] (2.4–3.2)	2.96[a] (2.33–3.23)
FVC (%)	66 (59–77)	71.3 (55.4–79.5)	83[a] (70–90)	79[a] (62–89)	78[c] (62–86)	77[a] (62–85)
RV (L)	5.28 (4.8–5.7)	4.86 (4.5–5.5)	4.1[a] (3.5–4.7)	4.0[a] (3.5–4.4)	4.4[b] (3.8–5.1)	4.13[b] (3.55–4.4)
RV (%)	228 (195–256)	218 (183–243)	189[a] (144–209)	174[a] (152–198)	200[b] (169–211)	169[b] (175–204)
TLC (L)	7.7 (7.1–9.0)	8.0 (7.46–8.73)	6.9[b] (6.5–8.1)	7.36[b] (6.9–8.1)	7.1[c] (7.0–7.2)	7.54[c] (6.91–8.21)
TLC (%)	135 (124–145)	129 (115–138)	118[b] (103–126)	117[b] (103–130)	109[c] (103–129)	119[c] (113–125)
SMWT (m)	385 (350–420)	375 (346–410)	480[a] (435–520)	460[a] (420–490)	460[a] (410–500)	450[a] (420–470)
MITT (Bruce class)	0.50 (0.50–1.0)	0.50 (0.50–1.0)	1.50[a] (1.5–2.5)	1.50[a] (1.0–2.0)	1.5[b] (1.5–2.0)	1.5[b] (1.0–2.5)
Pao_2 (mmHg)	71.5 (64–76)	68 (66–70)	75[a] (70–80)	70[a] (68–73)	72 (68–75)	69 (66–71)
$Paco_2$ (mm Hg)	39 (38–42)	40 (39–42)	38 (36–40)	39 (38–41)	38 (38–41)	40 (39–41)
Dyspnea index (score)	3 (3–4)	3.0 (3.0–3.0)	2[a] (2–2)	2[a] (1.0–2.0)	2[a] (2–2)	2[a] (2.0–2.0)
PF (SF-36 score)	25 (15–40)	25 (10–35)	50[a] (50–70)	50[a] (45–65)	50[b] (45–67.5)	50[b] (45–55)

Preoperative to postoperative changes: [a] $p < 0.0001$; [b] $p < 0.0008$; [c] $p < 0.05$.

BODE = body mass index, airflow obstruction, dyspnea, and exercise capacity; IQR = interquartile range; FEV_1 = forced expiratory volume in 1 second; FVC = forced vital capacity; IRQ = interquartile range; MITT = maximal incremental treadmill test; $Paco_2$ = arterial carbon dioxide tension; Pao_2 = arterial oxygen tension; PF (SF-36 score) physical functioning domain score of the Medical Outcomes Study Short-Form 36; RV = residual volume; SMWT = 6-minute walk test; TLC = total lung capacity.

eat, and walk within a few hours after the operation, and in most instances, physiotherapy was started the same day of the procedure.

There was no difference in awake versus control group median visual analogue scale scores at 24 hours (2 versus 2, $p = 0.23$) nor in their need of additional analgesia at the fourth postoperative day (4 versus 5 patients). Temporary catheterization was required for urinary retention in 2 patients in the awake group and 3 in the control group.

Ninety-day mortality was nil in both groups. The most relevant nonfatal complications were prolonged air leaks (> 7 days), which occurred in 9 patients (21%) in the awake group versus 19 patients (45%) in the control group ($p = 0.03$). Other less frequent complications included transient arrhythmias and pneumonia, which occurred in 4 patients and 1 patient, respectively, in the awake group and in 5 and 3 patients, respectively, in the control group. Finally, hospital stay was shorter in the awake group than in the control group, and overall medical costs were lower (Table 2).

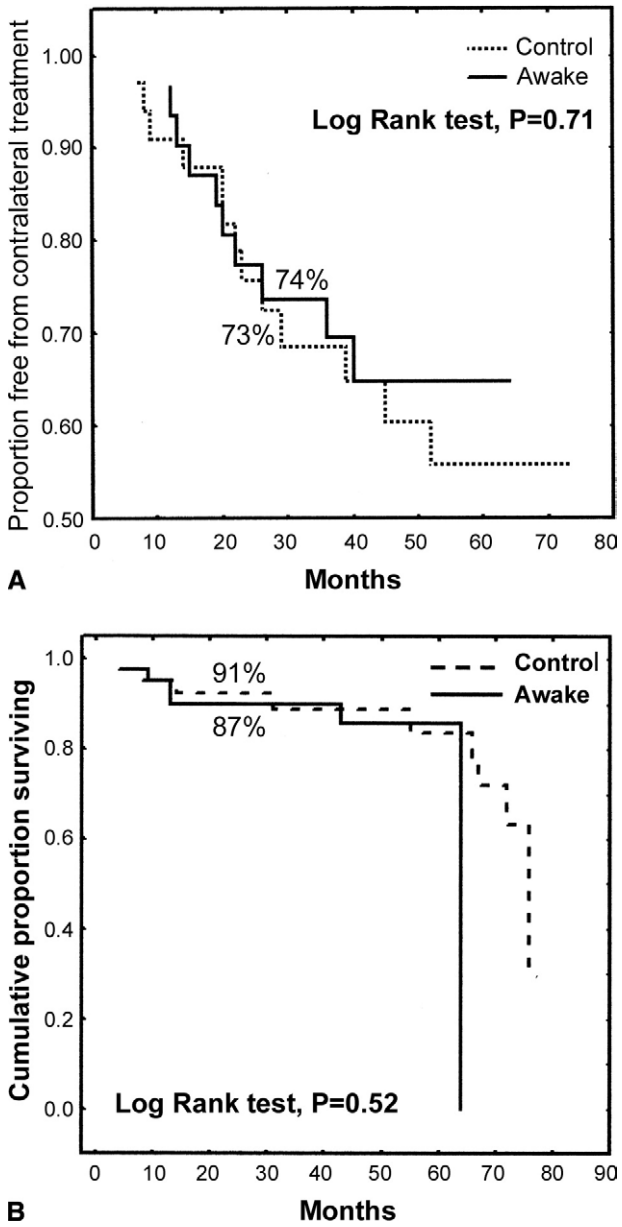

Fig 3. Kaplan-Meier curves show predicted freedom from (A) contralateral lung volume reduction surgery (log-rank test p = 0.71) and (B) survival (log-rank test p = 0.52) in control (dotted line) and awake patients (solid line).

No patients were lost to follow-up, which was 41 months in the awake group and 43 months in the control group. At 12 months, significant preoperative to postoperative improvements occurred in the BODE index (Fig 2) and other outcome measures, including FEV_1, FVC, and RV, which remained significantly improved for up to 2 years (Table 3). BMI increased due to a change in median body weight, which increased from 65 to 67 kg in the awake group ($p = 0.0005$) and from 68 to 69 kg in the control group ($p = 0.0002$). Intergroup comparison showed that FEV_1 and RV improved more in the awake group ($p < 0.04$ and $p < 0.03$, respectively) whereas FVC improved more in the control group ($p = 0.006$).

During follow-up, 10 patients (24%) in the awake group and 14 patients (29%) in the control group underwent completion of the bilateral treatment. Reasons for need of contralateral treatment were FEV_1 decline to baseline value in 15 patients (7 in the awake group; 8 in the control group) and reappearance of incapacitating dyspnea in 9 patients (4 patients in the awake group; 5 patients in the control group).

Overall, 6 patients in the awake group died of respiratory failure (n = 5) or a cancer-related cause (n = 1), and 9 patients in the control group died of respiratory failure (n = 6), cardiac disease (n = 2), or cancer-related causes (n = 1). The study groups did not differ in actuarial survival and freedom from contralateral treatment (Fig 3).

Comment

Nonresectional LVRS in awake patients is the culmination of 10 years' experience with comprehensive emphysema treatment at the Tor Vergata University and constitutes one further step within our adventure of minimizing both surgical and anesthesiologic trauma without jeopardizing the benefit achievable by resectional LVRS.

The main finding of this study is that nonresectional LVRS in awake patients resulted in a significant improvement in the multidimensional BODE index, which lasted for more than 2 years. Moreover, clinical results, freedom from contralateral treatment, and survival were highly satisfactory and comparable with those achieved in the control group, although hospitalization and overall costs were significantly reduced in the awake group.

A recent analysis of the National Emphysema Treatment Trial (NETT) results [20] has shown that air leak occurs in 90% of patients undergoing LVRS, is often prolonged, and is associated with a more complicated and protracted hospital course. Yet in the same study, surgical approach, buttressing, stapler brand, and intraoperative adjunctive procedures were not associated

with fewer or less prolonged air leaks. We believe that the smooth postoperative course observed after LVRS in awake patients reflected a more rapid recovery, with prompt resumption of main activities of daily life and a relatively low rate of prolonged air leaks, which compared favorably with the control group's results and other series data [2, 8, 20].

Nonresectional LVRS maintains the basic concepts outlined by Brantigan and colleagues [21] and refined by Cooper and colleagues [22], including a reduction of 20% to 30% of the lung volume, suturing performed along a single ideal line, and use of stapling devices. Yet, it adds some conceptual differences that might have contributed to reduce the incidence and duration of air leaks. First, peripheral suturing minimizes the interruption of subsegmental bronchi and vessels. Second, a linear but interrupted suture line is likely to be more flexible than a continuous one, theoretically reducing lung surface tension during lung reexpansion. Furthermore, our plication technique might result in a more uniform distribution of the lung expansion forces around the suture line due to the inlay buttress created by the plicated bullous tissue itself.

Celli and colleagues [17] proposed the BODE index as a simple multidimensional grading system that predicted the risk of death among patients with COPD better than each of the individual components. Among BODE components, FEV_1 was chosen because it can reliably predict health status, the rate of exacerbations of COPD, the pharmacoeconomic costs, results of LVRS, and the risk of death. The MMRC dyspnea scale and SMWT investigate other aspects of the disease and have been widely used in the assessment of LVRS results. Finally, BMI has been found to be inversely correlated with survival and, in our opinion, constitutes a further interesting outcome variable. Indeed, we have already reported that fat-free mass and body weight increased 6 months after LVRS, and this improvement correlated with a reduction in residual volume [23].

Imfeld and coworkers [18], recently reported that the postoperative BODE index improved from 7.2 to 4.0 at 3 months after bilateral resectional LVRS, and the postoperative BODE score predicted the risk of death better than each single component.

In a multicenter study by Miller and colleagues [5], surgical mortality was 16% at 2 years, with no 30-day mortality and two deaths at 90 days; the increase in FEV_1 was 30% or 265 mL, and improvement in SMWT was 78 m. The same authors have also found that LVRS costs an additional Can$28,119 compared with best medical care. Their conclusions were that cost of LVRS is high but in keeping with other treatment modalities currently available. In the NETT trial, cost-effectiveness analysis [11] showed direct medical costs of LVRS versus medical therapy were significantly higher in the surgical arm ($61,145 versus $15,738, respectively). Conclusions of this study were that LVRS is costly relative to medical therapy, although the procedure may be cost-effective if benefits are maintained over time.

Obviously, comparisons between our study and the aforementioned series are inappropriate because of major differences between countries in health care organization and costs of materials, hospitalization, and human resources. Nonetheless, our preliminary results seems to suggest that nonresectional LVRS in awake patients might dramatically reduce medical costs of this surgical procedure. This might be due at least in part to reduced in-operating room times, which in our study reflected an almost immediate postoperative transfer of the awake patients to the ward. This contrasted with the weaning time and recovery room time that were always required in general anesthesia patients to achieve a stable clinical condition.

In a recent update of the NETT trial [4], patients with upper-lobe-predominant emphysema and low exercise capacity demonstrated better 5-year survival, improved 3-year exercise capacity, and 5-year relief of dyspnea than medically treated patients. In our series, 38 of 42 patients (90%) had upper-lobe-predominant emphysema, and all patients had impaired exercise capacity, although this latter figure is not perfectly matched with NETT data owing to differences in exercise testing. Nonetheless, we had no 90-day mortality, and the 2-year survival rate was 87%, a figure that is in line with the best results in the literature [1, 2, 18].

Physiopathologic Considerations

In LVRS done under general anesthesia, one-lung ventilation is deemed necessary. However, several adverse effects can derive from this type of anesthesia, including an increased risk of pneumonia, impaired cardiac performance, neuromuscular problems, and damage related to mechanical ventilation, which includes barotrauma, volutrauma, and atelectrauma [24]. Furthermore, general anesthesia with instrumentation of the airways can elicit bronchospasm and life-threatening complications. Most of these adverse effects could be avoided by using epidural anesthesia in awake patients; however, the use of thoracic epidural anesthesia in patients with compromised respiratory function raises several theoretical concerns:

1. The motor blockade induced by epidural anesthesia might lead to respiratory failure.
2. The sympathetic blockade related to the epidural anesthesia can lead to an increased bronchial tone and airway hyperreactivity [25].
3. An open pneumothorax could have compressed the dependent lung, eventually resulting in further deterioration of patient's functional compromise.

Our preliminary experience with LVRS in awake patients suggests that most of these concerns were unfounded. In fact, simple administration of oxygen through a Venturi mask prevented hypoxemia, although permissive hypercapnia developed frequently. The pathophysiology of this event is not fully understood, but hypoventilation due to partial collapse of the operated lung and a rebreathing effect seem reasonable hypotheses. Nonetheless, the perioperative raise in carbon dioxide was well tolerated by the patients and resolved more

rapidly than in the control group. We attribute this feature to the better synchronization of rib-cage–abdominal motion, which was immediately evident after awake LVRS. A further effect that could have contributed to keep respiratory function satisfactory throughout the procedure is the maintained diaphragmatic motion, which might have decreased the detrimental effect of the abdominal pressure leading the paralyzed diaphragm to compress the dependent lung during general anesthesia.

Limitations

Our study has some limitations. First, although preoperative and postoperative patient data were prospectively stored in a database, the overall analysis has to be considered retrospective because BODE index results have been stored in a prospective manner since April 2004 and retrospectively in patients operated on before that date. Second, follow-up is still too short to draw definitive statements about advantages of nonresectional LVRS in awake patients versus the resectional procedure. Finally, the validity and cost-effectiveness of initial unilateral awake LVRS with completion of bilateral treatment at the reappearance of disabling symptoms must still be considered investigational and merits further investigation.

Conclusions

We have shown that sustained improvement in multidimensional BODE index, a high rate of freedom from contralateral LVRS, and satisfactory survival occurred after nonresectional LVRS in awake patients. These results compared with those achieved in a historical cohort undergoing resectional LVRS under general anesthesia, although the procedure in awake patients proved more cost-effective owing to a shorter hospitalization and lower costs. A randomized study is welcome to corroborate, implement, or contradict our encouraging findings.

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DISCUSSION

DR G. ALEXANDER PATTERSON (St. Louis, MO): I'd say that the short period of follow-up is a real problem with respect to analyzing a need for intervention on the other side. I gather by intervention you mean LVRS on the contralateral side; is that what you mean?

DR POMPEO: Well, actually, median follow-up was something more than 40 months for each group, then maybe is not too small to analyze the need for contralateral treatment. Anyway, you have seen that there are few patients needing a contralateral treatment within the first 24 months. Maybe there were somewhat more than 10 in each group. Many patients do not need any contralateral treatment for many years, indeed.

DR MALCOLM M. DECAMP (Boston, MA): I enjoyed that very much. We have all been searching for surrogates that would predict either favorable or poor outcomes for the management of these sick patients. Just a word of caution about the use of the BODE index. BODE has been validated across a larger spectrum of emphysema than we are talking about for volume reduction surgery. BODE is a predictor for bad outcomes as it declines. It has not been concretely validated in terms of an improving BODE correlating with improved survival.

You had excellent outcome in terms of survival in all your patients. It is a nice goal to come up with one of these composite indices of both adverse outcome and benefit, but we have to recognize that with LVRS, we are taking care of a fairly narrow spectrum of emphysema. When changing BODE in the positive direction, we need a larger study to make sure that the BODE index is really measuring what we think contributes to enhanced survival.

DR POMPEO: Thank you for your comments. I believe the most interesting thing in this issue is that BODE index includes some of the most employed outcome measures employed for lung volume reduction surgery, like the FEV_1, the modified Medical Research Council dyspnea index and the 6-minute walking test. And you have seen that even the body mass index is significantly modified by lung volume reduction surgery, as we have already shown in a paper published in the *Journal of Thoracic and Cardiovascular Surgery*, and mainly due to a net increase in fat-free mass and body weight after the procedure.

DR MICHAEL S. MULLIGAN (Seattle, WA): It is a little intimidating for some us to think about having one of these critically ill patients be wide awake while we make holes in their chest and operate on them. And what was the incidence wherein one of your patients would decompensate and then they'd need urgent airway control? And so if you think of that being done proactively, we consider that to be more safe. But did you have any occasion wherein you had to intervene, somebody was retaining too much CO_2, his oxygenation was failing, and you then had to urgently intubate, and isolating that lung was not that practical or easy in that context perhaps?

DR POMPEO: We did have 2 patients who needed the conversion to general anesthesia due to panic attack more than respiratory failure. Because as you have seen, oxygenation can be maintained quite easily during an awake procedure, the problem is that the rise in P_{CO_2} can become a problem if the procedure is going to be too long.

Two-Year Improvement in Multidimensional Body Mass Index, Airflow Obstruction, Dyspnea, and Exercise Capacity Index After Nonresectional Lung Volume Reduction Surgery in Awake Patients

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