Awake thoracoscopic bullaplasty

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Abstract

Objective: Staple excision of emphysematous bullae through general anesthesia is the standard surgical treatment of bullous emphysema. We have developed a new surgical technique entailing thoracoscopic bullaplasty performed in fully awake patients through sole epidural anesthesia.

Methods: This prospective nonrandomized trial included 35 patients undergoing awake thoracoscopic bullaplasty between 2002 and 2009. Preoperative work-up included computed tomography with algorithm for quantitative measurement of the bulla volume. Outcome measures included patient’s satisfaction with the anesthesia, scored into four grades (1 = unsatisfactory; 4 = excellent); ratio of arterial oxygen tension to fraction of inspired oxygen (PaO₂/FiO₂), and postoperative assessment of standard clinical measures at 6, 12, and 36 months.

Results: There were 29 men and six women with a median age of 60 years. Median volume of the bulla was 688 ml. Awake bullaplasty was successfully completed in 34 patients. Perioperatively, PaO₂/FiO₂ decreased significantly (analysis of variance (ANOVA), \( P < 0.0001 \)) though remaining satisfactory (\( > 300 \text{ mmHg} \)), whereas PaCO₂ increased intraoperatively (ANOVA, \( P < 0.0001 \)) but returned to baseline values 1 h after surgery (\( P = 0.20 \)). There was no mortality; four patients had air leaks longer than 7 days. Mean hospital stay was 4.9/2.2 days. Comparisons between pre- to 6-month changes in outcome measures showed improvements (\( P < 0.0001 \)) in forced expiratory volume in 1 s (FEV₁) (+0.37 l), residual volume (−1.16 l), dyspnea index (−2), and standard 6-min walk test (SWMT) (+71 m). These improvements lasted for up to 36 months and in no patient did operated bullae recur.

Conclusion: Our study suggests that awake thoracoscopic bullaplasty was well tolerated and easily performed in the majority of the patients, and significant clinical improvements lasted for up to 36 months.

Keywords: Bullous emphysema; COPD; VATS; Awake thoracic surgery; Thoracic epidural anesthesia

1. Introduction

Bullae are airspaces greater than 1 cm in diameter in the distended state resulting from localized emphysematous destruction of lung tissue. They can be rarely found as isolated lesions surrounded by relatively normal lung, but in many instances, they develop within a diffuse anatomic pattern of centrilobular or paraseptal emphysema [1,2].

Surgical treatment is advocated when the bulla enlarges as to cause symptoms or when complications such as pneumothorax, infection, or hemoptysis do occur [3].

Among the different surgical techniques that have been employed to treat emphysematous bullae, bullectomy with resection or plication of the bullae carried out through thoracotomy [4–6] or even median sternotomy for one-stage bilateral treatment [7] has been frequently employed to eliminate these space-occupying lesions.

To minimize tissue trauma and patients’ discomfort, bullectomy has been more recently performed also through video-assisted thoracoscopic surgery (VATS) [8,9] approaches.

Regardless of the surgical approach that is chosen, general anesthesia with one-lung ventilation is considered mandatory for bullectomy, although it may contribute to the overall procedure-related morbidity, particularly in patients with compromised pulmonary function.

We have recently started an investigational clinical program of awake VATS bullaplasty entailing use of a novel plication technique carried out through sole epidural anesthesia in fully awake patients.

The aim of this study is to analyze perioperative and intermediate-term results of this novel surgical procedure.

2. Materials and methods

From January 2002 to December 2009, 35 patients with bullous emphysema undergoing awake VATS bullaplasty were evaluated. Patients undergoing VATS due to primary spontaneous pneumothorax were excluded from this analysis.

Indications for the operation included impaired respiratory function and dyspnea in 22 patients, secondary...
spontaneous pneumothorax in nine, and patient’s request of prophylactic bulllectomy in four patients.

All patients gave written informed consent for the procedure and the Tor Vergata Ethical committee approved the study.

Contraindications for awake bullaplasty included patient’s refusal of the awake anesthesia, radiologic evidence of extensive pleural adhesions with pleural scarring and calcifications and/or a contraindication for thoracic epidural anesthesia, unfavorable anatomy, previous surgery of the cervical or upper thoracic spine, compromised coagulation (thromboplastin time < 80%, prothrombin time > 40 s, or platelets < 100 10^9/l), or bleeding disorder.

Pulmonary function tests included standard spirometry, plethysmography, and assessment of diffusing capacity for carbon monoxide by the single-breath technique. All spirometric data refer to postbronchodilator measures. Blood gases were also analyzed in all patients.

Radiologic study included end-inspiratory and end-expiratory chest X-ray and high-resolution computed tomography (CT). In addition, the volume of the bulla was calculated in a semiquantitative manner by volume-CT of the chest, acquired with LightSpeed scanner (General Electric Medical Systems, Milwaukee, WI, USA) [10].

Exercise tolerance was assessed by the standard 6-min walk test (SMWT). 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).

Perioperative outcome measures included changes in the ratio of arterial oxygen tension to fraction of inspired oxygen (PaO_2/FiO_2) and arterial carbon dioxide tension (PaCO_2) measured at four fixed time points (T1 = preoperative, lateral position; T2 = end-operative; T3 = 1 h postoperatively; and T4 = 24 h postoperatively), satisfaction with anesthesia scored into four grades (from 1 = unsatisfactory to 4 = excellent), and hospital stay. Clinical outcome measures included assessment of improvements in lung hyperinflation indicated by changes in plethysmographic residual volume (RV); in airflow obstruction as indicated by forced expiratory volume in 1 s (FEV_1); in subjective dyspnea as indicated by the modified Medical Research Council dyspnea score; in exercise capacity as assessed by the SMWT; and in quality of life as assessed by the physical functioning SF-36 score (PF).

2.1. Anesthesia technique

Technical aspects of thoracic epidural anesthesia have been previously described in detail [10]. Briefly, in all patients, the epidural catheter was placed at T4 level and continuous infusion of ropivacaine 0.5% and sufentanil 1.66 μg ml⁻¹ was started 20 min before the operation. The patient was placed in lateral decubitus position with the hemithorax targeted for surgery in a dependent position to facilitate gravity distribution of the anesthetic drugs toward that side of the chest. Intraoperatively, patients breathed room air, whereas additional oxygen through a Venturi-mask was delivered whenever necessary to keep arterial oxygen saturation > 90%. During wound closure, the anesthetic regimen was changed to ropivacaine 0.16% and sufentanil 1 μg ml⁻¹ at 2–5 ml h⁻¹.

Whenever conversion to general anesthesia was deemed necessary, it was carried out following insertion of a chest tube and one-layer closure of the thoracic incisions, placement of the patient in supine position, intravenous (I.V.) induction of anesthesia with propofol, and double-lumen tube intubation for single-lung ventilation.

2.2. Surgical technique

The patient was placed in full lateral decubitus position. A three-trocar access was employed for 30° camera and appropriate instrumentation. Whenever the bulla remained hyperinflated despite induction of the surgical pneumothorax, it was incised by endoscissors and deflated. Subsequently, the lung was grasped ventrally and dorsally at the base of the bulla and the central part of the lesion was introflexed with a cotton swab. Subsequently, both lung edges were grasped together with a single ring forcep and a 45-mm ‘no knife’ endostapler was applied at the base of the bulla on the plicated lung region, taking care to include in the suture line a limited amount of healthy tissue. Following firing of three cartridges, bullaplasty was accomplished with no tissue resection (Fig. 1). Finally, one chest tube was placed dorsally up to the top of the chest.

2.3. Statistical method

Group descriptive statistics are presented as median with quartile range (QR). Two-way ANOVA for repeated measures was employed to analyze perioperative changes in PaO_2/FiO_2 and PaCO_2. Stepwise analysis of paired data was performed by the Wilcoxon matched pairs test. All reported P values are two-sided. Statistical analysis has been performed by the Statistica 7.0™ software.
3. Results

During the study period, out of 39 screened patients, four were excluded due to refusal of an awake operation in four instances and to radiologic evidence of diffuse and calcified pleural adhesions requiring an intentional thoracotomy approach in one.

As a result, in the study cohort, there were 29 men and six women with a median age of 60 years. A total of 32 patients were smokers and 22 had quit smoking for at least 1 month at the time of the operation. No patient had α-1 antitrypsin deficiency. Out of nine patients operated on due to secondary pneumothorax, four patients underwent previous placement of a chest tube, while five were operated on an urgent basis. The bulla was localized in the upper lobes in 21 instances (13 right-sided and eight left-sided), in the lower lobes in 11 instances (six right-sided and five left-sided), and in the middle lobe in three (Fig. 2). An isolated bulla was found in eight instances whereas multiple bullae with well-preserved underlying lung tissue were found in six patients. Among 12 patients with giant bullous emphysema, median volume of the bulla was 1175 ml (QR: 1119–1397) ranging from 1040 ml to 3870 ml. Bilateral bullae were found in 23 patients (Table 1).

Awake bullaplasty was successfully completed in 34 patients. In two of these patients, a limited thoracotomy was carried out without conversion to general anesthesia. One patient needed conversion to general anesthesia due to severe adhesions. Perioperatively, PaO$_2$/FiO$_2$ changed significantly (Fig. 3). In particular, it decreased from 371 mmHg at T1 to 314 mmHg at T2 (Wilcoxon, $P < 0.0001$) though remaining satisfactory (>300 mmHg) and rapidly improving since 1 h postoperatively. PaCO$_2$ also changed significantly during the operation (Fig. 4) but returned toward baseline values 1 h after surgery (T1 vs T3, Wilcoxon, $P = 0.20$). Yet, when dividing patients in whom the bulla was opened to deflate it (16 patients) with those in whom bullaplasty was carried out on an intact bulla (17 patients), there was no perioperative difference in PaO$_2$/FiO$_2$ and PaCO$_2$ (Figs. 3 and 4).

No patient needed conversion to general anesthesia due to excessive hypercapnia or panic attacks. Patients' satisfaction with the anesthesia was scored as excellent by 22 patients and as good, satisfactory, or unsatisfactory in 9, 3, and one patients, respectively (median 4, QR: 3.0–4.0). There was no operative mortality; four patients had air leaks longer than 7 days. Median hospital stay was 5 days (QR: 3–6 days), and ranged between 2 and 13 days. In particular, seven patients had a hospital stay of 3 days and one of 2 days.

Median follow-up was 44 months (QR: 13–80 months). Comparisons between pre- to 6-month-postoperative outcome measures showed that significant improvements ($P < 0.0001$) occurred in FEV$_1$ (0.37 l, QR: 0.24–0.47 l), residual volume (1.16 l, QR: 0.9–1.6 l), dyspnea index (2, QR: 2.0–3.0), SMWT (71 m, QR: 40–110 m), and PF (9.3, QR: 4.5–16.0). All these improvements remained significant for up to 36 months (Table 2) and, so far, no patient had recurrence of the plicated bulla(e).

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Fig. 2. Preoperative radiologic findings of a large medium lobe bulla (A and B) and radiographic postoperative control (C).

Fig. 3. Perioperative changes in PaO$_2$/FiO$_2$.

Fig. 4. Perioperative changes in PaCO$_2$. 
4. Discussion

The main findings of our study are that awake thoracoscoptic bullaplasty was easily performed and well tolerated in the vast majority of the patients. Hospitalization was satisfactorily short and significant clinical improvements occurred postoperatively and lasted for up to 36 months.

These results corroborate and extend our previous findings suggesting that several VATS procedures, including resection of pulmonary nodules [10] and lung metastases [11], treatment of spontaneous pneumothorax [12], lung-volume reduction surgery [13], and pleural decortication for empyema thoracis [14] can be easily accomplished in awake patients. Advantages of awake thoracoscoptic procedures remain to be fully elucidated although there is evidence that avoidance of general anesthesia and one-lung ventilation facilitate a smooth and prompt postoperative recovery resulting in fast resumption of common daily life activity and short hospital stay, particularly in patients with compromised pulmonary function. In addition, elimination of weaning time can significantly shorten the overall inoperating room time by reducing the need of recovery room stay [10]. This can facilitate fast-track surgery programs and might potentially reflect in a reduction of overall procedure-related costs [12]. Another potential advantage of awake VATS is a reduced stress-hormones response [15]. The theoretical concern that operating on an awake, spontaneously breathing patient might be more technically demanding, was revealed to be groundless in our experience as following creation of the surgical pneumothorax, lung collapse is almost complete in patients with relatively well-preserved lung tissue. Moreover, the fear that the surgical pneumothorax might prove dangerous or intolerable, particularly in functionally most severely compromised patients, also was unfounded as even patients with a FEV1 as low as 0.65 l and a room-air PaO2 of 57 mmHg tolerated the awake procedure and maintained an acceptable oxygenation by simple oxygen addition through a Venturi mask.

Table 1. Demographics and baseline data.

<table>
<thead>
<tr>
<th>Demographics</th>
<th>Quartile range</th>
<th>Range</th>
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<tbody>
<tr>
<td>Age (years)</td>
<td>60</td>
<td>55—65</td>
</tr>
<tr>
<td>Gender (M/F)</td>
<td>29/6</td>
<td>—</td>
</tr>
<tr>
<td>Smoking exposure (pack-year)</td>
<td>10</td>
<td>5—20</td>
</tr>
<tr>
<td>Inhaled drug abuse (patients)</td>
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<td>—</td>
</tr>
<tr>
<td>Body mass index</td>
<td>23.9</td>
<td>22—27</td>
</tr>
</tbody>
</table>

Radiologic morphology data

| Bulla volume (ml)                     | 688            | 368—1140 | 204—3870 |
| Bulla/residual volume ratio (%)      | 22             | 10—27   | 5.5—50   |
| Giant bulla (>1000 ml) (N)           | 12             | —       | —       |
| Bilateral bullae (N)                 | 23             | —       | —       |
| Concomitant diffuse emphysema (N)    | 21             | —       | —       |

Averaged data expressed as median values with quartile range and absolute range.

Table 2. Clinical results after bullectomy.

<table>
<thead>
<tr>
<th></th>
<th>Baseline</th>
<th>6 months</th>
<th>1 year</th>
<th>3 years</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Median</td>
<td>QR</td>
<td>Median</td>
<td>QR</td>
</tr>
<tr>
<td>Dyspnea (score)</td>
<td>2</td>
<td>2—3</td>
<td>1</td>
<td>0—1</td>
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<tr>
<td>FEV1 (l)</td>
<td>1.43</td>
<td>1.34—1.85</td>
<td>1.80</td>
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<td>FEV1 (%predicted)</td>
<td>59</td>
<td>50—64</td>
<td>71</td>
<td>65—75</td>
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<tr>
<td>RVpleth (l)</td>
<td>3.8</td>
<td>2.9—4.5</td>
<td>2.46</td>
<td>1.7—2.95</td>
</tr>
<tr>
<td>RVpleth (% predicted)</td>
<td>216</td>
<td>202—405</td>
<td>150</td>
<td>122—166</td>
</tr>
<tr>
<td>DLCO (mmol/kPa/min)</td>
<td>2.75</td>
<td>2.1—3.4</td>
<td>2.7</td>
<td>2.1—3.4</td>
</tr>
<tr>
<td>PaO2 (mmHg)</td>
<td>78</td>
<td>71—84</td>
<td>81</td>
<td>73—88</td>
</tr>
<tr>
<td>SMWT (m)</td>
<td>416</td>
<td>360—450</td>
<td>470</td>
<td>442—520</td>
</tr>
<tr>
<td>PF (score)</td>
<td>52</td>
<td>39—55</td>
<td>63</td>
<td>48—75</td>
</tr>
</tbody>
</table>

Dyspnea index: modified Medical Research Council dyspnea score; FEV1: forced expiratory volume in 1 s; RVpleth: plethysmographic residual volume; DLCO: diffusion capacity for carbon monoxide; PaO2: arterial oxygen tension; SMWT: six minute walking test; PF: short form-36 items physical functioning.

\* P < 0.0001.

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Whenever the bulla remains hyperinflated, simple incision of the bulla walls results in complete collapse with no functional adverse effects and facilitates introflexion and plication of the lesion. Another theoretical concern was that opening the bulla might have induced deterioration of oxygenation due to the creation of a large bronchopleural fistula. However, in the clinical setting, it also proved groundless, as we have found no deterioration in oxygenation intraoperatively even when large incision of the bulla was carried out to facilitate deflation and surgical maneuvers. Instead, it was worthy of note that the bulla was carried out to facilitate deflation and improvement have been historically outlined suggesting relationships between size of the bulla and magnitude of improvement when the bulla exceeds in a volume one-third of a hemithorax [3,6,23].

In a recent study [11], we have proposed a simple surgically oriented classification system of emphysematous bullae that is based on radiological estimation of the bulla volume. In that study, we had found that the ratio bulla volume/RV constitutes an important positive predictive factor of postoperative improvement in pulmonary function and quality of life, particularly when this ratio is higher than 20%. Moreover, it has been recently suggested that bullectomy can improve lung function and exercise capacity by reducing dynamic hyperinflation [24]. Improvements in cardiac function can occur as well and might be addressed to improved venous return, recruitment of pulmonary vasculature, and improved cardiac geometry [8].

In our series, clinical improvements achieved in dyspnea index, pulmonary function, and quality of life by awake thoracoscopic bullaplasty have been highly satisfactory, although follow-up is still too short to draw final conclusions regarding the long-term effects of this novel surgical procedure.

4.1. Limitations

They include the nonrandomized nature of our investigation and the lack of a control group that precluded us from the possibility to achieve comparative results with standard bullectomy carried out through general anesthesia.

5. Conclusion

In conclusion, our study results suggest that awake thoracoscopic bullaplasty was well tolerated and easily performed in more than 90% of the patients. Hospitalization was satisfactorily short, and significant clinical improvements occurred postoperatively and lasted for up to 36 months. Larger randomized studies are welcome to confirm or contradict our promising findings.

References