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Research Article

Clinical Effectiveness of Chest Tubes in Retained Blood and Post-Pericardiotomy Syndromes to Control Clogging and Associated Complications in Cardiac Surgery: A Meta-Analysis

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Abstract

Retained blood syndrome and post-pericardiotomy syndrome are postoperative complications associated with cardiac surgery period as well as patient management outcome when chest tubes are used for pericardial and pleural drainage of the accumulated blood. This meta-analysis focuses on the effectiveness of chest tubes in post-pericardiotomy syndrome and retained blood syndrome. The evaluations used a comparative approach to analyze four key studies identified from medical research databases. Our analysis concluded that chest tubes usage for evacuating blood accumulated subsequent to surgery should be with extreme care by trained medical professionals with appropriate follow-up. A careful strategy will assist in an adequate clearance of unwanted fluid and air to reduce the occurrence of inflammation and clogging.

Keywords: *Post-Pericardiotomy Syndrome (PPS); Retained Blood Syndrome (RBS); Chest Tube Postoperative Intervention; Active Chest Tube Clearance (ATC); Cardiac Surgery*

Abbreviations

PPS: Post-Pericardiotomy Syndrome; RBS: Retained Blood Syndrome; ATC: Active Chest Tube Clearance

Introduction

Post-pericardiotomy syndrome (PPS) is a condition that was first described in 1954 [1]. This complication was noted among patients who exhibited fever and pleuritic pain after mitral valve surgery. The prevalence of PPS is higher among patients undergoing open procedures like opening the pericardium and percutaneous manipulations for stent and pacemaker implantations [2,3]. Prominent symptoms of PPS include fever, chest pain, and pericardial and pleural effusions [4]. Injury from cardiothoracic operations has been linked to PPS, that is associated with significant morbidity [5]. To avoid the complications, cardiac surgeons most often use active tube clearance system comprised of chest tube clearance, which could potentially protect patients from the PPS [6]. The proper management of chest tube is a

critical factor in achieving optimal benefits [7]. Since the recognitions of PPS etiology efforts have been directed to devise and assess interventions reducing this postoperative complication thus improving the quality of life for patients undergoing cardiothoracic surgery [8,9]. Several complementary approaches to the management and treatment of PPS have been established; the most recent include colchicine, which was recommended based on the latest clinical findings [8]. However, the underlying etiology of this postoperative complication is a determining factor when choosing the treatment approach [10]. This paper is a meta-analysis of the effectiveness of chest tubes in PPS and interventions for postoperative clogging.

Background of the Study

Various clinical interventions are used for the drainage of bleeding in the pleural space due to postoperative thoracic complications. According to Rozenman., *et al.* [11], chest tubes have been used as an immediate option for managing fluid evacuation in different forms of PPS. Numerous medical evaluations have been carried out to determine the risks versus benefits associated with this approach. For example, pneumothorax, chest trauma, hemothorax, symptomatic pleural effusion, and postoperative thoracic surgery are reported prominent indications for chest tube placement associated with PPS [11,12]. Cases with contraindication to chest tube placement, such as tension pneumothorax, have also been also described [13]. On the other hand, pulmonary blebs have been associated with a significant rate of contraindications [14]. Appropriate precautionary measures and patients' hematological status are crucial besides precautionary measure for using chest tube interventions in PPS patients; however, if preventive measures are not undertaken, usage of chest tubes should be avoided in patients with coagulopathy [15].

Besides PPS, retained blood syndrome (RBS) is another postoperative complication [16]. The prevalence of RBS is a common complication reported after cardiac surgery and is related to clogging as well as high morbidity and mortality rates in acute condition [17]. The postoperative bleeding in thoracic regions is also associated with mediastinal decompression and in some cases pulmonary re-expansion immediately after surgery. The prevalent strategy to overcome this issue is the use of chest-based drainage tubes [16,18]. The inserted tubes assist in draining blood to prevent accumulation around the heart and other peripheral thoracic organs. The reliability of the tubes for drainage is subject to potential occlusion by thrombi, which reduce their efficacy. Medical practitioners specializing in cardiothoracic surgery have noted that an occluded chest tube is inevitable and efforts are on the way to develop a system with relatively lesser occlusions [6]. There is a reported 35% possibility of thrombus formation within the tube, leading to the need for regular evaluations to increase drainage efficacy [16,18].

Although there is overlap between the clinical concepts relevant PPS and RBS the two complications linked with cardiac surgery, research has added knowledge on these topics through cross-sectional investigations and meta-analyses thus providing precise definitions and descriptions [18]. The PPS has been restricted to cases with nonspecific signs of pleural inflammation and, to some extent, pericardial syndromes. Therefore, the diagnosis of PPS is dependent on the presence of both pleural and pericardial inflammation. However, critical assessment of patients diagnosed with PPS reveals that the primary cause of this postoperative complication is retained blood, which could result in inflammatory signs diagnosed as PPS. The results of different analysis associate retained blood with interventions, such as reopening of the surgical incisions and washing the inflammatory surfaces and spaces, chest tube insertion, or percutaneous-based and pleural-based drainages [18]. Nevertheless, current data reveal that retained blood occurs in 13.8 to 22.7% of cases, with a similar rate of occlusion of 36% when a chest tube is used. The number of studies are very few and as such need for more evidence-based assessment is critical [16,18].

Objectives and Justification of the Study

The number of studies focusing on the etiological factors and pathological parameters associated with both the post-operative complications the PPS and RBS are limited [16,18]. As such the reliability of the ongoing empirical interventions for the drainage of blood within the thorax is unclear [17]. However, risk factors associated with postoperative bleeding indicate higher complications, which could lead to death in some cases. Therefore, the need for comparative assessment of the published literature and more evidence-based analysis of

patient outcome is a fundamental focus of pericardiotomy evaluations. Moreover, the overlap that exists between PPS and RBS indicates a knowledge gap that needs to be investigated, in terms of medical definitions and diagnostic clinical guidelines [18]. Since the first diagnosis of PPS, there has been an exponential increase in the level of awareness and practitioner-based knowledge regarding postsurgical complications and retained blood. However, more research needed in terms of improving patient outcome and efficiency of the chest tube as a drain approach in order to reduce clogging [7,19,20].

Based on the current information, this study takes into consideration assessing the levels of the effectiveness of the chest tube technique as a treatment of PPS and retained blood complications. In this analysis, we reviewed the current publications for extracting an overview of both these conditions. The empirical decision making is necessary since it provides the literature regarding the topic of the study and helps the clinical community. This study also sought to highlight the rate of RBS occurrence to evaluate how the nature of the condition defines the intervention applied. Moreover, the paper is tailored to determine the correlation between the use of chest tubes in treating RBS. The following is an overview of the key and secondary objectives that guided this meta-analysis:

1. To provide an overview of PPS and retained blood complications
2. To review the literature regarding thoracic surgery, PPS, RBS, and their main complications
3. To compare cross-sectional studies evaluating the use of chest tubes as interventions to determine patient outcomes and efficiency in post-cardiac-surgery bleeding
4. To provide recommendations for consideration regarding the use of chest tubes as a treatment method for PPS and RBS.

Materials and Methods

Literature Review

As noted earlier, RBS and PPS are postoperative complications associated with the timing of treatment and the clinical approach. Based on the two criteria of assessment, three forms of RBS including acute, sub-acute and chronic have been described [18]. Previous clinical studies have examined different population samples to determine risk factors, indications, treatment, recurrent rates for each type of RBS. Mainly the clinical approach for treatment is based on the nature and volume of bleeding as well as the time of response and occurrence of clogging [17]. The rate of RBS diagnosis varies from one publication to another; however, the approach to treatment has shown a significant level of correlation and reliability between publications. The following is an overview of the prevalence of RBS from the perspective of different scholarly assessments.

Cases regarded as acute RBS involve critical clinical conditions require immediate removal of the retained blood within a period of less than 48 hours. The accumulation of blood is mainly within the pericardium or the pleural spaces. The greatest concern in such cases is the monitoring and clearance of the retained blood or any thrombosis through repeat surgery. The reported average percentage of RBS cases requiring re-intervention within a period of less than 48 hours after surgery is 3 - 6% [21]. In most cases, acute RBS is associated with the reopening of the thoracic region, washing of the retained blood, and removal of thrombi. A well-known complication of this condition is the occurrence of large mediastinal thrombus burden [22]; however, through careful monitoring of the patient and timely drainage and washing of the involved spaces, the clinical outcome are significantly improved. Moreover, studies suggest that the use of chest tubes during reoperation can be an adjunctive treatment approach to reduce thrombosis [18].

On the other hand, sub-acute RBS represents postoperative cases occurring weeks to months after surgery requiring invasive interventions to remove the accumulating blood within the pericardial and pleural spaces associated with effusions. Treatment approaches include pericardiocentesis, thoracentesis, new chest tube, or pericardial window after the initial surgery [23,24]. The origin of the effusions is the lack of proper evacuation of blood around the lungs or heart. Although the accumulation of the non-evacuated blood could take place hours after the operation, symptoms develop after a period of a few days [25]. It is worth pointing out that approximately 60% of cardiac surgery patients are at risk of sub-acute RBS. Interventions for sub-acute RBS are successful; however, cases of reoccurrence represent about 2% of postoperative drainage interventions. Review of the existing literature indicates that the over 10% of cardiac surgery patients will continue to have effusions occupying over 25% of the hemithorax. Such cases will require chest tube drainage if they

are diagnosed after one month. Moreover, it is clear that since the effusion most commonly occurs on the left, pericardial and mediastinal drainage can be carried out depending on the patient condition [25].

The chronic RBS is a situation where the patient exhibits both bleedings as well as thrombosis that leads to inflammation, effusions, and pleural and pericardial fibrosis. The condition needs more clinical attention than other types of RBS due to coagulation within the pleural and pericardial spaces, leading to fibrosis [26]. Several clinical studies have attempted to explain the origin of the fibrosis in the presence of bleeding and inflammation. It is evident that the occurrence of adhesions emanates from the coagulated blood, which leads to the formation of a fibrin neomatrix [18,26]. Prominent complications associated with chronic RBS include dysfunctional respiratory and cardiac function due to extensive fibrosis. Although additional investigations are required to determine the correlation between fibrosis and retained blood within the pleural and pericardial space, it is clear that patients diagnosed with chronic RBS have a higher risk of developing fibrosis [27]. Furthermore, retained blood is also associated with other conditions, such as postoperative atrial fibrillation or a wound infection after surgery. These areas still require more evidence-based assessments to ascertain the reliability of current data [18].

Methodology

The study was based on a meta-analysis approach with a focus on cross-sectional studies. Cross-sectional studies are preferred for finding an answer for questions that involve usage of a particular intervention. Furthermore, the data is collected at a single point in time [28]. The first part of the meta-analysis was a systematic review of the key concepts that formed the baseline for the assessment of PPS and RBS. Therefore, a search was conducted in the main medical databases, including PubMed, that provides free access to the MEDLINE and the National Library of Medicine database including citations and abstract of studies in the field of medical, nursing, dental, veterinary, health care, and preclinical sciences journal articles [29]. Data is shown in Table 1. These searches further extended to the PubMed Central (PMC) that is a free digital repository of publicly accessible full-text articles in the above-described fields. The search criteria involved the selection of scientific studies that best described the use of chest tubes as an intervention for retained blood drainage and related cases of clogging. Therefore, the combination of three primary search phrases was used, including "post-pericardiotomy syndrome," "retained blood syndrome," and "chest tube postoperative intervention" as shown in Table 1. The cross-sectional studies that included a comparative assessment of patients with RBS that were subjected to chest tube drainage were included as the core research papers for this meta-analysis. The remaining search results evaluated for appropriateness. Such inclusion and exclusion criteria were necessary based on the designated objectives of the study.

Search Criteria	PMC	MedGen	NLM Catalogue	PubMed
Search Key Words	Post-pericardiotomy Syndrome, Retained Blood Syndrome, Chest Tube Postoperative Intervention	Post-pericardiotomy Syndrome, Retained Blood Syndrome, Chest Tube Postoperative Intervention	Post-pericardiotomy Syndrome, Retained Blood Syndrome, Chest Tube Postoperative Intervention	Post-pericardiotomy Syndrome, Retained Blood Syndrome, Chest Tube Postoperative Intervention
All Search Results of the Related Studies	12	11	7	13
Relevant to this Research	7	3	2	8
Relevant for Meta-Analysis Comparison	2	0	0	2

Table 1: *Summary of Database Search Results.*

Study	Year of Study	Sample Size	Number of RBS Cases	Relative Percentage
Vivacqua., *et al*. [21]	2011	18,891	566	3.0
Price., *et al*. [36]	2004	2297	148	6.4
Pompilio., *et al*. [37]	2011	5818	117	2.0
Ashikhmina., *et al*. [38]	2010	21,416	260	1.2
Lancey., *et al*. [39]	2001	202	12	9.4
Payne., *et al*. [40]	2002	345	41	11.9

Table 2: *Review of Retained Blood Syndrome Prevalence Rates.*

RBS: Retained Blood Syndrome

Results and Discussion

Based on extensive analyses and evaluations we found that the first critical review that was carried out involved a cross-sectional study conducted by Palatianos, Thurer, and Kaiser in 1985 [30]. This study examined patients who underwent pericardial operation over a period of ten years. The study included 71 participants between the age of 9 months and 75 years. The patients had various diagnoses; 53 of the reviewed individuals had pericardial effusion while 14 were operated on for pericardial constriction. Out of the 67 cases associated with postoperative complications like clogging, 21 underwent tube drainage. On the other hand, 10 patients underwent limited pericardiectomy, and the remaining were treated with extensive pericardiectomy [30]. Furthermore, the indications included a 3 out of 21 subxiphoid 30-day mortality rate and an after-tube drainage recurrent rate of complication was 2 out of 21 patients.

In 2015, Sirch., *et al*. [16] carried out another cross-sectional study that examined the effectiveness of chest tube drainage in cases of PPS and RBS. The objective of the study was to implement and assess the outcome of the Active Chest Tube Clearance (ATC) technique, a precautionary approach based on the clearance of thrombi within the tubes during the first 24 hours after surgery. The study included 1849 patients involving two-phase analysis, where the first stage involved an in-service education followed by universal implementation. Furthermore, among the 1849 surgical cases, 256 patients underwent RBS interventions, representing 19% of the total population. The 256 patients were subjected to ATC, and the rate of RBS cases reduced to 11.3%, representing a 43% reduction. The same results found in terms of the incidence of postoperative atrial fibrillation, which reduced from 30% to 20% when ATC was implemented [16].

On the other hand, Karimov and colleagues in 2013 examined the incidence of chest tube clogging occurring after cardiac surgery [31]. This research was a single-center, observational assessment that included 150 patients. At the end of the study, the researchers only collected complete data for 100 patients. Patients, who had undergone pulmonary bypass cardiac surgery beginning in October 2011, were examined. Chest tubes as an intervention for RBS physically observed at intervals of 2 - 4 hours and 6 - 8 hours after surgery. The objective of the continuous assessment of the tubes before and after removal was to ascertain the need for clearance or determine the existence of any form of obstruction. The outcome by inserting 234 tubes in 100 patients were examined, including 158 pericardial and 7 pleural tubes. The observed rate of clogging was 36%. This study concluded that clogging occurs at any time after surgery and that the use of chest tubes subject to clearance can enhance patient outcome and effectiveness of drainage for RBS [31].

In 2015, another cross-sectional study focusing on the impact of retained blood after cardiac surgery. The study has an inbuilt bias as cases requiring postoperative intervention to mitigate the outcomes of surgical complications [32] examined and treated between 2006 and 2013; overall, 6909 patients were assessed. A comprehensive case analysis included the assessment of cases that required subsequent intervention and blood drainage. Data revealed that out of the 6909 cardiac surgery patients, 1316 developed retained blood complications, representing a 19% incidence rate. The rate of retained blood after chest tube clogging was more common for cases involving coronary artery bypass grafting and valve surgery, at a rate of 28%, while the rate after elective surgery was 22% [32]. However, hemodynamic instability, as well as chest tube effectiveness, was higher if used within the 24-hour period. Therefore, the study concluded

that retained blood complications requiring re-intervention are common scenarios, calling for more analysis to increase the validity of the findings in this area. Table 3 represents the comparative assessment of the four cross-sectional studies.

Assessment Factor	Paltianos, Thurer, and Kaiser (1985)	Sirch., *et al.* (2015)	Karimov., *et al.* (2013)	Balzer., *et al.* (2015)
Number of patients who underwent surgery	71	1849	150	6909
Number of patient with RBS/PPS	56	256	100	1316
Percentage Rate of RBS/PPS	78.87	19	66.6	19
Number of patients who underwent chest tube intervention	21	256	100	i. Coronary artery bypass grafting and valve surgery at a rate of 28% Elective case rate of 22%
Contraindications	3 out of 21 for 30-day rate of mortality	The incidence of postoperative atrial fibrillation reduced from 30% to 20% when ATC was implemented	36% clogging rate for the 158 pericardial and 7 pleural chest tubes assessed	Chest tube effectiveness was noted to be higher within the 24-hour period
Cases that involved chest tube re-intervention	Not included	30	Not included	Not included

Table 3: *Comparative Assessment of the Cross-Sectional Studies.*

RBS: Retained Blood Syndrome; PPS: Post-pericardiotomy Syndrome

Discussion and Proposed Guidelines

Almost every patient undergoing heart surgery faces bleeding issue [33]. These post-operatives bleeding needs proper management for better health outcome. Otherwise, patients usually face conditions like RBS and PPS. Clinical intervention includes the drainage of the accumulating blood around the heart and lungs in the intensive care unit during the recovery period [34]. Under certain circumstances, the ineffective evacuation of removing blood lead to certain complications [35]. The use of chest tubes is considered an alternative treatment for sub-acute and chronic RBS [18]. On the other hand, the reviewed studies have linked this approach to re-intervention where repeated bleeding, clogging, and inflammation occurs. Such cases have prompted researchers to evaluate treatment patterns to determine the effectiveness of tube intervention for RBS diagnosis and blood drainage [34]. Based on this meta-analysis, it is clear that bleeding after the operation is associated with poor outcomes, with extreme cases leading to death if immediate measures are not taken. Therefore, the need for more careful consideration calls for an alternative approach to minimize associated risks [16].

One of the key factors signifying the need for urgent intervention in the case of bleeding after cardiac surgery is the volumetric restrictions of the mediastinal, pleural, and pericardial spaces. The limited size calls for immediate evaluation of any form of blood accumulation. The use of drainage tubes allows the opportunity to externalize the bleeding so that other types of unrecognized blood within the internal

spaces can be addressed [16]. Review of the literature indicates that tubes draining the lung and heart regions linked to suction canisters to allow drainage of the accumulated blood. Failure to carry out such corrective measures in a timely manner leads to the compression of the pericardium and the lungs, which may lead to cardiac and respiratory complications. On the other hand, cases of re-accumulation are inevitable, and in the event of an inflammatory reaction to thrombosis, the chances of repeat exudative effusions are very high [18]. Such instances have been associated with delayed recovery and readmission of patients, which affects the quality of outcomes related to chest tube intervention. All these observations suggest, there is a need to redefine the care process for cardiac surgery patients.

Moreover, the results of this analysis indicated that achieving safe and efficient drainage of accumulated blood within the pleural and pericardial spaces after cardiac surgery requires a comprehensive approach to care delivery. A team approach is essential when dealing with postoperative blood drainage. Chest tube insertion after the operation be performed by highly skilled medical professionals, and tubes should be monitored and managed to ensure that there is no clogging or formation of thrombi. The nurses need to be supervised by designated critical care providers to aid in locating possible internal bleeding not linked with the chest tubes. Prompt reaction to any form of clogging or chest tube obstruction is required whenever any indication suggests such possibilities. It is worth pointing out is that clogging is not easily noted during the intensive care unit treatment period since it is invisible and only manifest as physiological changes after a period of time. However, through a conventional care approach, the risk factors associated with inflammation and re-accumulation may be potentially reduced. Sirch., *et al*. showed that the implementation of ATC reduced the incidence of postoperative atrial fibrillation from 30% to 20% [18].

Furthermore, during our review of the literature, it was clear that studies on the topic of PPS and RBS are limited. If fact, studies pointed out the lack of unifying clinical guidelines with a high degree of validity and reliability [18]. Therefore, the need for more assessment in order to improve the effectiveness of chest tubes for postoperative blood drainage as well as methods of improving patient outcome is clearly required, as seen in this meta-analysis. Nevertheless, the unpredictable nature of RBS is another challenge that prevents efficient drainage and reduced chances of recurrence. Therefore, practitioners should consider high-quality care for all categories of patients, in particular with the use of chest tubes [16]. Implementation of ATC and efficient washing and clearing of blood after postoperative drainage will assist in improving early detection of repetitive bleeding. On the other hand, the occurrence of incomplete evacuation needs to be reduced through strict adherence to intensive care unit protocols relating to quality improvement initiatives [32].

Limitations of the Study

Although our evaluations are quite preliminary in nature, however, the findings are quite intriguing as far as complications associated with cardiac surgery are concerned and utilization of chest tube in the drainage of fluid and unnecessary air pressure. In describing limitations relevant to this study, the availability of limited conclusive data defining RBS and PPS besides the role of a chest tube in alleviating or exacerbating the complications. This study is an important meta-analysis, utilizing data from previous publications. These articles were obtained from the medical research databases; therefore, the outcome is subject to the search criteria and the inclusion and exclusion strategies used. There is a real possibility that certain studies having good relevance to the topic might be omitted due to our pre-defined inclusion and exclusion strategy. However, this paper is based on four cross-sectional studies, which limits the level of validity and reliability of the comparative assessment carried out in the article. Nevertheless, the topic of this research has not been studied extensively, which led to limited publication results from the databases used in this study.

Conclusion

Based on the evaluation of existing literature, we conclude that PPS is a complication that was first noted among patients who exhibited fever and pleuritic pain after mitral valve surgery. However, continuous assessment and research have shown that RBS also another postoperative complication having certain pathologies resembling with PPS that should be evaluated through future research. Studies have indicated different results associated with various interventions for RBS, such as the use of chest tubes. The treatment approach has also been noted to influence patient outcomes. For example, the incidence of postoperative atrial fibrillation reduced from 30% to 20%

when ATC was implemented. On the other hand, the use of chest tubes revealed different complications and recurrence of bleeding, where coronary artery bypass grafting and valve surgery showed a rate of 28%, and elective cases showed a rate of 22%. Nevertheless, the challenges associated with chest tubes partly emanate from the lack of unifying clinical guidelines with a high degree of validity and reliability. Moreover, limited data on methods to improve the efficacy of chest tubes for postoperative blood drainage and the inability to predict the nature of RBS contribute to the difficulty in managing this condition. The prevailing notion that that PPS is mediated through autoimmune disorder has been refined through new findings and suggested retained blood in RBS is the primary route cause of ensuing PPS.

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