

Chest Tube Selection in Cardiac and Thoracic Surgery: A Survey of Chest Tube-Related Complications and Their Management

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Abstract ***Background:*** **Blood accumulating inside chest cavities can lead to serious complications if it is not drained properly. Because life-threatening conditions can result from chest tube occlusion after thoracic surgery, large-bore tubes are generally employed to optimize patency.** ***Aims:*** **The aim of this study was to better define problems with current paradigms for chest drainage.** ***Materials and Methods:*** **A survey was conducted of North American cardiothoracic surgeons and specialty cardiac surgery nurses. A total of 108 surgeons and 108 nurses responded.** ***Results:*** **The survey revealed that clogging leading to chest-tube dysfunction is a major concern when choosing tube size. Of surgeons responding, 106 of 106 (100%) had observed chest tube clogging, and 93 of 106 (87%) reported adverse patient outcomes from a clogged tube. Despite techniques such as tube stripping, tapping, and squeezing, up to 51% of surveyed surgeons stated they are not satisfied with currently available tubes and procedures to avoid tube occlusion and some even forbid the stripping maneuver for fear of causing more bleeding by the negative pressures generated. In addition, respondents noted that patients experience increasing discomfort with increasing drain size.** ***Discussion:*** **The major reason surgeons choose large-diameter chest tubes is linked to concern about the suboptimal available methods to avoid and treat chest-tube clogging. Even though larger tubes are thought to be associated with more pain, physicians generally err on the side of caution to avoid clogging and insert tubes with larger diameters.** ***Conclusion:*** **Results of this survey highlight the frequent problems with clogging with current postsurgical chest drainage systems and suggest the need for innovative solutions to avoid clogging complications and overcome clinician concern and patient pain.**
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Postoperative drainage of surgical sites is a standard component of many operations and is employed routinely after cardiac and thoracic surgery. Patent drainage tubes are necessary to alert caregivers to internal bleeding, air leaks, and anastomotic leaks. Occlusion of drain tubes can lead to life-threatening complications, including tamponade, tension pneumothorax, and sepsis.[1,2] Additional surgery may be necessary if occluded tubes lead to development of empyema, pericardial tamponade, or a hemothorax that is large enough to cause loss of lung volume.[3-5] To avoid the aforementioned complications, surgeons typically employ larger-bore chest tubes after cardiac and thoracic surgery.[6] However, large-bore tubes are associated with significant patient discomfort; furthermore, even larger tubes frequently become clogged or occluded. In certain settings, the use of small-diameter tubes provides several advantages over standard-sized chest tubes, as smaller tubes facilitate safer insertion with a lower rate of infection-related complications and are considered to be more comfortable for the patient.[7,8] Although the aforementioned issues with chest tube drainage are well recognized, there has been little

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innovation in this area of patient care. To identify the most important unmet needs, we conducted a survey to gather and quantify concerns of cardiothoracic surgeons and nurses related to chest tube drainage. The results of this survey point to unmet needs and opportunities to improve patient care and safety by addressing patency issues with chest tubes.

MATERIALS AND METHODS

Cardiac and/or thoracic surgeons (n = 108) and cardiothoracic nurses (n = 108) responded to our survey. A total of 772 surgeons' surveys were sent out by electronic mail. A total of 150 nurses' surveys were distributed in the cardiac surgery intensive care unit setting. Surveys were completed by 108 of 772 (14%) surgeons and 108 of 150 (72%) nurses. The survey was constructed in two variant forms, one to surgeons (20 questions; Table 1) and another to nurses (10 questions; Table 2). Not all questions were answered by any given responder. The majority of participating nurses worked in an intensive care unit for postoperative heart surgery patients and had experience in managing patients with chest tubes.

The survey focused on the impact of particular factors (bleeding, clogging, and patient discomfort) on surgeon's choice of chest tube and on the effectiveness of currently employed clearance methods, including milking, tapping, squeezing, folding, and stripping of the chest tube, applied by nurses to minimize the potential of chest tube-related complications. Additionally, the surgeon's survey assessed the clinicians experience with alternative methods of chest drainage, including heparin-coated tubes and Blake drains. Finally, some questions were specifically focused on the impact of chest tube size and methods of management on patient pain and discomfort.

Most questions were answered with one of four percentage ranges (from 0% to 24%, 25% to 49%, 50% to 74%, and 75% to 99%) and finally 100%. For some questions, the answers were divided into any of four answers for ease of selection: completely negative, partially negative, totally positive, and partially positive. Some questions needed simply a "yes" or "no" answer. The survey questionnaires were prepared by a group of surgeons and nurses with extensive experience related to all aspects of chest tube-related care.

RESULTS

Chest tube selection

Clogging of chest tubes was observed by 106 of 106 responding surgeons (100%) and 98 of 104 nurses (94.2%). Adverse patient outcome related to clogging was experienced by 93 of 106 (87.7%) surgeons and 87 of 107 (81.3%) nurses. This experience influenced the surgeon's choice of chest tube size. Ninety-two of 106 (86.8%) surgeons reported that concern for the potential clogging within a chest tube affects their choice of chest tube diameter (e.g., 36 F vs. 20 F).

TABLE 1
Cardiothoracic Surgeon Chest Tube Survey

Question	Response (%)	Response (n)
1. Primary specialty?		
Cardiac surgery only	33.3	36
Cardiac and thoracic surgery	38.9	42
Thoracic surgery only	20.4	22
Pediatric heart surgery only	2.8	3
Adult and pediatric heart surgery and thoracic surgery	2.8	3
Other	1.9	2
Answered Question		108
Skipped question		0
2. Region of your practice?		
North America	98.1	106
South America	0.9	1
Asia	0.9	1
Answered question		108
Skipped question		0
3. Do you insert chest tubes and/or manage patients with chest tubes in your practice?		
Yes	100.0	108
No	0.0	0
Answered question		108
Skipped question		0
4. Does the concern for the potential for clogging within a chest tube impact your choice of chest tube diameter size to be inserted into a patient (e.g., 36 F vs. 20 F)?		
Yes	86.8	92
No	13.2	14
Answered question		106
Skipped question		2
5. If you have a case in which you expect bleeding, are you more likely to insert large-diameter chest tube (e.g., 36 F vs. 20 F)?		
0% to 24% of time	20.8	22
25% and 49% of time	3.7	4
50% and 74% of time	12.3	13
75% and 99% of time	18.8	20
100% of time	44.3	47
Answered question		106
Skipped question		2
6. Does your concern for the potential for clogging in a particular case impact your choice of the number of chest tubes to be inserted?		
0% to 24% of time	24.5	26
25% to 49% of time	8.4	9
50% to 74% of time	18.8	20
75% to 99% of time	17.9	19
100% of time	30.2	32
Answered question		106
Skipped question		2
7. Have you ever observed an adverse patient outcome related to chest tube clogging?		
Yes	87.7	93
No	12.3	13
Answered question		106
Skipped question		2

Continued.

TABLE 1
Continued

Question	Response (%)	Response (n)
8. Have you ever observed a blood clot or other debris clogging a chest tube (e.g., when the tube is removed or when you take a patient back to the operating room)?		
Yes	100.0	106
No	0.0	0
Answered question		106
Skipped question		2
9. Do you have a standard protocol(s) for nurses managing tube blood clots or debris (assume you have decided that the patient does not need to go back to the operating room)?		
Yes	61.3	65
No	38.7	41
Answered question		106
Skipped question		2
10. Which statement best suits your attitude toward chest tube "stripping"?		
I allow it	73.6	78
I discourage it	22.6	24
I absolutely forbid it	3.8	4
Answered question		106
Skipped question		2
11. Do you believe that the currently available techniques for nurses to deal with active chest tube clogging (e.g., tapping, folding, squeezing, and milking the tube) in the setting of bleeding are:		
Completely unsatisfactory	1.8	2
Usually unsatisfactory	49.1	52
Usually satisfactory	49.1	52
Completely satisfactory	0.0	0
Answered question		106
Skipped question		2
12. Do you ever temporarily insert a suction catheter into a chest tube while you are closing the wound at the end of a case in the operating room?		
0% to 24% of time	36.8	39
25% to 49% of time	10.4	11
50% to 74% of time	11.3	12
75% to 99% of time	17.0	18
100% of time	24.5	26
Answered question		106
Skipped question		2
13. In your opinion does heparin coating a chest tube significantly prevent clogging or clotting?		
Yes	21.2	22
No	78.8	82
Answered question		104
Skipped question		4

Continued.

TABLE 1
Continued

Question	Response (%)	Response (n)
14. Which of the following best characterizes your use pattern for small diameter (e.g., 20 F) Blake drains in cardiothoracic cases?		
I have never put in one	12.6	13
I tried them, but no longer use them	20.4	21
I tried them, but rarely use them	34.0	35
I routinely use them	33.0	34
Answered question		103
Skipped question		5
15. Would you insert a small diameter Blake drain in a case where you expect significant bleeding or clogging?		
0% to 24% of time	69.6	71
25% to 49% of time	8.8	9
50% to 74% of time	7.8	8
75% to 99% of time	3.9	4
100% of time	9.8	10
Answered question		102
Skipped question		6
16. What is the perceived advantage of using a Blake drain rather than a standard chest tube in a cardiothoracic case?		
It causes less pain	76.7	79
Design of the drain tip	20.4	21
Flexibility of catheter	50.5	52
Resistance to clogging	18.4	19
Other	9.7	10
Answered question		103
Skipped question		5
17. What is the perceived disadvantage of using a Blake drain rather than a standard chest tube in a cardiothoracic case?		
Potential for clogging	54.4	56
Potential for kinking	17.5	18
Inability to clear needed volume of fluid due to tube diameter	47.6	49
Inability to reliably clear air in setting of an air leak	35.9	37
Other	9.7	10
Answered question		103
Skipped question		5
18. In your opinion, to what degree does chest tube pain impact a patient's overall comfort after a cardiothoracic procedure?		
Significant	83.3	85
Insignificant	16.7	17
Answered question		102
Skipped question		6
19. Is this discomfort impacted by the diameter size of the chest tube (e.g., 36 F vs. 20 F)?		
Yes	74.5	76
No	25.5	26
Answered question		102
Skipped question		6

Continued.

TABLE 1
Continued

Question	Response (%)	Response (n)
20. Do you find that your patients with chest tubes complain of pain related to the chest tube?		
0% to 24% of the time	15.7	16
25% and 49% of the time	15.7	16
50% and 74% of the time	34.3	35
75% and 99% of the time	26.5	27
100% of the time	7.8	8
Answered question		102
Skipped question		6

Concern about postoperative bleeding had an important impact on the decision of most appropriate chest tube size. In particular, 47 of 106 responding surgeons (44.3%) reported that they are more likely to insert a larger-diameter tube in the setting of anticipated bleeding. In contrast, 22 of 106 surgeons (20.8%) would not let bleeding influence their choice of the size of chest tube selected. In addition, 71 of 106 surgeons (67%) routinely placed more than one large chest tube when clogging was anticipated in more than 50% of times.

Pain and discomfort

Surgeons and nurses reported the potential for chest tubes to cause pain. Eighty-five of 102 responding surgeons (83%) considered the pain resulting from a chest tube to be significant after a cardiothoracic procedure. In addition, 76 of 102 surgeons (74%) reported that the level of patient discomfort is related to the diameter of the chest tube. Ninety-seven of 106 responding nurses (91%) reported that pain is moderate to severe in patients with chest tubes.

Conventional chest tube management

Sixty-five of 106 responding surgeons (61.3%) reported that they have standard protocols to manage chest tube clogging. These protocols include milking, tapping, squeezing, folding, and stripping the chest tube. Regarding stripping of the chest tube, this procedure is allowed by 78 of 106 surgeons (73.6%), discouraged by 24 of 106 (22.6%), and forbidden by four of 106 (3.8%) surgeons. In contrast, 76 of 106 responding nurses (71.7%) asserted that stripping the chest tube was not allowed as a means to manage the clogged chest tube at their institution. Over half of all surgeons responding were unsatisfied with available techniques to clear a clogged or clogging chest tube: 52 of 106 (49.1%) usually unsatisfied; two of 106 (1.8%) completely unsatisfied; none were completely satisfied. Correspondingly, only three of 105 responding nurses (2.9%) considered the currently available techniques including tapping, milking, squeezing, or bending the tube to be completely satisfactory. Furthermore, the majority of nurses, 80 of 107 (74.8%), stated that

TABLE 2
Nurses Chest Tube Survey

Question	Response (%)	Response (n)
1. Do you manage patients with chest tubes?		
Yes	100.0	108
No	0.0	0
Answered question		108
Skipped question		0
2. In what location(s) do you care for patients with chest tubes?		
In the ICU	88.6	93
On the wards	11.4	12
In the ER	1.0	1
In the operating room	2.9	3
Other	8.6	9
Answered question		105
Skipped question		3
3. What is the primary reason the patients for whom you provide care have chest tubes?		
After heart surgery	91.7	99
After thoracic surgery	7.4	8
After trauma	0.9	1
Medical ICU	0.0	0
Other	0.0	0
Answered question		108
Skipped question		0
4. Do you find that your patients with chest tubes complain of pain related to the chest tube?		
0% to 24% of the time	3.7	4
25% and 49% of the time	13.1	14
50% and 74% of the time	30.8	33
75% and 99% of the time	37.4	40
100% of the time	15.0	16
Answered question		107
Skipped question		1
5. To what degree would you say chest tube pain impacts a patient's comfort?		
None	0.0	0
Minimal	8.5	9
Moderate	67.0	71
Severe	24.5	26
Answered question		106
Skipped question		2
6. Have you ever noted a chest tube to be clogged or to contain material in the tube that impairs outflow?		
Yes	94.2	98
No	5.8	6
Answered question		104
Skipped question		4
7. Have you ever witnessed an adverse patient outcome from a clogged chest tube? (Examples include pericardial tamponade, the need to go back to the operating room to wash out a clot, or progressive subcutaneous emphysema from an air leak)		
Yes	81.3	87
No	18.7	20
Answered question		107
Skipped question		1

Continued.

TABLE 2
Continued

Question	Response (%)	Response (n)
8. Does your institution allow nurses to strip chest tubes and chest drainage tubing to remove clots?		
Yes	28.3	30
No	71.7	76
Answered question		106
Skipped question		2
9. Do you find the currently available techniques to manage chest tube clogging (i.e., tapping, milking, squeezing, or bending the tube) in the setting of bleeding are:		
Completely unsatisfactory	1.9	2
Usually unsatisfactory	48.6	51
Usually satisfactory	46.7	49
Completely satisfactory	2.9	3
Answered question		105
Skipped question		3
10. Does managing chest tube clogging take you away from other important tasks?		
Yes	74.8	80
No	25.2	27
Answered question		107
Skipped question		1

management of clogged chest tubes is a time-consuming procedure that takes them away from other important care-related tasks.

A potential alternative to prevent chest tube clogging is the use of heparin-coated tubes. This alternative was previously believed to be an effective method in prevention of clogs. However, 82 of 104 responding surgeons (78.8%) doubted the effectiveness of this method. Another alternative is the use of Blake drains. Surgeons had mixed opinions about their use of Blake-type fluted, small-caliber drains after cardiothoracic surgery. While 34 of 103 responding surgeons (33%) have routinely used them, 13 of 103 (12.6%) have never used them. The perceived advantage of using a Blake drain rather than a standard chest tube is that a smaller diameter results in less pain (reported by 79 of 103 [76.7%]) and increased flexibility of the catheter (reported by 52 of 103 [50.5%]). However, the greatest perceived disadvantage of using the Blake drain was the potential for clogging (56 and 103 [54.4%] of responding surgeons) and inability to clear the volume of fluid (49 of 103 [47.6%]) and air (37 of 103 [35.9%]) needed due to their small diameter. With regard to the use of a Blake drain in the setting of expected bleeding or clogging (i.e., a reoperation on a patient taking clopidogrel or who had an empyema), 80 of 102 responding surgeons (78.4%) would use them less than 50% of the time, and 22 of 102 (21.5%) 50% to 100% of the time.

DISCUSSION

Cardiothoracic surgeons currently face a dilemma when choosing a method of postsurgical chest tube drainage. They must balance their concerns for patient safety that is jeopardized by clogging and dysfunction of tubes with their desire to limit patient discomfort. At the bedside, nurses are challenged by and frustrated with the task of directly managing chest tube-related pain and clogging. Our survey was designed to assess attitudes of practicing cardiothoracic surgeons and specialty cardiac surgery nurses related to chest tube clogging and pain to determine the factors these surgeons consider when choosing chest tubes and managing these patients.

The potential for clogging is one of the most important considerations in the selection of chest tubes in cardiothoracic surgery and trauma patients. Any tube used to drain a body space after surgery can become clogged. Tube clogging usually occurs in the setting of bleeding, as a thick clot can obstruct the lumen of the tube and prevent it from functioning properly. Chest tube clogging can be life threatening in cardiac surgery for two reasons.[9,10] First, inadequate drainage can cause internal bleeding to go unrecognized, leading to hemodynamic compromise and death. Second, undrained blood can pool in the pericardial space, creating cardiac tamponade. In addition, with air leaks after pulmonary surgery, a clogged tube can lead to pneumothorax (lung collapse), which can be another life-threatening condition if left untreated.[5]

All the 106 surgeons responding had seen chest tube clogging and nearly all reported adverse patient outcomes from clogging. Nurses caring for patients with chest tubes reported a similar experience. For the surgeon, the potential for clogging is a major consideration. When a surgeon selects a chest tube, the main question to address is the tube's internal diameter. This survey revealed that the choice of tube size nearly always involves the surgeon's perception of the risk of clogging. It is generally thought that the higher the perceived risk, the bigger the diameter of the tube chosen. If a surgeon is simply draining a small amount of air or fluid, a small-diameter tube is often chosen (20 F). Ongoing production of more viscous fluids such as blood or pus, particularly if being generated rapidly, requires a larger bore tube (32 or 36 F) to try to limit the potential for clogging. Even these tubes, however, frequently become occluded with clotted blood, fibrinous debris, or in the case of an empyema, pus.[11] Nearly all surgeons responding reported that the potential for a patient to experience clogging within the chest tube influences the size (internal diameter) of the drainage tube selected. Furthermore, nearly two-thirds of the time, the surgeon will place more than one tube when there is concern that the clinical scenario suggests increased potential for clogging.

When clinicians caring for patients in the perioperative period following chest trauma and surgery notice that clots are forming in the visible portion of the tube external to the patient, they often undertake measures to try to remove the clot. There are several

commonly used techniques for nurses to manage chest tube drainage when bleeding and clogging occur, including milking, stripping, tapping, and, in some circumstances, open suction.[12] Protocols exist in many institutions to direct how nurses manage clogging of a chest tube. However, none of these methods are considered totally reliable, and none of them is without risk of further complications. In addition, these manipulations can be painful for the patient.

One of the most controversial methods of clearing a chest tube is stripping. Stripping the connecting tubing between the chest tube and the collection canister was once one of the most commonly used techniques for trying to maintain chest tube patency. The "stripping" technique generates short bursts of extremely negative pressure at the ends of the tube. The safety of this method has been questioned, as pressures exceeding −400 cm of water can be generated adjacent to suture lines, leading some to think that this technique actually makes bleeding worse.[12] Nevertheless, because there are currently limited options to try to maintain tube patency, most surgeons allow chest tube stripping. In contrast to the surgeon's willingness to allow chest tube stripping, most nurses are under the impression that they are not allowed to strip a chest tube to keep it clear of clogging and clot.

Surgeons responding to the survey were split on their perception of current methods available to clear a clogging tube. Half felt the current methods are usually or completely unsatisfactory, and none of the surgeons surveyed felt they are completely satisfactory. Likewise, nurses were split on the effectiveness of current techniques to clear chest tubes once they become occluded or clogged, with over half stating that the current techniques are usually or completely unsatisfactory. Furthermore, 75% of nurses felt that managing chest tube clogging takes them away from other important tasks.

Attempts at technological improvement have failed to solve the clinical problem of maintaining drain patency. Heparin-coated chest tubes were introduced with the thought that the treatment would retard clot formation. This approach seemed promising theoretically, but has not proved useful, as clot and thick material formation still occur, debris still accumulates, and the clinical benefit is generally marginal.[13,14] To date, specialty coating of the tubes has done little to ameliorate the clogging issue, likely because when blood encounters the foreign surfaces of any tube, it coagulates. The surgeons who responded to our survey clearly do not believe that tube coating is the answer.

In recent years, there has been increasing interest in minimally invasive surgery and the use of smaller diameter chest tubes to limit incision size and pain after cardiothoracic interventions. Chest tubes, however, are generally considered painful to the patient by surgeons and nurses. More than 80% of surgeons responding felt that the chest tube contributed significantly to patient pain in the postoperative period. Similarly, a high percentage of nurses caring for patients with chest tubes reported that chest tubes are associated with significant pain. It has been suggested that chest tube-related pain increases the demand for postoperative analgesia[15] and also negatively affects respiratory mechanism, consequently increasing the risk of postoperative respiratory complications.[16] In addition, pain from chest tubes could impair patients' early ambulation after surgery, increasing the risk for a thromboembolic event.[17] In this survey, the majority of surgeons and nurses stated that the diameter size of the chest tube contributed to the degree of pain experienced by the patient. Thus, the concern for clogging competes with the concern for pain for the patient when choosing a chest tube diameter, suggesting that the surgeons are more likely to choose a larger diameter tube even though it will result in more pain for the patient.

Some surgeons have turned to the Blake-type fluted drain as a small-diameter alternative to the more commonly used polyvinyl chloride chest drains. Only 33% of surgeons responding routinely use Blake-type fluted drains, while two-thirds have tried them and rarely use them or have not tried them at all. Surgeons cited the small diameter and increased flexibility as having less potential for pain, as well as the increased flexibility of the drains as perceived advantages of the Blake drain. An overwhelming majority of surgeons responding would not use this type of drain when bleeding or thick secretions are expected, citing the potential for clogging and the inability to adequately drain a sufficient amount of air or blood as reasons to avoid these types of drains in this setting.

In conclusion, this survey showed the issues associated with current postsurgical chest drainage systems and necessitates innovative approaches to prevent or treat chest tube clogging when it occurs, as well as to miniaturize tube size to improve patient comfort. Innovation techniques may include adding suction systems or clearance apparatus to the chest tube that clears the tubes safely, effectively, and reliably from clogging and may facilitate downsizing the currently available chest tube to minimize the patient's pain and discomfort. We are currently investigating several approaches in animal experiments that will be published in a separate paper.

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