Optimal technique for the removal of chest tubes after pulmonary resection

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Objective: The objective is to determine the optimal manner to remove a chest tube after pulmonary resection.

Method: This was a prospective, randomized single-institution study. Patients who underwent elective thoracotomy for pulmonary resection by 1 or 2 general thoracic surgeons were randomized to have their chest tube removed on either full inspiration or full expiration. Both patient groups performed a Valsalva maneuver during tube removal. Outcomes included the incidence of clinically nonsignificant pneumothorax (defined as a new or increased pneumothorax on the post-chest tube removal chest roentgenogram in asymptomatic patients), symptoms, delayed discharge, and the need for a new chest tube.

Results: Between November 2008 and June 2011, 1189 patients underwent pulmonary resection, and of these 342 met the criteria for the study. Of the 179 patients randomized to have their chest tube removed on full inspiration, 58 (32%) had a larger or new pneumothorax after chest tube removal and 5 (3%) required intervention or delayed discharge. Of the 163 patients randomized to have their chest tube removed on full expiration, 32 (19%; $P = .007$) had a larger or new pneumothorax after chest tube removal, and only 2 (1%) required intervention or delayed discharge ($P = .78$).

Conclusions: Removal of chest tubes at the end of expiration leads to a lower incidence of non–clinically significant pneumothorax than at the end of inspiration. Because of these findings, this study was closed early and was thus underpowered for finding a statistically significant difference in the rare (1%-3%) clinically significant pneumothoraces. (J Thorac Cardiovasc Surg 2013;145:1535-9)

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Chest tubes have been used for centuries to drain the pleural space. Despite this long history of clinical use, the management of chest tubes has been mainly an art form without the application of evidence-based medicine until recently. Brunelli and associates,[1] Refai and colleagues,[2] and Cerfolio and Bryant[3] have performed many studies that have scientifically evaluated the optimal manner to manage tubes after pulmonary resection. The basic import of these studies has been to provide objective data to guide the management of chest tubes after pulmonary resection. The removal of chest tubes is a commonly performed procedure that occurs almost every day in hospitals. It is performed mainly in 1 of 2 ways: at the end of full inspiration or at the end of full expiration. Most practitioners ask the patient to perform a Valsalva maneuver during both techniques. Despite the fact that this is a common hospital procedure, we have been able to find only 1 study that has evaluated which of these 2 techniques is better, and this was in patients who did not have a pulmonary resection. Bell and associates[4] in 2001 evaluated the incidence of pneumothorax based on chest tube removal techniques in 69 trauma patients. The primary objective of this prospective randomized trial was to determine which of these 2 techniques was more effective at reducing the incidence of pneumothorax after chest tube removal in patients who underwent pulmonary resection. A second objective was to assess the frequency and severity of pneumothorax after chest tube removal.

METHODS

Patients who were more than 19 years of age and underwent a pulmonary resection via thoracotomy (lobectomy, segmentectomy, or wedge resection) were eligible to participate in this study. All operations were performed by 1 or 2 general thoracic surgeons (R.J.C. or D.J.M.). Patients who had a previous ipsilateral pulmonary resection, had a pulmonary resection for lung volume resection surgery, underwent pneumonectomy, received 3 or more chest tubes, were supported by a ventilator postoperatively, were unable to follow verbal directions, were discharged with a chest tube, and/or had a pulmonary resection via video-assisted thoracoscopic surgery or a robotic approach were excluded from this study. If a patient had 2 chest tubes placed, data were collected on the removal of the second

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chest tube. In general, patients received only 1 chest tube after pulmonary resection. A second chest tube was used only in patients who had significant air leaks at the completion of the operation that could not be sealed intraoperatively. One chest tube was inserted and positioned into the anterior apical chest after upper lobectomy and/or after middle lobectomy. It was positioned in the lower posterior apical chest after lower lobectomy. The tubes were tunneled and were secured to the skin with a single stitch. The type of chest tube used in this study was a 28F soft Deknatel (Teleflex, Kenosha, Wash) tube. Chest tubes were placed to suction the day of surgery and switched to water seal on the morning of postoperative day 1 before the chest radiograph and remained on water seal unless subcutaneous emphysema or an enlarging pneumothorax developed. Chest tubes were removed when the output was less than 450 mL per day and the air leaks were resolved. Air leaks were graded using a digital system as determined by a Thopaz unit (Medela Healthcare, Zug, Switzerland). Tubes were removed when there was no air leak. The Thopaz unit records air leaks in milliliters per minute, and we and others have shown that when the reading is 20 mL/min and less for 4 hours consistently, this corresponds to no air leak and thus tubes can be safely removed.[5,6] Thus in this study chest tubes were removed when the Thopaz reading was 20 mL/min or less for 4 hours.

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Randomization and Method of Chest Tube Removal

Patients were randomly assigned to have their chest tube removed in 1 of 2 ways: at the end of full inspiration or at the end of full expiration. All patients in both groups performed a Valsalva maneuver during chest tube removal. Patients whose medical record number ended with an even digit were randomized to have their chest tube removed on end-expiration and patients whose medical record number ended with an odd digit were randomized to have their chest tube removed on end-inspiration. Patients practiced the routine at least once before having their chest tube removed. The 2 techniques were described to the patient as shown below; the same dialogue was used for each patient:

1. End of inspiration (or maximal inspiration) was defined by asking the patient to take a deep breath in, ''hold it,'' and bear down as the tube was removed.
2. End of expiration (or maximal expiration) was defined by asking the patient to blow out fully and then bear down as the tube was removed.

In general, most chest tubes were removed by 1 of 3 clinical team members. All patients had Xeroform gauze (Kendall, Mansfield, Mass) applied to the chest tube removal site and cloth tape placed over it. All patients had posteroanterior and lateral chest radiographs performed in the radiology department within 2 to 4 hours after chest tube removal.

Definitions of Outcomes

A ''pneumothorax'' was defined as any visible air on the chest radiograph between the lung and the chest wall as reported by the radiologist. A ''new post–chest tube removal l pneumothorax'' was defined as the presence of a pneumothorax that was not visible before chest tube removal. A ''larger post–chest tube removal pneumothorax'' was defined as the presence of increased air space between the lung and ribs after the chest tube was removed compared with the chest radiograph when the tube was still in the thorax. A clinically significant pneumothorax was defined as a new or increased pneumothorax that caused increased dyspnea with documented decrease in oxygen saturation on pulse oximetry of at least 4%, the placement of a new chest tube or pleural catheter, or delay in discharge because of the pneumothorax. Significant clinical complications from the chest tube removal were (1) expanding subcutaneous emphysema that required reinsertion of another chest tube or (2) delay in discharge because of the new or increased pneumothorax. These patients were treated with a repeat chest radiograph in 4 hours, and a chest tube was placed if the pneumothorax continued to expand and the patient had clinical shortness of breath. However, patients who were asymptomatic were followed up with serial chest radiographs. Patients who had a stable pneumothorax or a clinically insignificant pneumothorax on the post–chest tube removal radiograph were discharged home the same day as removal of the last chest tube. All patients in the study had a follow-up chest radiograph 3 weeks after surgery or sooner if they had any increased dyspnea.

Statistical Analysis

Data were collected in Excel (Microsoft Corp, Seattle, Wash). Analysis was conducted using MedCalc software (Med Calc Software, Ostend, Belgium) and SAS version 9.1 (SAS Institute, Inc, Cary, NC). Fisher's exact test or the Pearson χ^2 test was used to assess categoric data. The Wilcoxon test was used for continuous variables. Associations among covariates (age, gender, smoking status, type of resection, number of chest tubes, presence of pneumothorax before removal, preoperative percent predicted forced expiratory volume in 1 second, history of moderate or extensive emphysema, and method of chest tube removal) and the dependent variable (new or increased pneumothorax after chest tube removal) were evaluated using univariate analysis. Variables with a probability of less than or equal to .10 in the univariate model were considered to be possible independent variables and subsequently entered into the multivariate model. Stepwise multivariate regression analysis was used to identify the predictors of a new or increased pneumothorax after chest tube removal.

The University of Alabama at Birmingham's Institutional Review Board approved this protocol (F081016009) as well as the prospective database (X030403013) used to collect information for this study; informed consent was obtained. This is a prospective randomized clinical trial registered with the National Institutes of Health's website (clinicaltrial.gov).

RESULTS

Between November 2008 and August 2011, 1189 patients underwent pulmonary resection by 1 or 2 general thoracic surgeons (R.J.C. or D.J.M.). Of these, 342 met the criteria for entry into this study. The flow of patients in this study is shown in Figure 1. Patient characteristics are shown in Table 1. Of the 342 patients in this study, 179 were randomized to have their chest tube removed on full inspiration and 163 were randomized to have their chest tube removed on full expiration. As shown in Table 2, 58 (32%) of the 179 patients randomized to have chest tube removed on inspiration had a pneumothorax develop after chest tube removal, and 5 (3%) of these patients required intervention (oxygen, reinsertion of chest tube). Of the 163 patients randomized to have their chest tube removed on full expiration, 32 (19%) had a pneumothorax develop after chest tube removal ($P = .007$); it was clinically significant in only 2 (1%) patients. The history of moderate or extensive chronic obstructive pulmonary disease ($P = .025$), percent predicted forced expiratory volume in 1 second ($P = .047$), and method of chest tube removal ($P = .012$) were associated with development of a new or enlarged pneumothorax after chest tube removal on univariate analysis. Age, gender, smoking status, type of resection, number of chest tubes, and presence of pneumothorax before removal were not associated with development of a new or enlarged pneumothorax after chest tube removal on univariate analysis.

DISCUSSION

''Evidence-based medicine'' is what physicians strive to use to make clinical decisions. However, much of medicine remains an art. It is impossible to study every aspect of

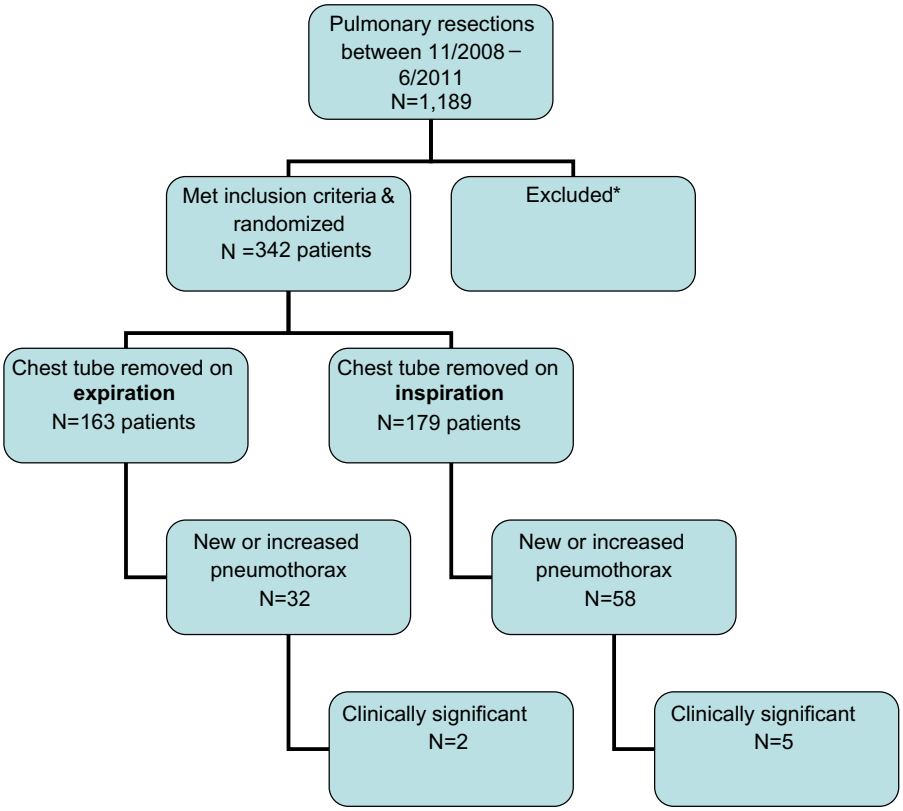


FIGURE 1. Flow of patients in this study. (Note, this study was stopped early because of these findings.) *Reasons for patient exclusion: robotic resection (293), video-assisted thoracoscopic surgery (380), discharged home with a chest tube (53), had an ipsilateral/previous thoracotomy (51), lung volume reduction surgery (5), more than 2 chest tubes (53), and other reasons (12).

patient care using a prospective randomized trial. During the past several years, several surgeons including Brunelli,[1] Marshall,[2] and us[3] have attempted to apply science to what has been an art form.[7] We have used prospective randomized studies to evaluate the best way to manage chest tubes in patients with air leaks,[8] the ability to remove tubes with high outputs,[9] and the use of digital devices and discharging patients home with chest tubes.[5] More important, Brunelli and others[10] have defined terms such as a fixed pleural space deficit, passive suction, and active suction. However, it is surprising that one of the single most common procedures performed by thoracic surgeons, the removal of chest tubes, has rarely been studied. This task has been delegated to the resident, intern, physician assistant, or nurse practitioner, and despite the fact that many physicians outsource this, the best technique to use is not known.

More than 11 years ago, Bell and associates[4] performed a prospective randomized study on 69 trauma patients who had chest tubes placed for hemopneumothorax. Half of the patients had their tubes removed at the end of maximal inspiration and the other half had their tube removed at the end of expiration. The Valsalva maneuver was used in both groups, similar to our study. Although Bell's group found no statistically significant difference in the rate of pneumothorax, there was a trend favoring the end-expiratory group (6% compared with 8% for end-inspiratory). The question is, does this apply to patients who have undergone pulmonary resection and who are more likely to have a pneumothorax after the removal of a chest tube?

In this study, we found a statistically significant difference in the pneumothorax rate after chest tube removal. Our study contains only patients who underwent thoracotomy and pulmonary resection; however, these findings probably are applicable to patients who have had a video-assisted thoracoscopic surgery or robotic approach. We decided to exclude these other patients to minimize the confounding variables of this study. In this article, we demonstrated that it was safer to remove a patient's chest tube at end-expiration rather than at full inspiration. Interestingly, this finding was directly opposite to our opinion going into this study. This supports the importance of prospective randomized trials and the need to question surgical dogma. Despite our traditions and opinions, often our biases are proven incorrect.

We stopped this study early, before obtaining statistically significant difference in rates of clinically symptomatic pneumothoraces. Our group discussed the findings at the interim analysis. Owing to the statistically significant difference in the overall pneumothorax rate, we stopped the

TABLE 1. Patient characteristics stratified by method of chest tube removal

	Chest tube removed on expiration 163 patients	Chest tube removed on inspiration 179 patients	*P* value
Age, y* (range)	60.3 (21-84)	61.7 (24-83)	.890
Gender male	86 (52.7%)	91 (50.8%)	.806
Moderate or extensive COPD and/or emphysema	22 (13.4%)	29 (16.2%)	.584
Steroid use for 1 mo or more	4 (2.5%)	9 (5%)	.338
Preoperative			
FEV_1%* ± SD	75% ± 12.2	71% ± 14.0	.793
DLCO%* ± SD	67% ± 15.7	68% ± 16.3	.899
Current smoker (quit <2 mo before surgery)	36 (22.1%)	30 (16.8%)	.268
Indication for surgery			
Malignancy	145 (88.9%)	155 (87%)	.617
Benign	18 (11%)	24 (13%)	
Operation			
Wedge	89 (54%)	100 (56%)	.764
Segment	14 (8.8%)	14 (7.8%)	
Lobectomy/bilobectomy	60 (36.8%)	65 (36.3%)	
Laterality			
Right	102 (62.6%)	117 (65%)	.595
Left	61 (37.4%)	62 (35%)	
No. of chest tubes			
1	151 (92.6%)	166 (92.7%)	.862
2	12 (7.4%)	13 (7.3%)	

There were no significant differences between the 2 groups. *COPD,* Chronic obstructive pulmonary disease; *FEV_1%,* percent predicted forced expiratory volume in 1 second; *SD,* standard deviation; *DLCO%,* percent predicted diffusion of carbon monoxide. *Medians are provided for continuous variables.

study for patient safety. Additionally, study accrual significantly tapered after February 2010 because we started using a robotic approach for most all of our patients with lung cancer instead of thoracotomy.

The strengths of this article include the large number of patients, the fact that all the tubes were inserted by 1 of 2 surgeons, and the majority of the tubes were removed by 1 of 3 persons. The chest tube remover used the same technique and dialogue at the time of chest tube removal. In addition, the groups had similar patient characteristics, extent of resection, and postoperative and chest tube management algorithms used. The use of a digital air leak meter that has been shown to be more accurate than an analog system for measuring air leaks also strengthens the conclusions of this study.[5]

The primary limitation to this study is that we did not achieve a statistically significant difference in patients who had clinically symptomatic pneumothorax. However, the numbers are low for these types of pneumothorax and its development may be based on other factors besides the technique used to remove the tube. A second limitation is that the criterion used for insertion of another chest tube is subjective. A third limitation is the fact that 25 patients (although the proportion of those with more than 1 chest tube was similar in both groups) had more than 1 chest tube.

TABLE 2. Outcomes stratified by method of chest tube removal

	Chest tube removed on expiration	Chest tube removed on inspiration	*P* value
No. of patients	163	179	
Hospital length of stay (d), median	3.25	3.50	.453
Readmission to hospital within 30 days of surgery (any reason)	5 (1.8%)	11 (4.0%)	.178
Findings after chest tube removal			
New or increased subcutaneous air or increase in pleural effusion	21 (13%)	30 (16%)	.090
Not clinically significant new or increased pneumothorax on chest x-ray film after chest tube removal	32 (19%)	58 (32%)	**.007**
Clinically significant pneumothorax on chest x-ray film after chest tube removal	2 (1%) Both treated with oxygen and overnight stay	5 (3%) Three treated with chest tubes Two treated with oxygen and overnight stay	.310

In conclusion, this prospective randomized study shows that removing a chest tube after pulmonary resection at the end of expiration while the patient performs a Valsalva maneuver has a lower incidence of nonclinically significant pneumothorax than removing it while the patient performs a full inspiration. However, clinically significant events after chest tube removal are rare (1%-3%) and this study size did not allow for a definitive answer as to whether removal technique influenced the rate of these events.

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