Evaluation of (Wet) and (Dry) Mediastinal Chest Drainage in Minimally Invasive and Conventional Cardiac Surgery

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ABSTRACT

Background: Drainage of fluid and evacuation of air from the pericardial and pleural spaces after cardiothoracic surgery is necessary to prevent effusion, tamponade, and pneumothorax, and also to detect hemorrhage. For this purpose, negative-pressure drains are placed in the mediastinum and pleural cavities. We compared the efficacy and safety of two systems wet and dry drainage for the management and monitoring of negative pressure and anti-reflux valve safety systems, to promote healing of the pleural and pericardial cavities.

Methods: Two devices for mediastinal chest drainage [Venice PAS (Wet) and Rome PAS (Dry); both Eurosets SRL, Medolla, Italy] were evaluated in terms of safety, efficacy and clinical outcomes in a cohort of 60 patients who underwent elective cardiac surgery procedures. The patients were divided into a minimally invasive cardiac surgery (MICS) group [n=30; mitral valve surgery (MVS) by right anterolateral mini-thoracotomy] and a conventional cardiac surgery (CCS) group [n=30; coronary arterial bypass grafting (CABG) in full sternotomy] at a single institution (Anthea Hospital GVM Care & Research, Bari, Italy).

Results: Negative pressure was managed with a target value of -20 cmH_2O measured in the chest tube and was related to the device: deviation of ± 1 cmH_2O for the Venice PAS (Wet) and 0 cmH_2O for the Rome PAS (Dry) in the MICS group; deviation of 1 ± 0.8 cmH_2O for the Venice PAS (Wet) and 0.8±0.2 cmH_2O for the Rome PAS (Dry) in the CCS group. A constant volumetric air leak meter (VALM) value and the absence of air-leak bubbling were correlated with the absence of air in the pleural cavity and complete pulmonary re-expansion to restore normal respiratory dynamics in the MICS group for both models of chest drainage. The maximum total pericardial blood drained was 1104 ± 302 ml with Venice PAS (Wet) and 1530 ± 230 with Rome PAS (Dry) in the CCS group. There were no reports of cardiac tamponade in either group.

Conclusions: The two mediastinal chest drainage devices [Venice PAS (Wet) and Rome PAS (Dry)] in this study were effective, accurate for measuring the applied negative pressure, and safe in their application after cardiac

surgery procedures via minimally invasive and conventional approaches for blood and liquid drainage, prevention of cardiac tamponade, and restoration of normal respiratory dynamics after surgical pneumothorax. Both systems are equipped with anti-reflux valves to prevent air and blood from entering the drainage, and no adverse events were reported.

BACKGROUND

In 1967, Deknatel introduced the first integrated disposable chest drainage unit based on the three-bottle system.[1] The clinical need for chest drainage arises anytime the negative pressure in the pleural cavity is disrupted by the presence of air and / or fluid, resulting in pulmonary compromise. The purpose of a chest drainage unit is to evacuate the air and / or fluid from the chest cavity to help re-establish normal intrathoracic pressure.[2] This facilitates re-expansion of the lung to restore normal breathing dynamics. A need also arises following heart surgery to prevent the accumulation of fluid around the heart. In patients with continual air or fluid leak, a chest tube, also called a thoracic catheter, is inserted. The distal end, which will be inside the patient's chest, has several drainage holes.[3] The last eyelet can be detected on chest X-ray as intermittent breaks in the radiopaque line. Once the chest tube has been properly positioned and secured, the X-ray should be checked to ensure that all drainage holes are inside the chest wall. The location of the chest tube depends on what is being drained.[4] Free air in the pleural space rises, so the tube is placed above the second intercostal space at the mid-clavicular line. Pleural fluid gravitates to the most dependent point, so the tube is placed at the 4th to 5th intercostal space along the mid-axillary line. Mediastinal tubes placed to drain the pericardium after open heart surgery are positioned directly under the sternum. Once the chest tube is in place, it is connected to a chest drainage unit. Drainage of fluid, or evacuation of air, from the pericardial and pleural spaces after cardiothoracic surgery is necessary to prevent effusion, tamponade, and pneumothorax, and also to detect hemorrhage.[5] The negative-pressure drains are placed in the mediastinum and pleural cavities.

In this context, we compared the efficacy and safety of systems for wet and dry mediastinal chest drainage in the management and monitoring of negative pressure and anti-reflux valve safety systems, to promote healing of the pleural and pericardial cavities.[6]

MATERIALS AND METHODS

Study Design: Between September 2022 and January 2023, two devices designed for mediastinal chest drainage [Venice PAS (Wet) and Rome PAS (Dry); both Eurosets SRL, Medolla, Italy] were evaluated in terms of safety, efficacy and clinical outcomes in a cohort of 60 patients who underwent elective cardiac surgery procedures at a single institution (Anthea Hospital GVM Care & Research, Bari, Italy).

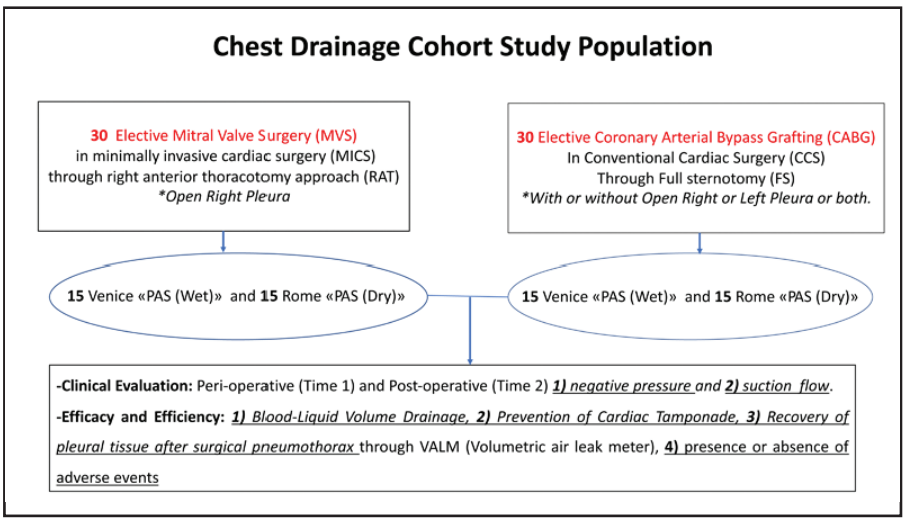

Figure 1. Study setting.

The patients were divided into a minimally invasive cardiac surgery (MICS) group (n=30) and a conventional cardiac surgery (CCS) group (n=30). The patients in the MICS and CCS groups were then randomly assigned to be treated with a Venice PAS (Wet) (n=15) or Rome PAS (Dry) (n=15) for chest drainage (Fig. 1). The GVM Care & Research review board approved the study (internal protocol; decision 17 August 2022) and each patient gave their informed consent. The study protocol was also approved by the local ethics committee.

Inclusion Criteria: The MICS group underwent elective, primary mitral valve surgery (MVS) by right anterolateral mini-thoracotomy and the CCS group underwent elective, primary coronary arterial bypass grafting (CABG) in full sternotomy.

Exclusion Criteria: Patients were excluded if they presented abnormal plasma lactate levels (>2 mmol/L) before entering cardiopulmonary bypass (CPB), renal or liver failure, obesity, uncompensated diabetes, autoimmune disease, active infection, any immunosuppressant therapy, or coagulation disorder. Patients undergoing surgery with circulatory arrest or who had preoperative hematocrit (Hct) <27% were also excluded.

Preoperative data

The following data were obtained preoperatively: patient demographic characteristics, comorbidities, baseline Hb, logistic European System for Cardiac Operative Risk Evaluation II score, and New York Heart Association functional class.

Surgical technique

Our surgical approaches for minimally invasive direct view during mitral surgery and conventional cardiac surgery have been described elsewhere. For MICS MVS procedures, arterial perfusion was always retrograde, and peripheral and aortic cross-clamping was external in all patients. Venous cannulation was peripheral with vacuum support and cannulas were inserted at 2 sites (jugular and

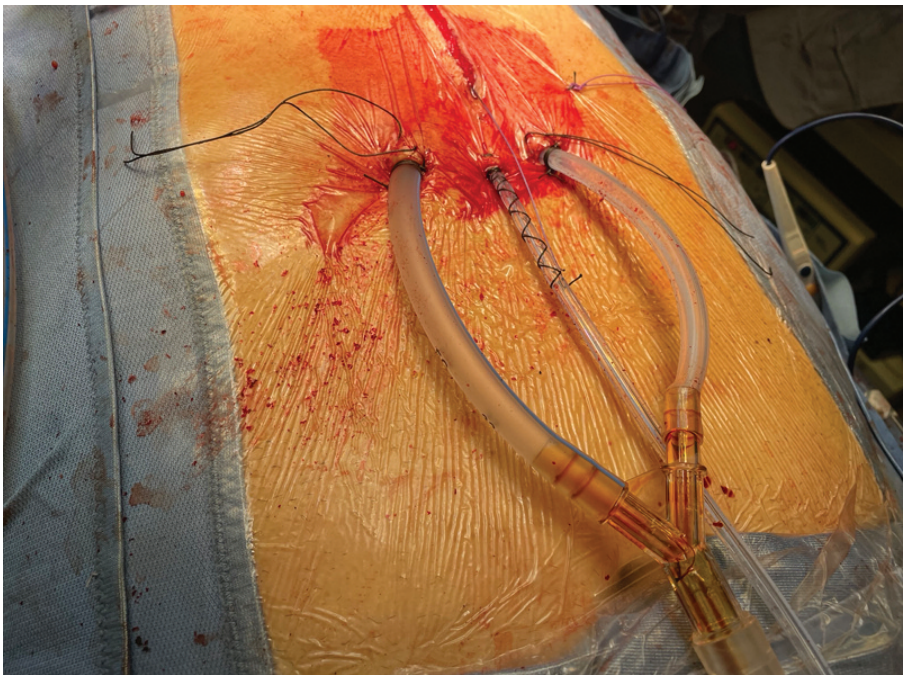

Figure 2. Positioning of drainage tubes in CCS.

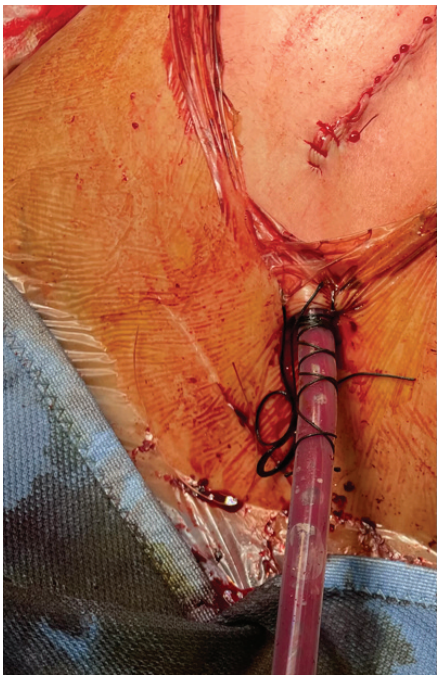

Figure 3. Positioning of drainage tubes in MICS.

femoral). Valve inspection and the respective procedure were performed through the left atrium under direct vision and the reconstruction technique was standardized.[7] For CCS CABG procedures, normothermic CPB was instituted with aortic and double-staged venous cannulas after median sternotomy and heparin administration.

Chest drainage with the Venice PAS (Wet) and Rome PAS (Dry): Features and management.

As a standard postoperative practice after CCS, patients receive two or three chest tubes (28F–32F), which are typically placed in the mediastinum to continuously monitor postoperative blood loss (Fig. 2) and to prevent undesirable blood collection, especially in the pericardial space, which could potentially lead to cardiac tamponade. In MICS, one chest tube (28 F) is placed at the 4th to 5th intercostal space along the mid-axillary line (Fig. 3). The chest tubes are connected to various drainage systems. In this study, we used a Venice PAS (Wet) (Fig. 4) and a Rome PAS

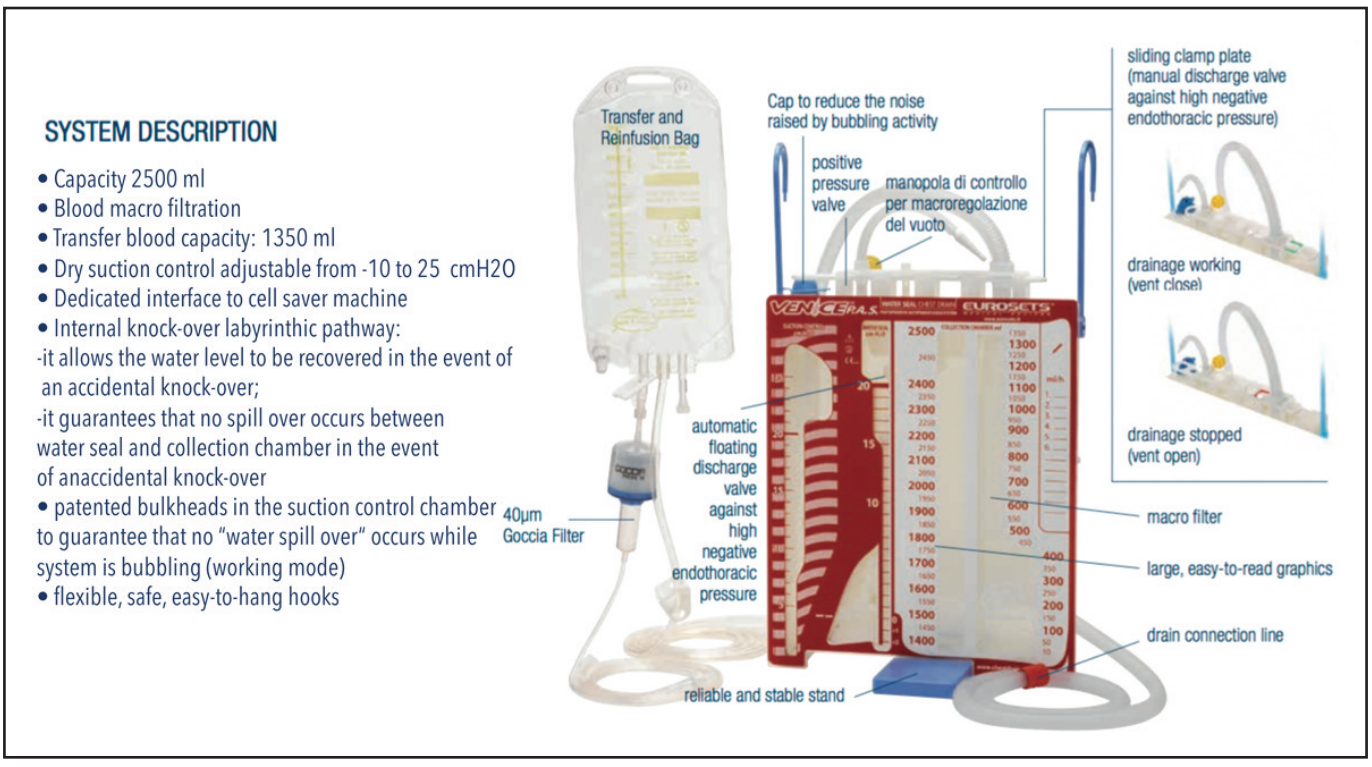

Figure 4. Venice PAS (Wet).

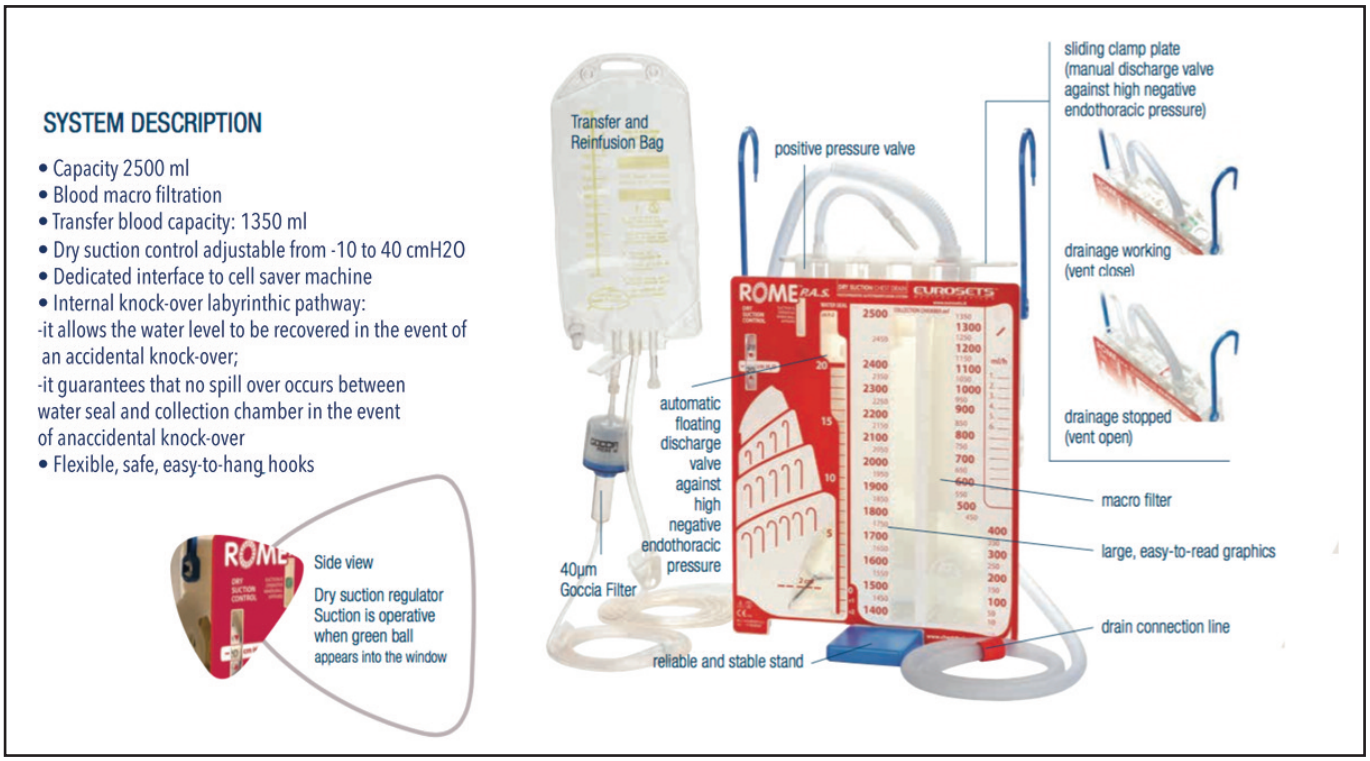

Figure 5. Rome PAS (Dry).

(Dry) (Fig. 5), both of which are autotransfusion systems that give the opportunity to maintain the sterility of the recovered blood and then reinfuse it back to the patient, with the possibility of a closed reinfusion circuit even during the drainage phase through a transfer and reinfusion bag. Suction of about -20 cm H_2O is usually applied. These collection containers have an integrated surge chamber and can be connected to external suction, which is usually integrated into the wall of the patient's room.

Chest Drainage Data Collection

Mean values regarding the accuracy of the negative pressure monitored and measured in the system (through a vacuum meter) and suction flow in the inlet of chest drainage (through a flowmeter) were obtained in the operating room, 10 minutes after positioning the chest drainage (Time 1), and at 10 minutes before its removal (Time 2). The maximum volume of blood-liquid drainage, the incidence of cardiac tamponade, the accuracy of a volumetric air-leak meter

Table I
Pre-operative data

	MVS MICS (n=30)	CABG CCS (n=30)	P-value
Age (years)	67 (62–78)	74 (67–79)	<0.577
Male sex	43.9%	38.7%	<0.055
Body mass index (kg/m^2)	27.4 (23.4–29.0)	25.2 (21.7–27.3	0.281
Body surface area (m^2)	1.84±0.5	1.82±0.7	0.69
Arterial hypertension	10.5%	39.1%	0.789
Oral antidiabetic drugs	2.2%	36.5%	0.006
Insulin	3.8%	29.6%	0.530
Hypercholesterolemia	12.1%	45.3%	0.009
Coronary artery disease	0.8%	99.2%	0.01
EuroSCORE II (%)	2.2 (1.6–2.8)	3.5 (1.1–5.6)	0.87
NYHA Class	2±0.6	2±0.9	0.53
Hemoglobin (g/dl)	11.3±1.1	11.4±1.2	0.86

Values represent the mean, median (interquartile range) or percentage. MVS, mitral valve surgery; CABG, coronary artery bypass grafting; CCS, conventional cardiac surgery; NYHA, New York Heart Association.

Table II
Post-operative data and chest drainage management results

MICS (n = 30)	Venice PAS (Wet) (n = 15)	Rome PAS (Dry) (n = 15)	P-value
Time 1			
Suction flow in the inlet of the mediastinal chest (L/min)	2	2	
Target chest drainage pressure (cm H_2O)	-20	-20	
Measured chest drainage pressure (cm H_2O)	-18.8 ±0.2	-20	0.002
Time 2			
Suction flow in the inlet of the chest from wall vacuumt (L/min)	2	2	
Target chest drainage pressure (cm H_2O)	-20	-20	
Measured chest drainage pressure (cm H_2O)	-18.9 ±0.4	-20	0.002
Duration of treatment (h)	36 ±2	34 ±2	0.44
Pericardial blood drained (ml)	732±50	698±45	0.045
Estimated water evaporation at 30 hours (ml)	7±1	0	0.001
Cardiac tamponade (n)	0	0	
Air-leak bubbling during VALM oscillation (n)	0	0	
CCS (n=30)	**Venice PAS (Wet) (n = 15)**	**Rome PAS (Dry) (n = 15)**	**P-value**
Time 1			
Suction flow in the inlet of the chest from wall vacuum (L/min)	2	2	
Target chest drainage pressure (cm H_2O)	-20	-20	
Measured chest drainage pressure (cm H_2O)	-19.2 ±0.2	-20	0.002
Time 2			
Suction flow in the inlet of the mediastinal chest (L/min)	2	2	
Target chest drainage pressure (cm H_2O)	-20	-20	
Measured chest drainage pressure (cm H_2O)	-17.9 ±0.3	-20	0.004
Duration of treatment (hours)	36 ±2	34 ±2	0.44
Pericardial blood drained (ml)	1104±302	1530±230	0.045
Estimated water evaporation at 30 hours (ml)	7±1	0	0.001
Cardiac tamponade (n)	0	0	
Air-leak bubbling during VALM oscillation (n)	0	0	

Values represent the mean, median (interquartile range) or percentage. MVS, mitral valve surgery; CABG, coronary artery bypass grafting; CCS, conventional cardiac surgery; NYHA, New York Heart Association.

(VALM) for evaluating the recovery of pleural tissue after surgical pneumothorax, and the presence or absence of adverse events were recorded.

Statistical analysis

Continuous data are expressed as the mean ± standard deviation or as the median with the interquartile range, and categorical data are shown as percentages. Cumulative survival was evaluated by the Kaplan-Meier method. All reported *p*-values are two-sided, and *p*-values of <0.05 were considered to indicate statistical significance. All statistical analyses were performed with SPSS 22.0 (SPSS, Inc., Chicago, IL, USA).

RESULTS

The preoperative data are shown in Table I.

As shown in Table II, the difference between the target negative pressure of -20 cmH_2O and the value obtained with a vacuum meter was ± 1 cmH_2O for the Venice PAS (Wet) and 0 cmH_2O for the group, and 1± 0.8 cmH_2O for the Venice PAS (Wet) and 0.8±0.2 cmH_2O for the Rome PAS (Dry) in the CCS group. The VALM value in the absence of oscillation and air-leak bubbling was correlated with the absence of air in the pleural cavity and complete pulmonary re-expansion on thoracic X-ray to restore normal respiratory dynamics in the MICS group for both types of chest drainage at Time 2. In both groups, the estimated water evaporation with the Venice PAS (Wet) device was 7 ml after 30 hours.

In the CCS group, the mean maxi-

mum total pericardial blood drained was 1104 ± 302 ml for the Venice PAS (Wet) and 1530 ± 230 for the Rome PAS (Dry) ($p<0.05$). None of the patients in either group experienced cardiac tamponade (Table II).

DISCUSSION

Postoperative pneumothorax is a potentially fatal complication that occurs in approximately 1.4% of patients after cardiac surgery.[8] Cardiac tamponade (CT) is also a potentially fatal complication following cardiac surgery and requires surgical reintervention in 0.1%–6% of cases. There are two types of CT: acute, which occurs within the first 48 h postoperatively, and subacute or delayed, which occurs more than 48 h postoperatively.[9] The latter does not show specific clinical signs, which makes it more difficult to diagnose. The factors associated with acute CT (aCT) are related to coagulopathy or surgical bleeding, while those associated with subacute tamponade have not been well defined. Prevention of this complication could save lives and reduce morbidity and costs in this large patient population. The collection containers described in this study have an integrated surge chamber and can be connected to external suction, which is usually integrated into the wall of the patient's room. The Wet seal system, which includes a water column, was the original method used to control the amount of negative pressure transmitted to the chest.[10] When integrated disposable drains were developed, this water column was transformed into a vacuum control chamber. The water level in this chamber determines the level of negative pressure that is transmitted to the chest. The challenges with water-based systems are the bubbling noise and evaporation of the water.[11] As the water evaporates and the water level drops, the amount of negative pressure transmitted to the chest will also decrease. Also, water-filled units take longer to install and if the drain is spilled, water can leak into other rooms or onto the floor. The Dry system features a self vacuum regulator. As long as there is adequate airflow from the wall suction source, the regulator will automatically adjust in response to changes in wall suction or the patient to maintain suction at the level set on the exhaust.[12] It is also quieter than wet suction exhausts since bubbling is not used for suction control. Plus, these drains provide a range of suction levels, from -10 cmH_2O to -40 cmH_2O, and evaporation is not a concern.[13] If the drain is spilled, it is less likely that water will spill between the chambers and flow out of the drain. In this context, we have presented in this report a clinical evaluation in terms of the efficacy and safety of two systems, Venice PAS (Wet) and Rome PAS (Dry) (both by Eurosets Eurosets SRL, (MO) Medolla, Italy), in a cohort of patients who underwent elective cardiac surgery procedures by minimally invasive and conventional approaches.

CONCLUSION

The two mediastinal chest drainage devices used in this study [Venice PAS (Wet) and Rome PAS (Dry); both from Eurosets SRL, (MO) Medolla, Italy] in this study were effective, accurate for measuring the applied negative pressure and safe in their application after cardiac surgery in minimally invasive and conventional approaches for blood and liquid drainage, prevention of cardiac tamponade, and restoration of normal respiratory dynamics after surgical pneumothorax. These two systems are equipped with anti-reflux valves for air and blood from the drainage to the patient, and no adverse events were reported. STI

AUTHORS' DISCLOSURES

IC is a consultant for Eurosets SRL (Medolla, Italy). The other authors declare that there are no conflicts of interest.

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Surg Technol Int. 2023, March 17; 42. pii: sti42/1663, doi: 10.52198/23.STI.42.CV1663