The values of intrapleural pressure before the removal of chest tube in non-complicated pulmonary lobectomies†

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OBJECTIVES: Digitalized chest drainage systems allow for quantification of air leak and measurement of intrapleural pressure. Little is known about the value of intrapleural pressure during the postoperative phase and its role in the recovering process after pulmonary resection. The objective of this investigation was to measure the values of pleural pressure immediately before the removal of chest tube after different types of pulmonary lobectomy.

METHODS: Prospective observational analysis on 203 consecutive patients submitted to pulmonary lobectomy during a 12-month period at two centres. Multiple measurements were recorded in the last hour before the removal of chest tube and averaged for the analysis. All patients were seated in bed in a 45° up-right position or in a chair, had a single chest tube and were not connected to suction during the evaluation period. Analysis of variance (ANOVA) was used to assess the differences in pleural pressure between different types of lobectomies.

RESULTS: The average maximum, minimum and differential pressures were −6.1, −19.5 and 13.3 cmH2O, respectively. The average pressures were similar in all types of lobectomies (ANOVA, P = 0.2) and ranged from −11 to −13 cmH2O, with the exception of right upper lobectomy (−20 cmH2O, all P-values vs. other types of lobectomies <0.05). Similar values were also recorded for maximum pressures (range −4.4 to −8.4 cmH2O) and minimum pressures (−31.6 cmH2O vs. ranged from −15.4 to −20.5 cmH2O, all P-values <0.01). The average pleural pressure was not associated with FEV1 (P = 0.9), DLCO (P = 0.2 or FEV1/FVC ratio (P = 0.6), when tested with linear regression. Similarly, the average pleural pressure was similar in patients with and without COPD (−12.1 vs. −13.0 cmH2O, P = 0.4). The ANOVA test was used to assess differences in pressures between different lobectomies.

CONCLUSIONS: The so-called water seal status may actually correspond to intrapleural pressures ranging from −13 to −20 cmH2O. Modern electronic chest drainage devices allow a stable control of the intrapleural pressure. Thus, the values found in this study may be used as target pressures for different types of lobectomies, in order to favour lung recovery after surgery.

Keywords: Digitalized chest drainage systems · Intrapleural pressure · Chest tube removal · Pulmonary lobectomies

INTRODUCTION

The recent advent of electronic chest drainage systems has improved the postoperative management of chest tubes, shortening their duration and the hospital stay [1–7]. The most important feature of these systems is the possibility to provide objective information about air leak that can be quantified and reproduced across different surgeons and different hospitals, reducing interobserver variability [2]. Another important feature of some of these devices is the measurement of intrapleural pressure [3–5]. Little is known about the value of intrapleural pressure during the postoperative phase and its role in the recovering process after pulmonary resection [3, 5–7]. Therefore, this information may help in tailoring the level of suction apparatus to achieve a target physiologic pressure compatible with the postoperative phase.

The objective of this investigation was to measure the values of intrapleural pressure immediately before the removal of chest tube after uneventful pulmonary lobectomy.

MATERIALS AND METHODS

This is a multicentre (Ancona, Italy and Salamanca, Spain), prospective observational analysis of 203 consecutive patients submitted to pulmonary lobectomy during a 12-month period (2009). For the purpose of this investigation, patients with prolonged air leak (>7 days, since these patients were usually discharged home with a portable chest drainage system and were
not available for the measurement), with pulmonary complications (which could have influenced the value of pleural pressure owing to different lung compliance) or with associated chest wall or diaphragm resections were excluded.

All patients were operated on by board-certified thoracic surgeons through a muscle sparing, nerve-sparing [8] lateral thoracotomy or video-assisted thoracoscopic mini-thoracotomy.

Both centres share the same inoperability criteria: predicted postoperative forced expiratory volume (ppoFEV1) <30% + predicted postoperative carbon monoxide lung diffusion capacity (ppoDLCO) <30% + maximum oxygen consumption (peakVO2) <10 ml/kg/min.

Preventative measures of air leak (i.e. pleural tent, buttressed staple lines or sealants) were not used in this series.

As a rule, only one chest tube was placed at the conclusion of the surgical procedure in a mid-chest position up to the apex. The chest tube was generally maintained on suction until the morning of the first postoperative day and then switched to no suction and managed according to institutional policies [6].

The digitalized system used in this investigation allowed for continuous multiple measurements (every 2 min) of airflow, maximum and minimum intrapleural pressures through a micro-electronic mechanical sensor technology (Digivent). This sensor was placed close to the canister. The data stored in the drainage system were subsequently downloaded to the computer by using an appropriate software and analysed. The pressure measurements recorded in the last hour (30 values per patient) before the removal of chest tube were averaged and used for the analysis. During the evaluation period, all patients were instructed to seat in bed in a 45° up-right position or in a chair. All of them had a single chest tube (Ch24) and were not connected to suction during the evaluation period.

Chest tubes were removed when no air leak was detected (<10 ml/min for 6 consecutive hours) and the pleural effusion was <400 ml/day.

Pleural pressures were expressed as cmH2O.

Descriptive statistics were expressed as means and standard deviations. Analysis of variance (ANOVA) was then used to assess the differences in pleural pressure between different types of lobectomies. Linear regression was also used to verify the association between pleural pressure with physiologic parameters (i.e. FEV1, DLCO, FEV1/FVC ratio). A P-value of 0.05 was considered statistically significant. All tests were performed on Stata 9.0 statistical software (Stata Corp. College Station, TX, USA).

RESULTS

The mean maximum, minimum and differential pressures (difference between maximum and minimum pressures) were −6.1, −19.5 and 13.3, respectively.

Figure 1 shows the box-plot of the average pressures in different types of lobectomies. The average pressures were similar in all types of lobectomies (ANOVA, P = 0.2) and ranged from −11 to −13 cmH2O, with the exception of right upper bilobectomy, which showed a lower average negative pressure (−20 cmH2O, all P-values vs. other types of lobectomies <0.05).

Similar values were also recorded for maximum pressures (range −4.4 to −8.4 cmH2O). Minimum pressures after right upper bilobectomy showed a significantly lower minimum pressure than all other types of lobectomies (−31.6 cmH2O vs. a range from −15.4 to −20.5 cmH2O, all P-values <0.01) (Table 1).

The average pleural pressure was not associated with the values of FEV1 (P = 0.9), DLCO (P = 0.2) or the FEV1/FVC ratio (P = 0.6), when tested with linear regression.

Similarly, the average pleural pressure did not differ in patients with and without chronic obstructive pulmonary disease (defined as FEV1 <80% and FEV1/FVC ratio <0.7) (−12.1 vs. −13.0 cmH2O, P = 0.4).

DISCUSSION

In a previous study, Cerfolio and Bryant [7] reported on the benefits of using digital systems in reducing the hospital stay. They also mentioned the importance of pleural pressure in chest tube management and the need of more investigation to understand better its physiologic meaning [7].

In a more recent study, we have shown that the level of both air leak flow and pleural pressures measured early after operation were independently associated with the duration of air leak [3].

However, the role of pleural pressure in the recovery phase after resection is still largely undetermined. This is mainly due to the lack of available systems capable of accurately monitoring this parameter in the postoperative period. With the recent introduction of digital chest drainage systems, however, this limitation has been partly overcome.

Table 1: Target pressure suction level for different types of lobectomies

<table>
<thead>
<tr>
<th>Type of lobectomy</th>
<th>Target pressure suction level (cmH2O)</th>
</tr>
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<tbody>
<tr>
<td>Right upper lobectomy</td>
<td>−14</td>
</tr>
<tr>
<td>Left upper lobectomy</td>
<td>−12</td>
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<tr>
<td>Right lower lobectomy</td>
<td>−12</td>
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<tr>
<td>Left lower lobectomy</td>
<td>−13</td>
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<tr>
<td>Middle lobectomy</td>
<td>−11</td>
</tr>
<tr>
<td>Middle lower bilobectomy</td>
<td>−13</td>
</tr>
<tr>
<td>Middle upper bilobectomy</td>
<td>−20</td>
</tr>
</tbody>
</table>

Figure 1: Box plot of the average pressures in different types of lobectomies. LLL: left lower lobectomy; LUL: left upper lobectomy; ML: middle lobectomy; MLB: middle lower bilobectomy; MUB: middle upper bilobectomy; RLL: right lower lobectomy; RUL: right upper lobectomy.
In fact, the system used in this investigation used a pressure sensor capable of recording the pressure values and store these values in the system for later download in the computer through an appropriate software. This allowed to analyse this information using prospectively recorded data.

The objective of the present investigation was to assess the values of pleural pressure in uncomplicated patients in the last hour prior to the removal of chest tube after pulmonary lobectomy.

The hypothesis behind this study was that the value of pleural pressure measured immediately before the removal of chest tube after non-complicated pulmonary lobectomy may represent a ‘physiologic’ pressure occurring in the recovery phase after surgery. It may be taken therefore as the target pressure when setting the suction level of drainage systems with the aim to promote the postoperative healing processes. These findings may be particularly helpful when using electronic chest drainage units providing a regulated variable suction capable of maintaining a stable intrapleural pressure [10].

Our results demonstrate that what we commonly defined as water seal (or no suction) actually translates into pleural pressures ranging from −13 to −20 cmH2O, according to different types of lobectomies. From the box plot of pleural pressures, it is also evident the existence of a large variability within the same type of lobectomy. This variability may depend on different factors such as uncontrolled siphoning effects within the chest tube, position of the patient, sudden coughing efforts, variable lung compliance etc.

However, taking into the account the inherent imprecision of the method and until more accurate technology providing a direct intrapleural measurement would not be available, the recorded values may be taken as a rough approximation of the actual intrapleural pressure. Pre-setting these values by using auto-regulating controlled digital units may set the stage for future studies focused on active pleural management (i.e. comparison of different levels of suction).

Our study may have some limitations including the fact that the pressure sensor was located near the canister. As such, the pressure measurements may have been influenced by uncontrolled factors such as position of the patient, position of the system relative to the patient, presence of fluid in the tube determining a siphoning effect [9].

Although the digital device used in this study (Digivent) is no longer available in the market, we are confident that the findings of the present study can be used to implement similar measurement software in the existing digital products [3]. Finally, the intrapleural pressure may vary in different zones of the pleural cavity. Ideally, the pressure should be separately measured by different sensors placed in different zones. This was not performed in the present study as we still lack the ad hoc technology to obtain intrapleural reliable measurements in the humans.

In conclusion, we were able to measure different levels of pleural pressure after different types of lobectomies. These data may be taken as reference values for future research in pleural management.

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Conflicts of interest: A.B. has a consultant agreement with Medela Health Care, Switzerland. G.V. has a consultant agreement with Atrium.

REFERENCES