Managing the pneumonectomy space after extrapleural pneumonectomy: postoperative intrathoracic pressure monitoring

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Abstract

Objective: Rapid fluid evacuation of the pneumonectomy space can cause ipsilateral mediastinal shift, contralateral lung hyperexpansion, compromised caval blood return and a precipitous drop in cardiac output. Conversely, rapid fluid accumulation can cause contralateral mediastinal shift with compression of the remaining lung and respiratory insufficiency. In this retrospective analysis, we evaluate the efficacy of intrathoracic pressure monitoring and intermittent fluid aspiration to manage the pneumonectomy space in the early postoperative period following extrapleural pneumonectomy. Methods: Prior to chest closure, a 14F Rob-Nel catheter was placed in the pneumonectomy space and connected to pressure tubing to monitor ipsilateral intrathoracic pressure continuously. Central venous pressure monitoring and serial chest X-rays were performed according to usual intensive care routine. Pneumonectomy space fluid was aspirated intermittently when there was increase in intrathoracic pressure, refractory hypotension, mediastinal shift on chest X-ray, or clinical decline. Postoperative imaging was re-evaluated retrospectively for confirmation of mediastinal shift by a senior radiologist. Results: From January to December 2008, 47 patients underwent extrapleural pneumonectomy for pleural mesothelioma (median age 65 years with range 34—79 years, 77% male). Twenty (43%) patients had left-sided disease and 32 (68%) received local heated intra-operative cisplatin-based chemotherapy. The median baseline pneumonectomy space pressure was 3 cm H2O (range: –6 to +12). The median amount of fluid withdrawn over the first 2 days postoperatively was 300 cc (range: 0—1980 cc). Thirty-one (69%) patients had minimal, if any, change in mediastinal position during the first 2 postoperative days with intermittent drainage performed when the pneumonectomy space pressure rose. Eleven (25%) patients had increasing contralateral shift, four of whom had return of the mediastinum to baseline during this time period. The median fluid drained from the four patients whose contralateral shift resolved was 290 cc (range: 220—800 cc) compared to 200 cc (range: 150—480 cc) from the seven patients whose contralateral shift remained, but this difference did not reach significance (p = 0.365). Conclusions: Intrathoracic pressure monitoring may be used as a guide for intermittent fluid evacuation of the pneumonectomy space prior to onset of clinical signs or symptoms, to avoid the cardiopulmonary risks of rapid fluid removal. Contralateral mediastinal shift should be treated with incremental drainage when there is a rise in intrathoracic pressure to prevent cardiovascular complications.

Keywords: Extrapleural pneumonectomy; Pneumonectomy space; Intrathoracic pressure; Mediastinal shift

1. Introduction

Pneumonectomy, once performed routinely to treat neoplasm or uncontrolled infection, now represents a much smaller proportion of pulmonary resections. Extrapleural pneumonectomy (pneumonectomy with resection of the pleura, diaphragm and pericardium) was introduced in the mid 20th century to treat tuberculosis and is now reserved for selected patients with malignancy, most commonly malignant pleural mesothelioma. Following pneumonectomy, multiple physiologic changes occur in the ipsilateral chest: accumulation of fluid and/or blood, resorption of residual air, and mediastinal and diaphragmatic displacement to reduce the size of the pneumonectomy space. The changes induced by pneumonectomy require careful management of the ipsilateral chest space to maintain haemodynamic and respiratory stability. Rapid fluid evacuation of the pneumonectomy space can cause ipsilateral mediastinal shift with contralateral lung hyperexpansion. This is thought to contribute to the development of idiopathic postpneumonectomy pulmonary oedema, a leading cause of pneumonectomy-associated mortality [1]. Moreover, excessive ipsilateral chest drainage after pneumonectomy can compromise caval blood return causing precipitous drop in...
cardiac output and hypotension. Conversely, rapid fluid accumulation in the pneumonectomy space may lead to contralateral mediastinal shift with compressive atelectasis of the remaining lung, hypoventilation, and respiratory compromise. Careful management of fluid accumulation in the ipsilateral chest in the early postoperative period following pneumonectomy is critical to protect the patient’s cardiovascular and pulmonary status. Managing fluid accumulation after extrapleural pneumonectomy is particularly challenging, since, even in the absence of bleeding, the chest wall has a propensity to produce fluid.

Several methods of controlling the pneumonectomy space have been proposed [2–5]. Miller and colleagues described a balanced drainage system for the management of an infected pleural space after pneumonectomy in 1975 [5]. Modern commercially available chest drainage systems include a model based on balanced drainage principles. A recent survey by the European Society of Thoracic Surgeons querying 120 centres across Europe and the United States demonstrated that half of the participating surgeons use a balanced drainage system for pneumonectomy in their practice [6]. Other surgeons use standard disposable chest drainage systems with underwater suction and a clamp-release schedule, no drainage, or intermittent thoracentesis [1]. While animal studies suggest a benefit from balanced drainage, human trials have not demonstrated any particular technique to be superior to the rest. Moreover, no clinical study has investigated the management of the pneumonectomy space specifically after extrapleural pneumonectomy, a procedure that carries with it more significant fluid shifts and associated haemodynamic and respiratory stresses than standard pneumonectomy.

The experience of managing the pneumonectomy space has led to several general guidelines. The space should not be drained rapidly or completely. Clinical indicators that should prompt drainage include elevated central venous pressure (CVP) with hypotension and contralateral mediastinal shift on chest X-ray. The ability to monitor intrathoracic pressure continuously may facilitate early recognition of potential cardiopulmonary dysfunction. Moreover, the ability to withdraw fluid intermittently as indicated clinically may provide a mechanism to intervene and prevent clinical decline.

We describe our single-centre experience with a novel technique to manage the pneumonectomy space and potential clinical sequelae. With this technique a red rubber Rob-Nel catheter, introduced in the pneumonectomy space at the time of surgery, is used to transduce and thereby monitor the intrathoracic pressure after extrapleural pneumonectomy. The same catheter is used to withdraw fluid as necessary, generally in increments of 150 cc. In a hypothesis-generating analysis, we sought to evaluate the utility of this technique as part of the early postoperative management of patients undergoing extrapleural pneumonectomy for pleural mesothelioma.

2. Materials and methods

This is a retrospective analysis of a cohort of 47 consecutive patients who underwent extrapleural pneumonectomy for malignant pleural mesothelioma, with or without local intra-operative heated cisplatin-based chemotherapy, between January and December of 2008. All patients were evaluated in the Brigham and Women’s Hospital Division of Thoracic Surgery clinic and candidacy for extrapleural pneumonectomy was based on functional status, isolation of disease to the ipsilateral chest without mediastinal, diaphragmatic or diffuse chest wall extension, negative cervical mediastinoscopy (or downstaging after induction chemotherapy for positive mediastinoscopy), and adequate cardiopulmonary reserve. Institutional review board approval was obtained for collection of these data from the International Mesothelioma Program Patient Data Registry.

2.1. Perioperative management

Extrapleural pneumonectomy was performed by the same surgeon (DJS) according to techniques previously described [7]. Prior to chest closure, a 14F Rob-Nel red rubber catheter was placed in the pneumonectomy space through a separate stab wound and connected to a pressure transducer to monitor ipsilateral intrathoracic pressure continuously (Fig. 1a). This catheter was chosen because of its small but effective size and the ease of connecting it to a pressure-transducer setup via a three-way stopcock. As is our standard technique, upon turning the patient to the supine position, air was removed from the chest via the Rob-Nel catheter: 500 cc for left-sided resection in women, 750 cc for right-sided resection in women or left-sided in men, and 1000 cc for right-sided resection in men.

Patients were managed postoperatively in a thoracic surgery intensive care unit (ICU). CVP was monitored continuously and serial chest X-rays were taken daily or for any signs or symptoms of clinical decline (e.g. dyspnoea, chest pain, hypotension, or hypoxia). Pneumonectomy space pressure and CVP were measured in cm H2O and recorded by the ICU staff at hourly intervals and at times of change. In general, fluid was allowed to accumulate in the pneumonectomy space. Fluid was evacuated via the Rob-Nel catheter in increments of 150 cc per aspiration only for persistently elevated intrathoracic pressure, refractory hypotension, mediastinal shift on chest X-ray, or clinical decline (including postoperative bleeding). In extenuating circumstances, such as postoperative bleeding or persistent hypotension with elevated CVP and/or pneumonectomy space pressure, fluid may have been withdrawn in larger amounts. In particular, in one patient with haemorrhagic drainage who was thought to have postoperative bleeding, volumes as high as 750 cc were evacuated.

2.2. Data collection

The individual ICU flowsheets were reviewed for each patient for pneumonectomy space pressure and CVP. Baseline pressures were calculated from the average pneumonectomy space pressures for the first 4 h for each patient. Data were gathered on the timing and amount of fluid drained from the ipsilateral chest for the first 2 days following surgery for each patient. Inpatient charts and electronic medical records were reviewed to verify the information collected. Chest X-rays for the first 2 postoperative days were retrospectively
re-evaluated for mediastinal shift by a senior radiologist blind to the CVP and pneumonectomy space pressure data. Mediastinal position on a given chest X-ray was scored on a seven-point scale depending on the direction and severity of any shift observed: severe ipsilateral (−3), moderate ipsilateral (−2), mild ipsilateral (−1), midline (0), mild contralateral (+1), moderate contralateral (+2), and severe contralateral (+3). Date and time for each study were obtained from the chest X-ray reports in patients’ electronic records.

2.3. Statistical analysis

The amount of fluid aspirated in the first 2 postoperative days was treated as continuous non-normally distributed data with the distributions for various binary categories compared using the Mann—Whitney U test.

3. Results

From January to December 2008, 47 patients underwent extrapleural pneumonectomy for malignant pleural mesothelioma (median age 65 years with range 34—79 years, 77% male). Twenty (43%) patients had left-sided disease and 32 (68%) received local intra-operative heated cisplatin-based chemotherapy. Two patients were excluded from analysis: one whose record had incomplete initial post-operative ICU data and another who was treated with postoperative antibiotic intracavitary irrigation for empyema encountered at the time of extrapleural pneumonectomy. Some patients had negative intrathoracic pressure at baseline, because air was evacuated from the chest at the end of the procedure (see above). The median baseline pneumonectomy space pressure for all patients was 3 cm H2O (range: −6 to +12). The catheter remained in place for a median duration of 3 days (range: 2—5 days). The median amount of fluid withdrawn over the first 2 postoperative days was 300 cc (range: 0—1980 cc). There was no significant association between the amount of fluid aspirated postoperatively and gender, side, or use of intra-operative heated chemotherapy.

Five distinct patterns of change in mediastinal position were observed over the first 2 postoperative days. The amount of fluid aspirated during this time differed for patients demonstrating each of these patterns (Table 1). Thirty-one patients (69%) had minimal, if any, shift in either direction on their chest X-ray for the first 2 postoperative days. While 14 of these patients (31% of the entire cohort) had mild ipsilateral or contralateral shift, 17 (38%) had a midline mediastinum on all chest X-rays performed during this time. The median amount of fluid aspirated for patients with minimal or mild shift was 300 cc (range: 0—790 cc). Pressure, fluid aspiration, and chest X-ray data from a representative patient in this group are depicted in Fig. 2. Note that aspirations at hours 21, 38, 39 and 44 were

mediastinal shift: note the increase in intrathoracic pressure as well as CVP and the decreased oxygen saturation recorded on the monitor.
Two other patients (4% of the total) had large ipsilateral shifts that resolved without intervention over the time period (data from a representative patient depicted in Fig. 3). One other patient (2%) had a large ipsilateral shift associated with 1980 cc of fluid aspiration, but this was in the context of postoperative bleeding (Fig. 4). Aspiration of 750 cc transiently dropped her intrathoracic pressure, which rose again. Aspiration of 400 cc again dropped her pneumonectomy space pressure, but it rose once more as she accumulated fluid rapidly. She was explored for bleeding (at time indicated with arrow) with resolution of the bleed but no specific source was found.

4. Discussion

We describe a novel technique of continuous intrathoracic pressure monitoring and intermittent fluid aspiration to manage the pneumonectomy space for patients undergoing extrapleural pneumonectomy for pleural mesothelioma. Controlling the pneumonectomy space requires a balance between fluid accumulation and drainage. Rapid fluid and/or air evacuation can result in severe ipsilateral shift with compromise of caval blood return, remaining lung hyper-expansion and potential pulmonary oedema (Fig. 1b). Conversely, rapid fluid accumulation without drainage can lead to contralateral shift with compromise of function of the remaining lung (Fig. 1c).

Pressure, fluid, and chest X-ray data from the patients in our series demonstrate five distinct patterns of physiologic change in the early postoperative period following extrapleural pneumonectomy. Most patients (69%) experienced minimal, if any, mediastinal shift in the first 2 days after surgery, and we believe this stability is, in large part, due to the careful intermittent drainage permitted by our technique. As indicated by the vertical lines in Fig. 2, fluid

Table 1

<table>
<thead>
<tr>
<th>Change in mediastinal position</th>
<th>Number of patients (%)</th>
<th>Median fluid aspirated in cc (range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mild or no mediastinal shift</td>
<td>31 (69%)</td>
<td>300 (0–790)</td>
</tr>
<tr>
<td>Ipsilateral shift resolved</td>
<td>2 (4%)</td>
<td>0 (0)</td>
</tr>
<tr>
<td>Ipsilateral shift unresolved</td>
<td>1 (2%)</td>
<td>1980 (1980)</td>
</tr>
<tr>
<td>Contralateral shift resolved</td>
<td>4 (9%)</td>
<td>290 (220–800)</td>
</tr>
<tr>
<td>Contralateral shift unresolved</td>
<td>7 (16%)</td>
<td>200 (150–480)</td>
</tr>
</tbody>
</table>

Fig. 2. Mild contralateral shift: this represents data from a single patient. The top panel of the graph represents the radiographic position of the mediastinum graded from –3 (indicating severely ipsilateral) to +3 (indicating severely contralateral) with the horizontal line crossing at 0 representing a midline mediastinum. The individual points in the top panel represent the time at which each chest X-ray was taken. The middle panels indicate the central venous and pneumonectomy space pressures, respectively, with vertical marks indicating the timing and volume of fluid evacuation. This patient had only mild contralateral mediastinal shift that was controlled with several aspirations performed when pneumonectomy space pressure rose. Note that the pneumonectomy space pressure dropped after aspirations at hours 21, 38, 39, and 44.

Fig. 3. Ipsilateral shift resolved: this patient had moderate ipsilateral shift that resolved over the first 24 h postoperatively as the space filled with fluid appropriately and no fluid evacuation was required.

Fig. 4. Ipsilateral shift unresolved: this patient had several aspirations even before pressure was measured for clinical indications (bleeding). Withdrawal of 750 cc transiently dropped her intrathoracic pressure, which rose again. Aspiration of 400 cc again dropped her pneumonectomy space pressure, but it rose once more as she accumulated fluid rapidly. She was explored for bleeding (at time indicated with arrow) with resolution of the bleed but no specific source was found.
rise in intrathoracic pressure corrected the mediastinal shift. and early intervention with fluid aspiration in response to a large contralateral shift in whom careful monitoring and drainage, her case demonstrates how the pneumonectomy space pressure remained elevated. Although this difference was not statistically significant, possibly owing to small sample size, this observation suggests that intermittent drainage in response to a rise in pneumonectomy space pressure can help maintain mediastinal stability. 

There are clear limitations to this study, which is a retrospective analysis of an empiric technique. The patient cohort is heterogeneous. Some patients received induction chemotherapy while others did not; some were enrolled in protocols, while others not; and some received intracavitary chemotherapy, while others did not. Sample sizes were too small to power statistically significant results once patients with ipsilateral and contralateral shifts were divided into separate groups. A randomised prospective study would enable more stringent evaluation of this technique, but the relatively small number of patients undergoing extrapleural pneumonectomy for mesothelioma each year, compared with the number of patients undergoing pulmonary resection for lung cancer, for example, limits the ability to conduct a large randomised trial.

The patterns of discrete intrathoracic pressure measurements, chest X-rays, and fluid aspirations for patients in our series suggest that intrathoracic pressure may be related to mediastinal position on chest X-ray and that fluid aspiration to control pressure may influence mediastinal position. This study provides preliminary data to further test the hypothesis that intrathoracic pressure monitoring allows the surgeon to detect subtle changes in physiology before the development of more clinically deleterious effects such as hypotension or respiratory insufficiency. A prospective clinical trial planned at our institution will include continuous recording of transduced pressure with timestamping of radiographs and aspirations to permit analysis of temporal relationships among these events and statistical comparison among patients.

Currently, most clinicians rely on the chest X-ray to detect mediastinal shift. While CVP may be a helpful indicator of changes in intrathoracic pressure and position of the mediastinum, it is heavily influenced by other factors such as ventricular function and positive pressure ventilation. Moreover, CVP is only an indirect measure of pressure in the ipsilateral chest. In contrast, continuous intrathoracic pressure monitoring provides directly measured minute-to-minute data on pressure in the pneumonectomy space which, we hypothesise, influences the position of the individual patient’s mediastinum. This method avoids the delay and radiation imparted by frequent chest X-rays. The Rob-Nel catheter can be used in the operating room on chest closure after extrapleural pneumonectomy to remove air in a systematic attempt to establish a midline mediastinum postoperatively. In addition, use of the Rob-Nel catheter for intermittent drainage enables the surgeon to intervene in situations of increased intrathoracic pressure to correct contralateral shift. Removing fluid in increments eliminates the risk of ipsilateral mediastinal shift that may occur with continuous and/or rapid fluid removal from the pneumonectomy space.

The patterns that emerged from our patient data were consistent with our hypothesis, as illustrated above. Based on these results, we find utility in this technique and offer our recommendation for this unique method of managing the pneumonectomy space in the early postoperative period. Contralateral mediastinal shift should be treated with evacuation was generally performed when pneumonectomy

Fig. 5. Contralateral shift resolved: this patient developed contralateral shift, but the mediastinum returned to midline with incremental aspirations performed when pneumonectomy space pressure remained elevated.
incremental drainage for rise in intrathoracic pressure to prevent cardiopulmonary complications.

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References