Institutional report - Thoracic general

Elective intensive care after lung resection: a multicentric propensity-matched comparison of outcome

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Received 12 July 2005; received in revised form 5 September 2005; accepted 7 September 2005

Abstract

The study was aimed at assessing the influence of the elective ICU admission on the early outcome after major lung resection by analyzing the different postoperative management policies of two centers. Center A managed all patients in a dedicated ward, resorting to ICU for complications requiring invasive assisted ventilation. In center B, high-risk patients were electively transferred to ICU immediately after operation. Propensity score was used to match those patients of center B electively admitted to ICU (96 of 205), with counterparts from center A (96 of 205). The outcome of these matched pairs were then compared. There was a trend of reduced total morbidity (23% vs. 35%, respectively; \(P=0.06\)), cardiovascular (13.5% vs. 23%, respectively; \(P=0.09\)) and pulmonary complication rates (9.3% vs. 18%, respectively; \(P=0.09\)), but a longer postoperative hospital stay (11.5 vs. 9.7, respectively; \(P=0.015\)) in the patients electively admitted to ICU, compared to matched center A patients. Mortality rates were not different (7.3% vs. 7.3%; \(P=1\)). Since the elective postoperative ICU admission did not show a clear-cut outcome benefit over the management in a dedicated ward, this practice should be limited to highly selected patients in order to efficiently utilize the available resources.

Keywords: Lung resection; Outcome; Intensive care management; Postoperative management; Morbidity; Mortality

1. Introduction

In many centers high-risk candidates for lung resection are electively admitted to the Intensive Care Unit (ICU) immediately after surgery.

However, the cost-effectiveness of this practice is controversial.

The objective of this study was to investigate the effect of the postoperative elective ICU management on the early outcome of patients submitted to major lung resection. To this purpose, we analyzed patients from two Italian general thoracic surgery units with different postoperative management policies and both without the availability of a thoracic High Dependency Units (HDU).

In center A, all patients are admitted to a dedicated general thoracic surgery (GTS) ward immediately after operation, resorting to ICU in case of complications needing invasive ventilation or monitoring.

In center B, selected high-risk patients were electively transferred to ICU immediately after operation.

This study compared the outcome of those patients of center B that were selected to be electively admitted to ICU with that of propensity case-matched counterparts of unit A after major lung resection.

2. Patients and methods

We analyzed 362 patients (205 in center A and 157 in center B) submitted to lobectomy/bilobectomy (168 in center A and 132 in center B) or pneumonectomy (37 in center A and 25 in center B) from January 2003 through December 2004.

This is an observational study performed on prospective databases of two tertiary referral centers located in two different Italian regions.

Center A has a dedicated GTS ward staffed, 24 h a day, 365 days a year, with specially trained nurses and chest physiotherapists. In the early postoperative period the patients are monitored by means of ECG monitor and pulse oxymeter. Non-invasive systemic blood pressure, respiratory rate, body temperature and central venous pressure (if a central venous catheter is in place) are recorded every other hour (or more frequently if indicated) on a special chart. Every bed has oxygen and aspiration points, Flo-gard infusion administration and syringe pumps are available. The nurse-to-patient ratio is 1:4. The surgical team is comprised of four certified thoracic surgeons and two residents. At least one thoracic surgeon is always present.
in the ward during the day, and one is always on-call at home during the night. In addition two general surgeons provide back-up during the night within the hospital.

Center B has also a dedicated GTS ward with similar characteristics. The nurse-to-patient ratio is 1:4. The surgical team is comprised of four certified thoracic surgeons. At least one thoracic surgeon is always present in the ward during the day, and one is always on-call at home during the night. In addition one general surgeon provides back-up during the night within the hospital. The ICU of this center is a closed ICU with an intensivist-to-patient ratio of 1:5 during the day and 1:10 at night, and a nurse-to-patient ratio of 1:2. The unit is staffed with certified critical care physicians.

In both centers, operation was contraindicated in those patients with a predicted postoperative forced expiratory volume in one second (ppoFEV1) less than 30% of predicted [1], and with hemodynamic instability. In center A, symptom-limited stair climbing test was systematically used for risk stratification before operation and even those patients with a critical ppoFEV1, but with a satisfactory exercise tolerance, were considered for operation [2].

In both centers, lung resections were performed through a muscle-sparing thoracotomy, whenever possible. Postoperative treatment was standardized, and consisted of judicious fluid infusion, antibiotics prophylaxis in the first 24 h, anti-thrombotic prophylaxis, chest physiotherapy, and adequate analgesic therapy. Bronchodilators were administered if needed and patients were mobilized as soon as possible.

The postoperative policy of center A was mainly dictated by the shortage of ICU beds in the hospital, which is a major regional trauma center, and by the lack of a dedicated HDU.

In center B, ICU selection was performed by using previously published criteria [3], which include the followings: all pneumonectomy patients; lobectomy patients with ASA 2 3 or CCI 2 4 or FEV1 2 50%. For patients requiring assisted ventilation, weaning and discontinuing ventilatory support was performed according to evidence-based guidelines [4]. The patients were transferred from ICU to the GTS ward once deemed in a clinically stable state at the discretion of the intensivists. This policy was allowed by a greater availability of ICU beds (no emergency department and trauma center in the hospital).

3. Statistical analysis

Selection bias was addressed by constructing propensity scores [5]. The aim of the analysis was to match those patients of center B (96 patients) who were selected to be admitted electively to ICU in the immediate postoperative period (Group B-ICU) and those of center A, immediately managed in a dedicated GTS ward (Group A-GTSW) according to baseline characteristics, and compare surgical outcomes between the matched groups. Before matching patients, a parsimonious explanatory model was developed by bootstrap bagging for variables selection. The probability of elective ICU admission (propensity score) was estimated by logistic regression analysis incorporating the variables identified in the parsimonious model (whose stability was assessed by bootstrap analysis) plus additional baseline variables. Therefore, the variables used in the model were the following: age; type of operation (lobectomy vs. pneumonectomy); arterial carbon dioxide and oxygen tensions; presence of a concomitant cardiac disease; Charison Comorbidity Index (CCI) [6]; American Society of Anesthesiats (ASA) score; predicted postoperative forced expiratory volume in one second (ppoFEV1); predicted postoperative carbon monoxide lung diffusion capacity (ppoDLCO); neoadjuvant chemotherapy; diabetes; presence of an extended resection (see Appendix A). The propensity model is not parsimonious. In fact, the goal is to balance patient characteristics by incorporating ‘everything’ recorded that may relate to either systematic bias or simply bad luck that has otherwise unbalanced the comparison groups of interest, ignoring usual concerns about model overdetermination [5]. All variables were complete. Greedy matching techniques were then used to select center A counterparts to the planned ICU admitted patients of center B by choosing the patient with the nearest propensity score [5]. The procedure yielded 96 well-matched pairs. The early outcomes (morbidity, mortality, length of postoperative stay, failure-to-rescue rate—see Appendix A) in the two groups of propensity score-matched patients were compared by using Chi-square test for categorical variables and the unpaired Student’s t test or the Mann–Whitney test for continuous ones. All statistical tests were two-tailed, and a significance level of P < 0.05 was selected. The analysis was performed by using the Statview 5.0 (SAS Institute; Cary, NC) and the Stata 8.2 (Stata Corp., College Station, TX) statistical softwares.

4. Results

Cumulative morbidity rates in center A and B were 27.3% and 25.6%, respectively. Mortality rates in center A and B were 4.9% and 4.5%, respectively. In center B, 96 patients out of 157 (61%) were selected and electively admitted to ICU immediately after operation. Table 1 shows the results of the comparison of baseline and operative characteristics between the two propensity score adjusted groups. Mean length of ICU stay for B-ICU patients was 69.1 h (S.D. 8.4;
5. Discussion

The EACTS/ESTS working group on Structures in Thoracic Surgery stated that patients submitted to lung resection or other major general thoracic procedures should be managed in a dedicated GTS unit with access to an ICU and availability of a HDU [7].

The aim is to optimize the postoperative monitoring and treatment of these patients in a cost-effective manner. Due to shortage of resources and personnel, dedicated thoracic HDU are still not widely available [8,9]. Therefore, in many centers selected high risk patients are electively admitted to ICU in the immediate postoperative period. The appropriateness of this policy is still controversial and this study aimed to assess its influence on early outcome.

In this study we found that center B patients, electively admitted to ICU immediately after lung resection, had a reduced incidence of cardiopulmonary morbidity, but a similar mortality and a longer postoperative hospital stay compared to propensity score-matched patients of center A, that were nursed in a dedicated GTS ward. Both management policies analyzed in this study have inherent drawbacks.

The greater incidence of cardiopulmonary complications in the A-GTSW patients compared to propensity case-matched B-ICU ones may be explained by a lower nurse-to-patient ratio [10], lack of a continuous monitoring, and a higher threshold for invasive procedures (the repeated bronchoscopies performed in B-ICU patients in the case of increased bronchial secretions may explain the reduced incidence of pneumonia—Table 3).

However, the similar mortality rate (from the present analysis it is impossible to ascertain whether some of the deaths in the A-GTSW could have been prevented by an elective ICU admission) and the prolonged postoperative hospital stay question the cost-effectiveness of elective ICU admission in these types of surgical patients.

The provision of dedicated thoracic HDUs would probably optimize the outcome and the resource utilization in both centers [9,11–13]. This study has possible limitations. First, it was a retrospective, non-randomized analysis of two different centers’ management policies. Even though the propensity score analysis constitutes the most rigorous method for investigating the causal effects in this setting [5], it cannot account for unknown variables affecting outcome that are not correlated strongly with measured variables. Thus, results cannot be interpreted as definitive. Risk models of emergency ICU transfer after lung resection would be most useful for optimizing the selection of those patients to be electively managed in an intensive environment and to construct proper randomized trials investigating the efficiency of this management policy.

Second, the ICU selection criteria of center B, although clinically sound and reflecting the daily practice of that unit, were not prospectively validated.

Third, in multicentric studies dealing with complications, the definition and recording of complications are always critical issues. In this study every effort was made to

<table>
<thead>
<tr>
<th>Variables</th>
<th>A-GTSW (96 cases)</th>
<th>B-ICU (96 cases)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Morbidity (n%)</td>
<td>34 (35%)</td>
<td>22 (23%)</td>
<td>0.06</td>
</tr>
<tr>
<td>Cardiovascular complications (n%)</td>
<td>22 (23%)</td>
<td>13 (13.5%)</td>
<td>0.09</td>
</tr>
<tr>
<td>Pulmonary complications (n%)</td>
<td>17 (18%)</td>
<td>9 (9.3%)</td>
<td>0.09</td>
</tr>
<tr>
<td>Mortality (n%)</td>
<td>7 (7.3%)</td>
<td>7 (7.3%)</td>
<td>1</td>
</tr>
<tr>
<td>Failure-to-rescue (%)</td>
<td>17.6%</td>
<td>31.8%</td>
<td>0.3</td>
</tr>
<tr>
<td>Postoperative hospital stay (days)</td>
<td>9.7 (5.6)</td>
<td>11.5 (7.7)</td>
<td>0.015</td>
</tr>
</tbody>
</table>

Results are expressed as means ± standard deviations unless otherwise specified. Failure-to-rescue rate is the percentage of deaths among complicated patients.

Mann–Whitney test; Chi-square test; Fisher’s exact test.

Table 2

<table>
<thead>
<tr>
<th>Complications</th>
<th>A-GTSW</th>
<th>B-ICU (during ICU stay)</th>
<th>B-ICU (during ward stay)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arhythmia</td>
<td>16</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>Cardiac ischemia</td>
<td>2</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Cardiac failure</td>
<td>1</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Atelectasis</td>
<td>4</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Pneumonia</td>
<td>8</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>ARDS</td>
<td>4</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Respiratory failure</td>
<td>6</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Pulmonary edema</td>
<td>0</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Stroke</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Renal insufficiency</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>Sepsis</td>
<td>0</td>
<td>3</td>
<td>0</td>
</tr>
</tbody>
</table>

See Appendix A for definition of complications.

Table 3

 median 42 h), 54 patients (56.3%) stayed in ICU less than 48 h and 16 of these patients (17%) required intubation and assisted ventilation (mean length of intubation: 56.3 h; median: 9.2 h; extremes: 50 min–430 h).

Table 2 shows the results of the comparison of outcome between the two propensity score matched groups. In summary, there was a trend toward an increased total morbidity (P=0.06), cardiovascular (P=0.09) and pulmonary complications rates (P=0.09) in the A-GTSW compared to the B-ICU patients. No significant differences were noted in terms of mortality (P=1) and failure to rescue rates (P=0.3). Table 3 shows the types of complications in the 2 groups. The mean postoperative hospital stay was 1.8 days longer in the B-ICU patients compared to the A-GTSW ones (P=0.015).

Nine A-GTSW patients needed emergent postoperative ICU admission for cardiopulmonary complications (7 of them died). Among the B-ICU patients who were transferred to the ward, four required to be emergently re-admitted to ICU for severe cardiopulmonary complications. Of the 22 complicated B-ICU patients, 14 (64%) experienced their complications during their ICU stay. Moreover, in the B-ICU group, 1 patient died during his elective ICU stay, 3 patients died after they were transferred to the ward, and 3 died after they were re-admitted to ICU for complications. Causes of death were respiratory (4 in A-GTSW and 3 in B-ICU groups, respectively), cardiac (3 in A-GTSW and 3 in B-ICU groups, respectively) and septic (1 in B-ICU group) in origin.

The EACTS/ESTS working group on Structures in Thoracic Surgery stated that patients submitted to lung resection or other major general thoracic procedures should be managed in a dedicated GTS ward.
uniform the definition of variables and only those complications that were thought to increase the complexity of management were taken into consideration for the analysis.

In conclusion, we found that the elective postoperative ICU management did not clearly improve the early outcome after major lung resection. Therefore, this policy should be limited to highly selected patients (through the development of risk-adjusted models) in order to correctly utilize the available resources in the most efficient manner.

HDUs should be implemented to optimize the postoperative management without the need for the patients to be nursed in an extremely stressful environment of the intensive care.

The satisfactory results obtained in the patients managed in the GTS ward show that the thoracic surgical team, in close liaison with the intensive care team, should be the primary individuals responsible for the postoperative management of these patients.

Appendix A:

A.1. Baseline and operative variables

For the purpose of the present study the following spirometric variables were considered: forced expiratory volume in one second (FEV1); carbon monoxide diffusion lung capacity (DLCO); predicted postoperative FEV1 (ppoFEV1) calculated by the formula (preoperative FEV1/number of preoperative functioning segments) x number of postoperative functioning segments; predicted postoperative DLCO (ppoDLCO) calculated by the formula (preoperative DLCO/number of preoperative functioning segments) x number of postoperative functioning segments.

Pulmonary function tests were performed according to the American Thoracic Society criteria. DLCO was measured by the single-breath method. Results of spirometry were collected after bronchodilator administration and were expressed as percentage of predicted for age, sex and height.

The number of functioning segments was estimated by means of CT scan, bronchoscopy findings and a quantitative perfusion lung scan was used.

For the purpose of the present study, a concomitant cardiac disease (cardiac co-morbidity) was defined as follows: previous cardiac surgery, previous myocardial infarction, history of coronary artery disease, current treatment for hypertension, arrhythmia, or cardiac failure. The following additional variables were used to construct the propensity model: age, type of operation (lobectomy vs. pneumonectomy), presence of an extended resection, arterial carbon dioxide level (PaCO₂), arterial oxygen tension (PaO₂), diabetes, concomitant cardiac disease, neoadjuvant chemotherapy, Charlson comorbidity index (CCI), ASA score. CCI is a comorbidity index which was shown to predict postoperative complications after lung resection [6]. For the purpose of the present study a resection was considered extended when associated with resection of parietal pleura (extrapleural resection), chest wall, mediastinal structures or diaphragm.

A.2. Outcome variables

Postoperative complications and mortality were considered as those occurring within 30 days from operation or during a longer period if the patient was still in the hospital. According to the EACTS/ESTS thoracic surgery database, [14], the following complications were included: (a) pulmonary complications: respiratory failure requiring mechanical ventilation for more than 48 h; pneumonia; atelectasis requiring bronchoscopy; pulmonary edema; pulmonary embolism; (b) cardiovascular complications: myocardial infarction; hemodynamically unstable arrhythmia requiring medical treatment; cardiac failure; stroke; (c) other complications: sepsis, acute renal failure. The proportion of deaths among the complicated patients was termed ‘failure to rescue’ [15].

References
