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ORIGINAL ARTICLE

ADULT CARDIAC

Incidence of chest tube clogging after cardiac surgery: a single-centre prospective observational study

Jamshid H. Karimov[a], A. Marc Gillinov[b,*], Laura Schenck[c], Myra Cook[c], Denise Kosty Sweeney[c], Edward M. Boyle[d] and Kiyotaka Fukamachi[a]

[a] Department of Biomedical Engineering, Lerner Research Institute, The Cleveland Clinic, Cleveland, OH, USA
[b] Department of Thoracic and Cardiovascular Surgery, Miller Family Heart and Vascular Institute, The Cleveland Clinic, Cleveland, OH, USA
[c] Cardiothoracic Intensive Care Unit, Nursing Institute, The Cleveland Clinic, Cleveland, OH, USA
[d] St Charles Medical Center, Bend, OR, USA

* Corresponding author. Department of Thoracic and Cardiovascular Surgery, Miller Family Heart and Vascular Institute, Cleveland Clinic, 9500 Euclid Avenue/J4-1, Cleveland, OH 44195, USA. Tel: +1-216-4458841; fax: +1-216-6361393; e-mail: gillinom@ccf.org (A.M. Gillinov).

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Abstract

OBJECTIVES: Chest drainage following cardiac surgery is used to avoid complications related to the accumulation of blood and serous fluid in the chest. We aimed to determine the incidence of chest tube clogging and the role of bedside assessment in identifying the potential for failure to drain.

METHODS: Data from 150 patients undergoing cardiac surgery using cardiopulmonary bypass from March to October 2011 were prospectively entered into a database. Chest tubes were visually inspected and functionally assessed at four time intervals (Hours 0, 2–4, 6–8 and at removal), defining need for clearance and presence of partial or complete obstruction.

RESULTS: Complete data were available for 100 patients. We assessed 234 chest tubes: pericardial (n = 158); pleural (n = 76). The incidence of chest tube clogging for the entire group was 36% (any tube completely clogged at any time), with increased prevalence of clogging observed in urgent and reoperative cases and in those with increased intraoperative blood use. Among 51 tubes resulted to have a thrombus formation observed inside the chest tube at removal, 44 were clogged primarily in the internal portion of the tube, meaning that clogging could not be confirmed by simple bedside inspection of the indwelling tube.

CONCLUSIONS: The chest tubes can become clogged at any time after their placement. The status of urgency, reoperations and use of blood products can be contributing factors increasing the incidence of chest tube clogging. Clinicians likely underestimate the prevalence of this failure to drain, as most clogging occurs in the internal portion of the tube.

Keywords: Chest • Haemothorax • Pleural space • Postoperative care • Surgery • Complications

INTRODUCTION

Chest tubes (CTs) are commonly used for patients who have undergone a cardiothoracic procedure or who have suffered chest trauma. The principal purpose of CTs is to maintain cardiorespiratory function and haemodynamic stability by avoiding complications related to the accumulation of blood and clots, air, debris or other fluids [1, 2] in the pericardial sac and pleural space. The quality and status of postoperative haemostasis and the occurrence of bleeding from surgical sites are often assessed by the volume and character of drainage output. Drainage is traditionally accomplished *via* large-bore CTs, which must be properly positioned [1] and managed. Residual blood and subsequent thrombus formation have often been suggested as a possible cause of CT occlusion, which can be life threatening and compromise postsurgical haemodynamics [3, 4]. Such occlusion is a well-documented complication of cardiac surgery in adults [5]. This fact implies that the effectiveness of postoperative thoracic drainage can adversely influence surgical outcomes and delay patients' recovery.

With only a few studies reported to have measured this outcome [3, 6, 7], the incidence of CT clogging itself, along with the predictable efficacy of bedside visual and functional assessment of CTs, remains uncertain. The objectives of this pilot prospective observational study were to determine the incidence of CT clogging in general cardiac surgical populations using current subjective visual and functional assessments of tubing at bedside and to evaluate the reliability and effectiveness of this routine assessment of pleural and/or pericardial CTs in identifying the clots inside the CT and the potential compromise in drainage.

MATERIALS AND METHODS

Patients and study setting

This study proposal was approved by the Institutional Review Board. Informed consent was deemed not required, as the study did not involve any surgical or pharmacological therapy beyond those routinely performed and administered during standard cardiac surgery patient care, before, during and after surgery. There was no additional risk to the study subjects or other patients.

This pilot prospective observational study enrolled 150 patients (all comers) regularly scheduled for cardiac surgery in the Department of Thoracic and Cardiovascular Surgery from March to October 2011. All the patients underwent cardiac surgery involving cardiopulmonary bypass (CPB). Operations were performed by three staff surgeons with >15 years of experience. This study was not specific to the patient's gender, race, sex or ethnicity. No alteration was made to hospital clinical protocols, operative techniques, working guidelines or standards of medical therapy and care.

Data collection was performed at the patient's bedside in the intensive care unit and the ward by a limited number of registered nurses who had undergone an internal study-specific training before the study began. This training was important because of the subjective character of the visual data and was intended, as much as possible, to standardize the definitions of variables related to CT assessment. Data collection consisted of registering CT status (visual and functional assessment) in the dataforms specifically designed for this study; data were recorded at four time intervals once the patient arrived in the intensive care unit (at Hours 0, 2–4 and 6–8 and at CT removal) and were finalized after the extraction of all tubes.

The CT suction setup consisted of same-brand straight thoracic polyvinylchloride catheters (Argyle™, Covidien, MA, USA) connected to the Atrium Express™ dry seal chest drain system (Atrium Medical Corporation, NH, USA). Once started, the uninterrupted suction (set to −10 cmH_2O per our protocol) was maintained and tubes were not detached and/or suctioned from within the lumen until their removal.

Eligibility criteria

Data collection was not limited to high-risk patients (vulnerable individuals). The inclusion criteria were age ≥18 years; primary or reoperative, conventional or minimally invasive cardiac surgery employing CPB; CTs placed at surgery and morning cases (Round A). The exclusion criteria were ventricular assist device or total artificial heart implantation, heart transplants and robotic-assisted procedures. All patients conforming to the inclusion criteria were included in this study.

Priority in enrolment was given to the morning (Round A) cases. These cases were chosen to ensure the regular availability of patients for the limited number of study-trained nurses and to obtain an uninterrupted follow-up of the patients studied during the remainder of the same postoperative day. The first data collection was scheduled to take place at least 1 h after surgery. All eligible patients were screened for medical history and preoperative risk factors according to a standard protocol.

Additional clinical data consisted of preoperative demographic data, perioperative data related to the cardiac procedure itself (CPB data, aortic cross-clamping time and CT location [pericardial and/or pleural]) and postoperative outcomes.

Definition of terms

All tubes were defined as pericardial or pleural. Evaluation of CT status was based on visual inspection and functional assessment of each CT, structured into three blocks per each evaluation, according to the following visual description (Fig. 1).

Visual inspection

- No occlusion: no visible signs of internal obstruction; CTs are clean.
- Partial occlusion: some obstruction can be visually identified inside the tube. The obstruction can be of any extent, but the CT lumen is not closed.
- Complete occlusion: some obstruction is visibly identifiable at some level of the CT. The extent of obstruction may vary. The CT lumen may be occluded at any one visible level/segment of the tube.

Functional assessment

- Flow not impaired: no signs of impairment in CT patency, no signs of obstruction and no need for milking or stripping to dislodge the clots. Some clots may be present, but CT drainage is dynamic.
- Flow partially impaired: some signs of impaired CT patency, signs of obstruction and possible need for milking and stripping to dislodge clots. Clots are present, but CT drainage is still dynamic.
- Flow completely impaired: signs of impairment in CT patency, significant signs of obstruction in any visible level/segment of the tube and need to notify a surgeon. Clots of varying extent may be present at any level of the CT. Drainage flow is visibly not recognizable/present.

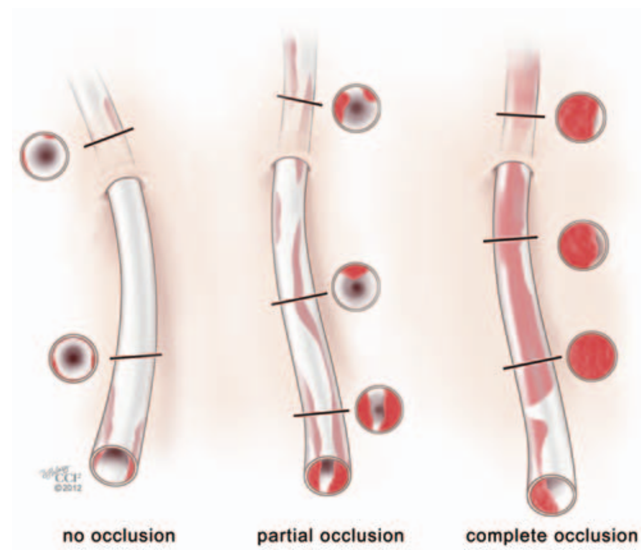

Figure 1: Illustration of the bedside visual and functional assessment of the chest tubes. Three types of occlusion identified for this study are shown with schematically rendered cross-sectional views.

It is important to note that the visual assessment of the CTs (both pericardial and pleural) was requested to be performed prior to CT removal. Thus, thrombus identification was possible only after CT removal, when both internal and external portions/segments of CTs were available for comparison.

End-points

The primary objective of the present study was to determine the incidence of CT clogging in a general population of cardiac surgery patients (all comers). The secondary objective was to identify which variables are associated with patients who have CT clogging. The study also aimed to define morbidity and mortality of patients who had clogged CTs vs those who did not. In addition, the study was oriented to determine the role of routine bedside assessment in identifying the failure of CTs to allow proper drainage.

Statistical analysis

Descriptive statistics for categorical variables are reported as percentages, and continuous variables are reported as mean ± standard deviations (SDs). Categorical variables were compared using the χ^2 test. Continuous variables were compared using Student's *t*-test as appropriate.

RESULTS

From the original 150 patients enrolled, data for the study were extracted for 100 patients on the basis of dataform completeness. Mean age was 64.2 ± 13.3 years, and the majority of patients were men (67%).

A total of 234 CTs were evaluated using the study dataforms at the four time intervals, in pericardial (n = 158) and pleural (n = 76) tubes. Of the 100 patients, 90 patients had at least one pericardial tube (28 Fr = 9; 32 Fr = 81); 68 patients had two pericardial tubes inserted (28 Fr = 8; 32 Fr = 60). A right pleural tube was placed in 45 patients (28 Fr = 11; 32 Fr = 34). A left pleural tube was placed in 31 patients (28 Fr = 9; 32 Fr = 22). The CT distribution in all patients is shown in Fig. 2 per type of tube and in Fig. 3 per total of patients.

Partial occlusion (parietal clot deposition) on visual inspection was observed 33 times in pericardial tubes and two times in pleural tubes. On functional assessment, the flow through the CTs was found to be partially compromised (impaired) 47 times in pericardial tubes and seven times in pleural tubes. No complete occlusions were observed in either pericardial or pleural tubes at the three time intervals (Hours 0, 2–4 and 6–8); however, at removal, thrombus formation was observed in 44 pericardial tubes (39 in internal portion) and 7 pleural tubes (five in internal portion); the thrombi observed in the internal portion of the pericardial and pleural CTs were unidentifiable before the removal of the CTs. This finding is schematically rendered in Fig. 4. In only 25 pericardial tubes before the time of removal was the 'need for clearance' found, and manipulations such as stripping and/or milking were applied. Three pericardial tubes required a 'constant need to manipulate' before removal. Stripping and/or milking was necessary only in three pleural tubes, with no complete flow impairment observed prior to removal. Complete visual and functional assessment data are presented in Table 1. The observation of patients with noticeable CT clogging and flow impairment prior to removal was found to increase over time. The mean total output in all tubes was 482.6 ml in pericardial tubes and 338.7 ml in pleural tubes. Removal times (postoperative day) for both clogged (1.52 ± 0.2 days) and non-clogged (1.26 ± 0.1 days) CTs were comparable, averaging 1.36 ± 1.0 days for all patients.

The demographic and preoperative characteristics of the study group and subgroups (clogged patients and non-clogged patients) are presented in Table 2. The incidence of CT clogging for the entire patient group was 36% (clogged at least once in any tube during any time interval). There was no statistically sig-

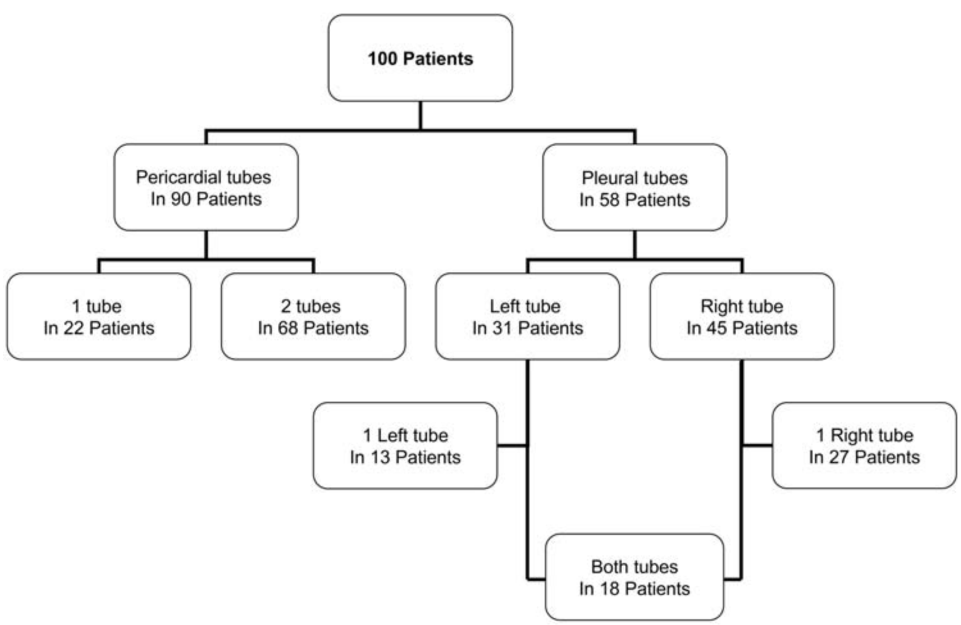

Figure 2: Chest tube distribution in all patients per type (n = 100).

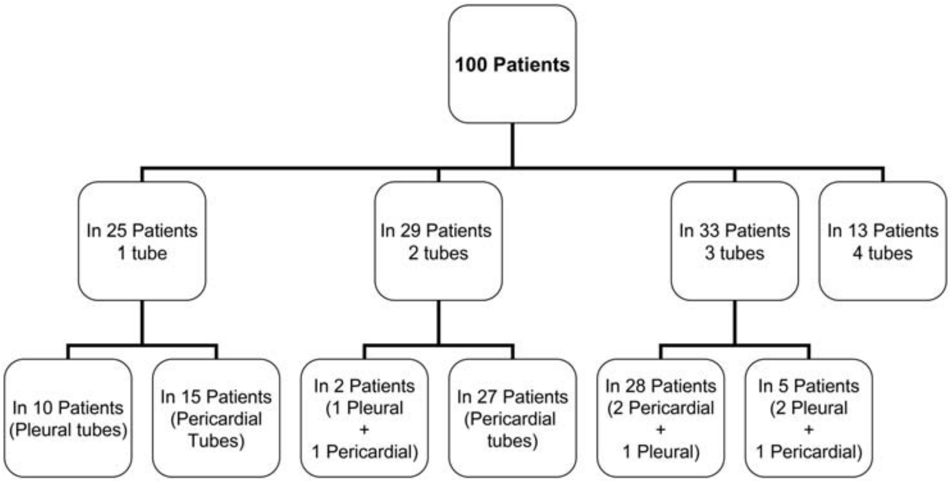

Figure 3: Chest tube distribution in all patients per number ($n = 100$).

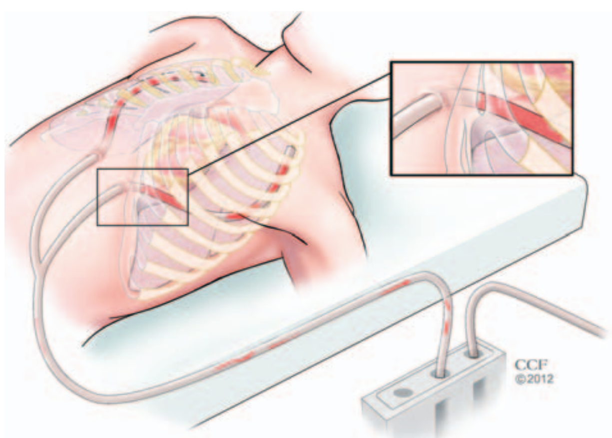

Figure 4: Illustration of the occlusion in chest tube portions inside and outside the body. Most clogging occurs in the internal portion of the chest tube (examples of clogging are shown). Thus, the prevalence of this failure of fluids to drain adequately can be underestimated by evaluation of the external portion only (which appears clean).

nificant difference between the two groups by age, sex or anthropometric data. Patients in the clogged group ($n = 36$) were slightly younger and overweight (82.8 ± 2.9 kg) vs those in the non-clogged group ($n = 64$) and had already had preoperative cardiovascular interventions more often (44.4%) than non-clogged patients (28.1%). Although non-clogged patients were in a better functional class (NYHA), both subgroups exhibited normal preoperative left ventricular function (mean ejection fraction of 56.0 ± 10.5%) and comparable renal function. Chronic obstructive pulmonary disease was a prevalent finding in clogged patients (27.8 vs 15.6%).

Procedural characteristics of the study population are presented in Table 3. For the majority of the patients (80%), this procedure was their first cardiovascular surgery. There were more patients in the clogged group for whom this procedure was a reoperation (25%) vs those in the non-clogged group (17.2%). Urgent surgery was performed in 21% of the patients; of those receiving urgent surgery, there was a higher number of clogged patients (38.9 vs 10.9%; $P = 0.001$).

The incision type varied in patients: full median sternotomy (70%), mini-thoracotomy (11%) and partial sternotomy (16%). Use of CPB was planned in all patients; however, in 1 patient, the operating surgeon chose not to use CPB intraoperatively. Aortic cross-clamping was used in 98% of the cases, with longer clamp times in the clogged group (92.4 ± 5.7 vs 78.4 ± 4.1 min; $P = 0.05$). The need for intraoperative blood use was higher in the clogged group (38.9 vs 20.3%; $P = 0.05$) for any blood products used. Total operative time was slightly longer in clogged cases (5.02 ± 1.40 vs 4.42 ± 1.28 h).

Postoperative outcomes and complications are outlined in Table 4. Postoperative blood product use was higher in clogged patients (38.9 vs 32.8%); such blood products were needed in 35 study patients. Of importance, from all blood products used, the postoperative blood platelets were used significantly more often in clogged patients (22.2 vs 4.7%; $P = 0.007$). With regard to postoperative complications, permanent stroke was observed in 2 patients, both in the clogged group (5.6%; $P = 0.058$). Renal failure (11.1%; $P = 0.006$) and cardiac arrest (5.6%; $P = 0.058$) occurred only in patients from the clogged group. Thirty-two study patients experienced postoperative atrial fibrillation; of these, more than twice as many patients were from the clogged group (50 vs 21.9%; $P = 0.005$). On average, the non-clogged patients were discharged earlier after surgery (7.3 ± 0.5 vs 8.4 ± 0.7 days) compared with the clogged group. There was no hospital mortality during the study observation.

DISCUSSION

In cardiac surgical patients, CTs are susceptible to clotting and thrombus formation after surgery [3, 7, 8], and the occlusion (blockage/clogging) of CTs by thrombus can lead to quite serious complications, such as acute tamponade, haemothorax and pericardial effusion [3, 9]. Therefore, adequate drainage is essential to minimize the accumulation of blood in the pericardial and pleural spaces, and CT patency must be ensured for a sufficient amount of time [1] until tube removal. Surgeons consider the potential for clogging when they choose the diameter size and number of CTs placed after surgery [7]. Little is known, however, about how often clogging actually occurs, as the status

Table 1: The complete visual and functional assessment data on all pericardial and pleural tubes used in 100 patients

Action for each tube type	Time points, each tube				Time points, all tubes			
	Hour 0 Tubes 1/2	Hours 2–4 Tubes 1/2	Hours 6–8 Tubes 1/2	Removal Tubes 1/2	Hour 0 all tubes Tubes 1 and 2	Hours 2–4 all tubes Tubes 1 and 2	Hours 6–8 all tubes Tubes 1 and 2	Removal all tubes Tubes 1 and 2
Pericardial tubes								
Visual inspection								
No occlusion	88/65	83/60	83/62	68/50	153	143	145	**118**
Partial occlusion	2/3	7/8	7/6	22/18	5	15	13	40
Complete occlusion	–/–	–/–	–/–	–/–	–	–	–	–
Functional assessment								
Flow not impaired	88/65	85/62	85/63	80/57	153	147	148	137
Flow partially impaired	2/3	5/6	5/5	10/11	5	11	10	21
Flow completely impaired	–/–	–/–	–/–	–/–	–	–	–	–
Need for clearance								
No need	88/66	83/62	83/64	–/–	154	145	147	–
Stripping, milking etc.	1/1	6/6	7/4	–/–	2	12	11	–
Constant need to manipulate	1/1	1/–	–/–	–/–	2	1	–	–
Thrombus observed								
No thrombus	–/–	–/–	–/–	65/49	–	–	–	114
Yes (total # of tubes)	–/–	–/–	–/–	25/19	–	–	–	44
Portion inside body	–/–	–/–	–/–	21/18	–	–	–	39
Portion outside body	–/–	–/–	–/–	4/1	–	–	–	5
Pleural tubes								
Visual inspection								
No occlusion	45/31	44/31	44/31	40/28	76	75	75	**68**
Partial occlusion	–/–	1/–	1/–	5/3	–	1	1	8
Complete occlusion	–/–	–/–	–/–	–/–	–	–	–	–
Functional assessment								
Flow not impaired	45/31	44/31	44/31	41/30	76	75	75	71
Flow partially impaired	–/–	1/–	1/–	4/1	–	1	1	5
Flow completely impaired	–/–	–/–	–/–	–/–	–	–	–	–
Need for clearance								
No need	45/31	43/31	44/31	–/–	76	74	75	–
Stripping, milking etc.	–/–	2/–	1/–	–/–	–	2	1	–
Constant need to manipulate	–/–	–/–	–/–	–/–	–	–	–	–
Thrombus observed								
No thrombus	–/–	–/–	–/–	40/29	–	–	–	69
Yes (total # of tubes)	–/–	–/–	–/–	5/2	–	–	–	7
Portion inside body	–/–	–/–	–/–	4/1	–	–	–	5
Portion outside body	–/–	–/–	–/–	1/1	–	–	–	2

of the unseen internal portion of the CTs upon removal has never been studied.

CT clogging is reported to influence the completeness of drainage [6] and may have adverse effects [7, 10]. The management of CTs has traditionally consisted of makeshift mechanical methods [11], such as milking and tapping to remove clots, thereby maintaining the patency of tubing [2]. One of the most controversial methods is CT stripping, which can generate transient high levels of negative intrathoracic pressure and can be detrimental to tissues and areas being drained [11, 12]. Milking of CTs, especially at a location close to where they exit from the skin, may inadvertently push back into the chest cavity any clots that may be occluding the thoracic tube eyelets [13]. It is suggested that these procedures be performed only when the tubing is likely to be blocked with clots [8]. However, there appears to be no evidence or any agreed guideline as to whether the CT manipulation is more effective than suction alone or even whether such manipulation is harmful [11]. Nor is it clear which form of manipulation is to be used [8, 14] and whether the manipulation is to be applied routinely, only when tubes are blocked [6, 8], or not at all [15]. These questions remain controversial. There is no proper consensus regarding the definition of manipulation methods [14] and no objective means of evaluating the presence of a clot inside the CT is available at present.

It is also important to mention that milking and/or stripping is not defined as a standard nursing care in the intensive care units within our institution. It is actually against our written policy and would only be done with a physician's order and under direct supervision during the manipulations.

The volume of chest tube drainage after cardiac surgery has been recently reported as an independent potential risk factor and predictor of mortality, also associated with other adverse outcomes, including increased hospital and intensive care stay and increased duration of mechanical ventilation [16]. This adds

Table 2: Demographic and preoperative characteristics

	All patients (*n* = 100)	Clogged patients (*n* = 36)	Non-clogged patients (*n* = 64)	*P*
Age (years)	64.2 ± 13.3	62.7 ± 2.2	65.0 ± 1.7	0.4
Male	67 (67%)	27 (75.0%)	40 (59.7%)	0.2
Weight	80.6 ± 17.4	82.8 ± 2.9	79.4 ± 2.2	0.35
Height	172.1 ± 10.2	173.3 ± 1.7	171.4 ± 1.3	0.36
Prior cardiovascular intervention	34%	16 (44.4%)	18 (28.1%)	0.1
Prior CABG	10%	5 (13.9%)	5 (7.8%)	0.8
Prior valve surgery	12%	7 (19.4%)	5 (7.8%)	0.3
Prior other cardiac surgery	3%	3 (8.3%)	0 (0.0%)	0.02
Prior congenital surgery	4%	1 (2.8%)	3 (4.7%)	0.3
Prior other cardiac PCI	12%	7 (19.4%)	5 (7.8%)	0.3
CHF[a]	11%	8 (22.2%)	3 (4.7%)	0.008
NYHA Class II	6%	4 (11.1%)	2 (3.1%)	0.7
NYHA Class III	4%	3 (8.3%)	1 (1.6%)	
NYHA Class IV	1%	1 (2.8%)	0 (0.0%)	
Ejection fraction (%)	56.0 ± 10.5	53.9 ± 1.7	57.2 ± 1.3	0.14
Creatinine level	1.04 ± 0.37	1.1 ± 0.06	1.0 ± 0.04	0.1
COPD	20%	10 (27.8%)	10 (15.6%)	0.2
Mild	11%	4 (11.1%)	7 (10.9%)	
Severe	5%	3 (8.3%)	1 (1.6)	
Moderate	4%	3 (8.3%)	2 (3.1%)	

[a]NYHA class represented for CHF patients only.
CABG: coronary artery bypass graft; CHF: congestive heart failure; COPD: chronic obstructive pulmonary disease; NYHA: New York Heart Association functional classification; PCI: percutaneous cardiac intervention.

Table 3: Procedural characteristics of the study population

	All patients (*n* = 100)	Clogged patients (*n* = 36)	Non-clogged patients (*n* = 64)	*P*
Incidence (first or redo)				
First cardiovascular surgery	80%	27 (75.0%)	53 (82.8%)	0.35
Redo	20%	9 (25.0%)	11 (17.2%)	
Status (elective or urgent)				0.001
Elective	79%	22 (61.1%)	57 (89.1%)	
Urgent	21%	14 (38.9%)	7 (10.9%)	
CABG	35%	16 (44.4%)	19 (29.7%)	0.14
Valve	91%	33 (91.7%)	58 (90.6%)	0.87
Incision type				0.18
Sternotomy median	70%	30 (83.3%)	43 (67.2%)	
Mini-thoracotomy	11%	2 (5.6%)	9 (14.1%)	
Sternotomy partial	16%	4 (11.1%)	12 (18.7%)	
CPB (full use)	99%			
Perfusion time	106.9 ± 39.5	115.4 ± 6.6	102.3 ± 4.9	0.12
Aortic occlusion (employed)	98%	34 (94.5%)	64 (100%)	0.04
Cross clamp time	83.3 ± 33.5	92.4 ± 5.7	78.4 ± 4.1	0.05
IABP	1%	1 (2.8%)	0 (0.0%)	0.15
Intraoperative blood products given	27%	14 (38.9%)	13 (20.3%)	0.05
Intraoperative RBC	22%	12 (33.3%)	10 (15.6%)	0.56
Intraoperative FFP	8%	6 (8.3%)	2 (3.1%)	0.11
Intraoperative CRYO	1%	1 (2.8%)	0 (0.0%)	0.24
Intraoperative platelets	10%	6 (11.1%)	4 (4.7%)	0.51
Aortic procedure	51%	24 (66.7%)	27 (42.2%)	0.01
Mitral procedure	49%	14 (38.9%)	35 (54.7%)	0.1
Tricuspid procedure	9%	3 (8.3%)	6 (9.4%)	0.84
Pulmonic procedure	1%	0 (0.0%)	1 (1.6%)	0.34
Skin incision to closure time (hours)	4.49 ± 1.32	5.02 ± 1.40	4.42 ± 1.28	0.3

CABG: coronary artery bypass graft; CPB: cardiopulmonary bypass; CRYO: cryoprecipitate; FFP: fresh frozen plasma; IABP: intraaortic balloon pump; RBC: red blood cells.

Table 4: Postoperative outcomes and complications

	All patients (*n* = 100)	Clogged patients (*n* = 36)	Non-clogged patients (*n* = 64)	*P*
Postoperative blood products needed	35%	14 (38.9%)	21 (32.8%)	0.54
Postoperative RBC	34%	14 (38.9%)	20 (31.2%)	0.31
Postoperative FFP	8%	5 (13.8%)	3 (4.7%)	0.14
Postoperative CRYO	4%	3 (8.3%)	1 (1.6%)	0.13
Postoperative platelets	11%	8 (22.2%)	3 (4.7%)	0.007
Postsurgical complications				
Complications—any	50%	21 (58.3%)	29 (45.3%)	0.2
Reoperation, bleeding	1%	0 (0.0%)	1 (1.6%)	0.3
Reoperation, valve dysfunction	1%	1 (2.8%)	0 (0.0%)	0.2
Perioperative MI	1%	1 (2.8%)	0 (0.0%)	0.2
Infection, sternum, deep	1%	0 (0.0%)	1 (1.6%)	0.3
Infection, thoracotomy	0%	0 (0.0%)	0 (0.0%)	
Infection, leg	1%	1 (2.8%)	0 (0.0%)	0.2
Infection, arm	0%	0 (0.0%)	0 (0.0%)	
Permanent stroke	2%	2 (5.6%)	0 (0.0%)	0.058
TIA	0%	0 (0.0%)	0 (0.0%)	
Postoperative paralysis	1%	1 (2.8%)	0 (0.0%)	0.2
Prolonged ventilation[a]	8%	5 (13.9%)	3 (4.7%)	0.2
Pulmonary embolism	1%	0 (0.0%)	1 (1.6%)	0.3
Pneumonia	0%	0 (0.0%)	0 (0.0%)	
Renal failure	4%	4 (11.1%)	0 (0.0%)	0.006
Renal dialysis required	1%	1 (2.8%)	0 (0.0%)	0.01
Acute limb ischaemia	1%	0 (0.0%)	1 (1.6%)	0.3
Heart block	1%	0 (0.0%)	1 (1.6%)	0.3
Cardiac arrest	2%	2 (5.6%)	0 (0.0%)	0.058
Anticoagulant	1%	0 (0.0%)	1 (1.6%)	0.3
Tamponade	0%	0 (0.0%)	0 (0.0%)	
Gastrointestinal—any	2%	0 (0.0%)	2 (3.1%)	0.13
Atrial fibrillation	32%	18 (50.0%)	14 (21.9%)	0.005
Aortic dissection	0%	0 (0.0%)	0 (0.0%)	
Other complication[b]	13%	4 (11.1%)	9 (14.1%)	0.33
Postoperative discharge date	7.7 ± 4.2	8.4 ± 0.7	7.3 ± 0.5	0.45
Total hospital length of stay	9.1 ± 6.1	10.6 ± 1.0	8.3 ± 0.8	0.2

CRYO: cryoprecipitate; FFP: fresh frozen plasma; RBC: red blood cells; MI: myocardial infarction; TIA: transient ischaemic attack.
[a]Pulmonary insufficiency requiring ventilator >24 h.
[b]Any postoperative complication not specifically identified by the Society of Thoracic Surgeons that affects the hospital length of stay and/or outcome.

strength to the suggestion that the detriment in outcomes associated with postoperative bleeding may be related to inefficient clearing of blood and retained clots from the chest due in part to chest tube clogging.

Finally, as noted in this study, the degree of clogging cannot always be appreciated by inspecting the tubes prior to removal, because the internal portion of the CT may be occluded even when the external portion appears clear. This state of uncertainty emphasizes the need to address current CT clearance strategies or to find means by which to test CT clearance systems as a way to improve outcomes and possibly reduce hospital costs.

Despite many recent improvements in intraoperative management and postoperative care, the failure of chest drainage tubes remains an important cause of complications after cardiac surgery [2, 7, 14] and may have adverse effects on patients' recovery and adequate rehabilitation. The ability to identify patients particularly at risk of complications is important [17]. As the methods of objective evaluation (identification and characterization) of clots inside the tubing in a timely fashion appears to be inconsistent in the literature, with only a few studies reported to have measured this outcome [3, 6, 7], the incidence of CT clogging itself along with the efficacy of bedside visual and functional assessment of CTs remains uncertain and is the prime rationale for the present study.

The dedicated dataforms were designed to assess the results of the visual inspection and functional assessment of each CT placed in patients undergoing cardiac surgery in a single department and operated by a limited number of surgeons (*n* = 3). CTs were observed by trained registered nurses, recording data at the patient's bedside at four time intervals (Hours 0, 2–4, 6–8 and at removal) according to the evaluation criteria on the dataforms. Understanding the extremely subjective character of the data, we developed a description to characterize CT appearance for experienced nurse professionals and to standardize the collected data.

There are several limitations to our study. First is the small, nonhomogeneous group of patients and the subjective character of visual assessment data. One potentially important factor—whether surgeries were emergent/urgent or planned—was not determined and grouped separately. The study also included both primary (80%) and reoperative (first and multiple) surgeries. The most important limitation, however, is the subjective character and criteria of the visual and functional CT assessment, which could not be precisely determined and resulted in exclusion of 50 patients' data due to incompleteness. We certainly expected the difficulties with visual assessments. The missing data were detected since the study's beginning, thus having complete and incomplete forms at the same time. All data had to be recorded at bedside and could not be filled retrospectively to complete the study forms. For this reason, we decided to exclude the incomplete forms until we obtained a 100 patient mark, which was our goal. Notably, the excluded dataforms served as a learning curve for the nursing personnel in interpreting the visual findings into quantifiable parameters.

The density and morphological organization of clots at removal were not analysed. The study did not attempt to define the efficacy of CT management and treatment of postoperative CT clogging. Although we noted the difference in subjective visual assessment of tubes with their actual status at removal, this question was not approached systematically but will be the object for further research with possible use of quantifiable variables.

Nevertheless, this is the first time that the incidence of CT clogging has been characterized and the association with more high-risk patients or those with bleeding has been identified. Patients today are often exposed to preoperative anticoagulation and antiplatelet therapies, which leads to higher risks of bleeding postoperatively, higher transfusion rates [18] and increased rates of chest re-explorations for bleeding [19, 20]. This state of affairs raises the question of whether CT clogging in the setting of excessive postoperative bleeding may contribute to increased numbers of complications that could affect outcomes. In this study, the clogging patients were found to have a higher incidence of atrial fibrillation ($P = 0.005$), permanent stroke ($P = 0.058$), renal failure ($P = 0.006$) and a trend toward a higher incidence of cardiac arrest ($P = 0.058$). Our findings suggest that even in this cohort of patients, most of them undergoing elective surgery, the complication rates were higher, and this factor may affect hospital costs.

We are now planning a study that incorporates imaging methods with the graded visual and functional assessment of CT clogging at bedside. Using quantifiable techniques such as ultrasound and/or computed tomography would allow us to obtain a dynamic picture by which to analyse the status of CTs in the early postoperative period, before their extraction from the chest.

In conclusion, our findings suggest that CTs can become clogged any time after their placement in a considerable number of patients undergoing cardiac surgery. The standard incision type, reoperations and peri- or postoperative need for blood can be contributing factors, increasing the incidence of CT clogging and compromised drainage. At the time of CT removal, the internal portion of tubes appeared to be most clogged, but healthcare personnel cannot identify these clogs before their removal. Further studies are needed to elucidate the incidence in a wider cross section of patients that includes higher acuity urgent and emergent cases in which the incidence of CT clogging may be higher and the consequences more severe.

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Conflict of interest: A. Marc Gillinov and Edward M. Boyle have financial interests in Clear Catheter Systems (Bend, OR) that include ownership in shares and a royalty agreement.

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