Electronic chest tube drainage devices and low suction following video-assisted thoracoscopic pulmonary lobectomy

Jessica A. Bowman[1], Garth H. Utter[1,2]

[1]Department of Surgery, Division of Trauma and Acute Care Surgery, [2]Department of Surgery Outcomes Research Group, University of California, Davis, CA, USA

Correspondence to: Garth H. Utter, MD, MSc. Department of Surgery, Division of Trauma and Acute Care Surgery; 2335 Stockton Boulevard, Room 5027, Sacramento, CA 95817, USA. Email: ghutter@ucdavis.edu.

In an effort to improve patient outcomes and shorten hospital length of stay for patients undergoing pulmonary lobectomy, clinicians have focused on standardizing the postoperative management of chest tubes. The 2017 clinical practice guidelines from the Society for Translational Medicine recommend using electronic (or "digital") drainage systems for patients undergoing elective lobectomy (1). Guidelines in 2019 from the European Society of Thoracic Surgeons for enhanced recovery after lung surgery are in agreement, strongly recommending electronic drainage systems, albeit based on low-quality evidence (2). Electronic drainage systems provide consistent suction based on a preset value. In contrast, traditional analog devices may result in variable pressure based on the length of tubing, siphon effect, and patient positioning. In a prospective evaluation of patients undergoing video-assisted thoracoscopic surgery (VATS) for pulmonary lobectomy who had a chest tube placed to "water seal" with a traditional drainage device, measured pressures ranged from –20 to –13 cmH_2O (3).

Electronic drainage devices provide uniform, longitudinal data, which potentially reduces inter-observer variability in the decision to remove a chest tube. In a randomized trial in which two thoracic surgeons with similar experience were asked to assess chest tube withdrawal criteria, use of an electronic device improved overall agreement with the kappa coefficient increasing from 0.37 to 0.88 (4). Agreement may have improved because the electronic device reports "real-time" air leaks, as well as the rate over prior time intervals, which may be easier to interpret than intermittent bedside observation of traditional devices. Having quantitative data makes it easier to standardize withdrawal criteria and may be more reassuring to physicians.

Electronic drainage systems have been shown to reduce the duration of chest tubes as well as hospital length of stay. In a randomized, multicenter study of patients undergoing pulmonary lobectomy or segmentectomy, patients were allocated to either an electronic (intervention) or traditional (control) drainage device set to –20 cmH_2O. Patients with the electronic device had a shorter duration of air leak (1.0 versus 2.2 days, P=0.001), shorter time to chest tube removal (3.6 versus 4.7 days, P=0.0001), and shorter hospital length of stay (4.6 versus 5.6 days, P<0.0001) (5). Additionally, patients in the intervention group reported improved comfort and portability of the device. In a meta-analysis, electronic drainage devices were associated with a decreased risk of prolonged air leak (RR 0.54, 95% CI, 0.40–0.73), chest tube duration [standardized mean difference (SMD) –0.35, 95% CI, –0.60 to –0.09], and hospital length of stay (SMD –0.35, 95% CI, –0.61 to –0.09) (6). However, because it is difficult to completely standardize chest tube management—even despite protocols—variation in physician behavior could have confounded these unblinded comparisons.

The ideal postoperative chest tube pressure has been controversial, and prior recommendations were based on open procedures (i.e., thoracotomy) and traditional drainage devices. In theory, placing a chest tube to suction assists with pleural apposition and thus helps to seal any potential air leaks. However, greater suction may also maintain patency of an air leak, and water seal may be a better method to reduce ongoing air leaks (7). In a randomized trial among patients undergoing lobectomy or bilobectomy who had an air leak on the first postoperative day, patients assigned to either water seal or –20 cmH$_2$O suction had no significant difference in the duration of air leak, proportion with a prolonged air leak, or hospital length of stay (8). In another randomized trial among patients undergoing lobectomy (not only those with an air leak), there was no significant difference in the duration of air leak or time to chest tube removal based on the chest tube being to water seal or to suction (9). Two meta-analyses reported no difference in the duration of air leak, proportion of patients with prolonged air leak, duration of chest tube, or hospital length of stay based on water seal or suction, but concluded that early use of suction may prevent development of postoperative pneumothorax (10,11). In a more recent meta-analysis, Lang *et al.* reported longer air leak duration, chest tube duration, and hospital length of stay with suction (12). They concluded there is level 1A evidence to support placing chest tubes to water seal after non-pneumonectomy lung resection.

In their recent randomized trial, Holbek *et al.* sought to determine whether –2 cmH$_2$O suction reduces drainage duration, air leak duration, fluid production, and complications compared to –10 cmH$_2$O suction for patients undergoing VATS lobectomy (13). The authors conducted this unblinded, superiority-powered trial at a single institution in Denmark. They enrolled patients who were 18 years or older scheduled for elective VATS lobectomy for suspected primary lung cancer. After completing a lobectomy via a standard 3-port anterior approach, surgeons performed an intraoperative leak test with additional procedures as needed to control any identified air leak. They inserted a chest tube in the anterior, inferior port site. Nurses then opened opaque, sealed envelopes to assign consecutive patients to either –2 cmH$_2$O suction (intervention) or –10 cmH$_2$O suction (control) in a 1:1 fashion. All patients had a digital drainage device (Thopaz, Medela AG, Switzerland) to ensure correct, consistent suction, and all were exposed to a similar enhanced recovery after surgery ("ERAS") protocol.

The investigators sought to enroll 230 patients (assuming 10% loss to follow up) to be able to rule out a median reduction in the time from chest tube placement to removal of 18 hours or more between treatment groups with 90% power. The study was partially funded by the device manufacturer, but the authors reported that the manufacturer did not have access to or influence on the conduct or interpretation of the trial.

The team evaluated 447 patients for eligibility, and randomized 230, equally split between the control or intervention groups. The authors' CONSORT diagram reveals some inefficiencies in the randomization process and protocol adherence. Eight patients were excluded after randomization (three from the intervention group and five from the control group) because the planned VATS lobectomy was converted to a different procedure or because more than one chest tube was placed. Because the investigators had appropriately planned to randomize subjects shortly before connecting the chest tube to a collection system (i.e., at the end of the operation), they could have prevented this problem by better controlling the decision to randomize these patients. Failing that, they should have included these eight subjects in the analysis because post-randomization exclusions risk introducing bias. Additionally, four patients in the intervention group and three in the control group had their suction level set incorrectly (i.e., randomized to –2 cmH$_2$O but set to –10 cmH$_2$O suction, or vice versa). Despite the merits of a true intention-to-treat analysis, the investigators chose to present only a per protocol analysis (i.e., as if these subjects had been allocated to the treatment they actually received), which also may have introduced bias (14). This misallocation was reportedly an error of omission—staff forgot to change the drainage device settings after randomization—and thus would seem less likely to cause bias. However, it is curious that, although the Thopaz device has a default factory setting of –2 kPa (approximately –20 cmH$_2$O), the misallocation occurred in both directions.

The primary outcome was drainage duration, defined as the time from chest tube insertion to chest tube removal, and the investigators attempted some standardization of chest tube management, an essential feature for an unblinded study. Chest tubes were not removed before postoperative day one. Prior to removal, patients must have had an air leak <20 mL/min for at least 12 hours and serous output. The authors did not require as a criterion for chest tube removal that the output be less than a threshold amount of drainage, reflecting current, more liberal trends

1740

Bowman and Utter. Electronic drainage devices and low suction

in chest tube management (15). By their own admission, though, Holbek et al. hint at the difficulty in standardizing such a complicated process as chest tube management. They had to modify the study protocol mid-course to allow clinicians to reduce the level of suction for air leaks lasting longer than five days. Importantly, even though the criteria triggering the primary outcome were time-dependent, the authors do not describe how frequently the patients and drainage devices were assessed for chest tube removal, only that chest tubes were not removed overnight. Again, given the open-label nature of the trial, seemingly small differences in tube management and drainage device assessment potentially could introduce bias towards earlier removal in the intervention group.

Drainage duration was significantly shorter in the intervention group (median 27.4 versus 47.5 hours, P=0.047). Because chest tubes were not removed overnight, this meant that the duration the chest tube was in place in patients in the intervention group was one day shorter (i.e., removed on postoperative day one versus postoperative day two in the control group). The earliest time that patients met criteria for chest tube removal was approximately 10–12 hours before chest tubes were removed (17.2 versus 35.7 hours, P<0.001). Despite the shorter chest tube duration in the intervention group, there was no difference in hospital length of stay. As the authors note, a protocol to remove the chest tube as soon as criteria are met would have further reduced chest tube duration and may have reduced hospital length of stay. However, depending on overnight staffing, it has the potential to increase complications, as well.

For example, one potential ill effect of earlier chest tube removal is that patients could develop subsequent pneumothoraces or effusions. Though not overtly described as a secondary outcome, the authors appropriately reported chest tube reinsertion as a consequence of the amount of suction. There was not a statistically significant difference, but more patients in the -2 cmH_2O group required chest tube reinsertion for pneumothorax or subcutaneous emphysema.

Total chest tube drainage volume was significantly lower in the intervention group, and the authors suggest this was a direct result of an increased pressure gradient. Another randomized trial of high versus low suction levels (-20 versus -5 cmH_2O) in patients undergoing lobectomy measured chest tube drainage at 24 and 48 hours, and it also found that greater suction was associated with increased drainage at both time points (16).

The authors showed no difference in other secondary outcomes, including the proportion of patients with a persistent air leak >5 days (14.4% versus 24.3%, P=0.089). Having "any complication" was higher, though not significantly so, in the -10 cmH_2O group. The only patients that developed a wound infection, empyema requiring fibrinolysis, or sepsis were in the -2 cmH_2O group. When low-suction protocols are further studied, researchers should consider monitoring these complications to ensure there is no significant increase in their incidence.

Holbek et al. address an important question about the optimal management of chest tubes following elective VATS lobectomy. There is a growing body of literature supporting the use of electronic drainage devices because they provide consistent pressure, facilitate interpretation of air leaks by quantifying their volume and duration, and improve patient mobility because they are portable. Consistent with the criteria for chest tube removal used by Holbek et al., liberalizing or ignoring thresholds for pleural fluid output is becoming more common. Air leak rates on the order of <20–30 mL/min for an 8–12-hour range appear acceptable. Although the authors' per protocol analysis contains some flaws, and their study allowed some room for bias to have contributed to their findings, it adds to a growing body of evidence that the use of electronic drainage devices set to -2 cmH_2O is probably a safe practice that can shorten chest tube duration and thus modestly expedite the care of patients undergoing elective VATS lobectomy.

Acknowledgments

Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

References

1. Gao S, Zhang Z, Aragon J, et al. The Society for Translational Medicine: Clinical practice guidelines for the postoperative management of chest tube for patients undergoing lobectomy. J Thorac Dis 2017;9:3255-64.
2. Batchelor TJP, Rasburn NJ, Abdelnour-Berchtold E, et

al. Guidelines for enhanced recovery after lung surgery: Recommendations of the Enhanced Recovery After Surgery (ERAS(R)) Society and the European Society of Thoracic Surgeons (ESTS). Eur J Cardiothorac Surg 2019;55:91-115.

3. Refai M, Brunelli A, Varela G, et al. The values of intrapleural pressure before the removal of chest tube in non-complicated pulmonary lobectomies. Eur J Cardiothorac Surg 2012;41:831-3.

4. Varela G, Jimenez MF, Novoa NM, et al. Postoperative chest tube management: measuring air leak using an electronic device decreases variability in the clinical practice. Eur J Cardiothorac Surg 2009;35:28-31.

5. Pompili C, Detterbeck F, Papagiannopoulos K, et al. Multicenter international randomized comparison of objective and subjective outcomes between electronic and traditional chest drainage systems. Ann Thorac Surg 2014;98:490-6; discussion 496-7.

6. Wang H, Hu W, Ma L, et al. Digital chest drainage system versus traditional chest drainage system after pulmonary resection: A systematic review and meta-analysis. J Cardiothorac Surg 2019;14:13.

7. Marshall MB, Deeb ME, Bleier JI, et al. Suction vs water seal after pulmonary resection: A randomized prospective study. Chest 2002;121:831-5.

8. Brunelli A, Monteverde M, Borri A, et al. Comparison of water seal and suction after pulmonary lobectomy: A prospective, randomized trial. Ann Thorac Surg 2004;77:1932-7; discussion 1937.

9. Prokakis C, Koletsis EN, Apostolakis E, et al. Routine suction of intercostal drains is not necessary after lobectomy: A prospective randomized trial. World J Surg 2008;32:2336-42.

10. Coughlin SM, Emmerton-Coughlin HM, Malthaner R. Management of chest tubes after pulmonary resection: A systematic review and meta-analysis. Can J Surg 2012;55:264-70.

11. Deng B, Qian K, Zhou JH, et al. Optimization of chest tube management to expedite rehabilitation of lung cancer patients after video-assisted thoracic surgery: A meta-analysis and systematic review. World J Surg 2017;41:2039-45.

12. Lang P, Manickavasagar M, Burdett C, et al. Suction on chest drains following lung resection: evidence and practice are not aligned. Eur J Cardiothorac Surg 2016;49:611-6.

13. Holbek BL, Christensen M, Hansen HJ, et al. The effects of low suction on digital drainage devices after lobectomy using video-assisted thoracoscopic surgery: A randomized controlled trial. Eur J Cardiothorac Surg 2019;55:673-81.

14. Gupta SK. Intention-to-treat concept: A review. Perspect Clin Res 2011;2:109-12.

15. Mesa-Guzman M, Periklis P, Niwaz Z, et al. Determining optimal fluid and air leak cut off values for chest drain management in general thoracic surgery. J Thorac Dis 2015;7:2053-7.

16. Lijkendijk M, Neckelmann K, Licht PB. External suction and fluid output in chest drains after lobectomy: A randomized clinical trial. Ann Thorac Surg 2018;105:393-8.