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CT-Guided Drainage of Pericardial Effusion after Open Cardiac Surgery

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Abstract
Purpose This study was designed to evaluate the safety and efficacy of CT-guided drainage of the pericardial effusion in patients after cardiac surgery.
Materials and Methods The study included 128 consecutive patients (82 males, 46 females; mean age 66.6 years, SD: 4.2) complicated by pericardial effusion or hemopericardium after cardiac surgeries between June 2008 and June 2016. The medical indication for therapeutic pericardiocentesis in all patients was hemodynamic instability caused by pericardial effusion. The treatment criteria for intervention were evidence of pericardial tamponade with ejection fraction (EF) <50%. The preintervention ejection fraction was determined echocardiographically with value between 30 and 40%. Exclusion criteria for drainage were hemodynamically unstable patients or impaired coagulation profile (INR <1.8 or platelet count <75,000). Drains (8F–10F) were applied using Seldinger's technique under CT guidance.
Results Pericardiocentesis and placement of a percutaneous pericardial drain was technically successful in all patients. The mean volume of evacuated pericardial effusion was 260 ml (range 80–900 ml; standard deviation [SD]: ±70). Directly after pericardiocentesis, there was a significant improvement of the ejection fraction to 40–55% (mean: 45%; SD: ±5; $p < 0.05$). The mean percentage increase of the EF following pericardial effusion drainage was 10%. The drainage was applied anteriorly (preventricular) in 39 of 128 (30.5%), retroventricularly in 33 of 128 (25.8%), and infracardiac in 56 of 128 (43.8%). Recurrence rate of pericardial effusion after removal of drains was 4.7% (67/128). Complete drainage was achieved in retroventricular and infracardiac positioning of the catheter ($p < 0.05$) in comparison to the preventricular position of the catheter. Recorded complications included minimal asymptomatic pneumothorax and pneumomediastinum 2.3% (3/128) and sinus tachycardia 3.9% (5/128).
Conclusion CT-guided drainage of postoperative pericardial effusion is a minimally invasive technique for the release of the tamponade effect of the effusion and improvement of cardiac output.

Keywords CT-guided · Drainage · Pericardial effusion · Cardiac surgery

Introduction

Pericardial effusion is reported in the literature as one of the most frequent complications after open cardiac surgeries. The reported incidence of this complication varies in the literature between 1.5% and 61% [1, 2]. Echocardiography is the initial imaging modality of choice to evaluate the presence of pericardial effusion as well as to assess its hemodynamic relevance [3]. However, computed tomography (CT) and magnetic resonance imaging (MRI) provide an accurate assessment of pericardial effusion, especially when the findings are not conclusive by the echocardiography. Both CT and MR imaging modalities

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have wider field of view and would define the distribution of pericardial effusion. In addition, CT and MRI may provide valuable information about the loculated and septated effusions, type of effusion and/or associated pericardial thickening [4]. Measurement of CT attenuation may provide the initial characterization of the effusion. A fluid collection with attenuation close to that of water is likely to be a simple serous effusion. Pericardial effusion with CT-attenuation values higher than water would suggest either hemopericardium or purulent exudate. On the other hand, cases of chylopericardium are more possible when pericardial effusion has a low CT- attenuation due to high lipid content [5]. CT allows the accurate guidance for pericardiocentesis in different approaches preventricular, retroventricular, and infracardiac with high safety. Moreover, the CT guidance allows adequate planning to avoid injury of the internal mammary arteries or intercostal vessels or traversing the pleural recesses. The pumping function of the heart is affected adversely by the amount of pericardial effusion. The compromising (tamponading) threshold value of pericardial effusion on cardiac output varies from 100 to 200 ml (in rapidly accumulating effusion) to 2000 ml (in slowly developing pericardial effusions) [6]. The surgical management of hemodynamically significant pericardial effusion includes pericardiostomy or window operation [1]. Pericardiocentesis is a procedure where fluid is aspirated from the pericardial space by percutaneous route. In patients with cardiac tamponade, this procedure would be considered as life-saving [7].

The purpose of the current study was to evaluate retrospectively the safety and efficacy of CT-guided drainage of hemopericardium and pericardial effusion in patients post cardiac surgeries and correlation of the clinical outcome with echocardiography (Fig. 1).

Materials and Methods

Patients

A total 128 consecutive patients with symptomatic pericardial effusion post cardiac surgery were included (82 males, 46 females; mean age 66.6 years, SD: 4.2), between June 2008 and June 2016. Cardiac operations were: valve replacement in 51 patients, coronary artery bypass in 19 patients, and aortic replacement due to aortic aneurysm in 22 patients and post Stanford Type 1 aortic dissection in 36 patients. The medical indication for therapeutic pericardiocentesis in all patients was hemodynamic instability caused by pericardial effusion, with compromise of the cardiac output consisting with pericardial tamponade. Medical records were reviewed to determine the clinical criteria, echocardiographic features, pericardiocentesis details, effusion characterization, and outcomes, including success and complications. The institutional review board approved the current study. Due to the retrospective nature of the study, the patient consent was waived by the institutional review board.

Preprocedure Assessment

Echocardiography was done using ACUSON X300 Ultrasound System (Siemens, Erlangen) prior to all pericardiocentesis procedures. The considered parameters to assess the pericardial effusion effect on the hemodynamic stability were cardiac compression or collapse, the size of the inferior vena cava, lack of inspiratory collapse, and inspiratory variation of Doppler mitral and tricuspid inflow velocities. The indication criteria for intervention were evidence pericardial effusion with an echo-free space of $\geq$1 cm at its greatest width associated with ejection fraction (EF) <50%. The preintervention ejection fraction was determined echocardiographically with value between 30 and 40%. Exclusion criteria for drainage were hemodynamically unstable patients or impaired coagulation profile (INR <1.8 or platelet count <75,000).

CT-Guided Pericardiocentesis

All pericardial drainages were performed by five interventional-radiologists with experiences between 8 and 20 years in thoracic interventions. The coagulation profile was controlled prior to intervention for each patient. Fresh-frozen plasma or transfusion of platelet concentrates were used to correct unsatisfactory bleeding profile (INR <1.8 or platelet count <75,000).

A spiral chest CT scan was performed by using a multislice CT scanner (Somatom Plus 4; Siemens Healthcare, Erlangen, Germany) followed by multiplanar reconstruction. CT examinations were performed with a tube-voltage of 120 kV, tube-current of 120 mAs, and a collimation of 2.5 mm. For all procedures, an initial puncture was performed using a 17.5-gauge puncture needle with lengths between 10 and 15 cm. The drains used ranged between 8- and 10-French (Somatex Medical Technologies GmbH, Berlin, Germany).Planning of the puncture route was performed using the initial planning CT examination, avoiding injury of the internal mammary arteries, intercostal vessels, and coronary vessels, or traversing the pleural recesses. This is followed by surface marking of the point of puncture on the skin. The pericardiocentesis was performed under aseptic conditions using local anesthetics (Scandicain 1%). The careful insertion of the coaxial needle into the pericardial effusion was monitored to verify adequately the needle's position (Fig. 2).

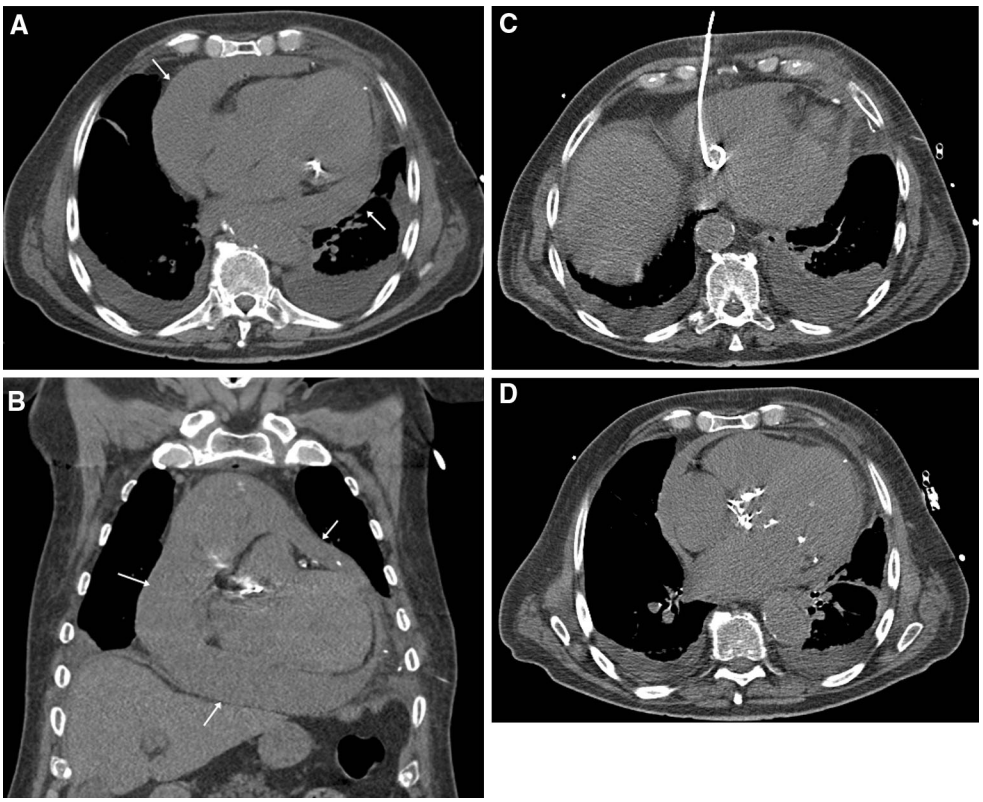

Fig. 1 Serial CT images in mediastinal window of a 65-year-old male patient post aortic and mitral valve replacement with limited cardiac output. CT scan was performed on the fifth postoperative day. Axial CT image (**A**) and coronal CT image (**B**) show circumferential pericardial effusion with maximal axial diameter 3.5 cm (*white arrows*). The CT images also show bilateral pleural effusion. The tamponading effect is predominantly on the right and left atria. **C** CT-guided pericardiocentesis from anterior aspect parasternal with infracardial application of 8F-drain in coaxial technique. **D** Adequate evacuation of 800-ml bloody effusion

Upon entry of the puncture-needle through the pericardium into the pericardial sac, the core of the puncture needle was removed leaving the needle sheath in place. The endoluminal position of the coaxial position also was confirmed by fluid withdrawal. Microbiological and cytological analyses were performed on samples collected from the effusion. A guidewire was then inserted through the needle sheath in Seldinger's technique. Dilatation of the tract was determined by the gauge of the required drain. The pigtail drainage catheter was inserted over the guidewire and then manually drained the effusion and followed by single CT images to ensure complete evacuation of the pericardial fluid. Fixation of the drain to the skin was then performed. Technical success was defined as the application of the draining catheter inside the pericardial cavity and evacuation of the pericardial fluid. Clinical success of the technique was defined as the evacuation of the pericardial effusion and alleviation of the cardiac tamponade with improve the cardiac output. The approach for pericardial drainage was classified according to the position of the draining catheter into preventricular, retroventricular, and infracardiac approach, based on CT imaging. Vital signs were monitored (including blood pressure, heart rate, and blood oxygen saturation).

The pericardial draining catheter was maintained in place until the pericardial effusion was completely evacuated. Complete evacuation was achieved when the drained volume over 24 h was less than 30 ml and the residual fluid within the pericardial sac noncircumferential and with a diameter <2 mm on echocardiogram.

CT morphologically the pericardial effusion was classified into free circumferential effusion and capsulated pericardial effusion. In the former, the effusion was diffusely accumulated inside the pericardial sac around the cardiac margin. While the in the later form, the pericardial effusion was localized.

Statistical Analyses

Bias- for Windows was used for statistical analysis. The mean and standard deviation were calculated. Percentages or absolute numbers were used to present categorical data. The level of statistical significance (p) was set in the current study at 0.05. The independent sample T test was used to compare the baseline results. Analysis of the nonparametric values was performed using the Wilcoxon rank test.

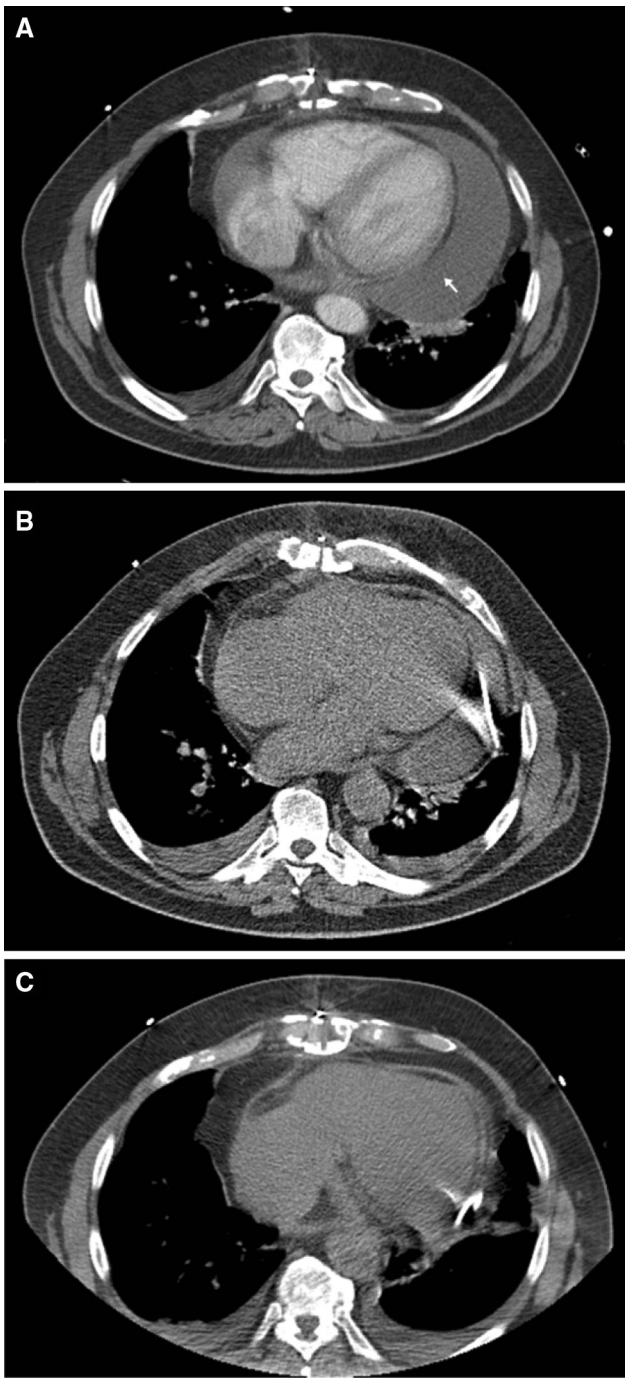

Fig. 2 Serial CT images in mediastinal window of a 71-year-old male patient post reconstruction of the ascending aorta and aortic arch due to Stanford Type 1 dissection, complicated by hemopericardium. **A** Axial CT Image showing posterior and left lateral pericardial effusion axial diameter 2.5 cm (*white arrow*). **B** CT image showing the application of the 8F-pericardial drain in a retroventricular position from a left parasternal access. **C** CT image after evacuation 450-ml bloody effusion. The heart chambers are expanded after releasing the tamponading effect of the hemopericardium

Further evaluation and analysis of significant variables was performed using the Multivariance Cox-Regression test.

Results

Pericardiocenteses and application of pericardial drain was technically successful in all patients. The mean volume of evacuated pericardial effusion was (range 80–900 ml, mean: 260 ml, SD: ± 70). The effusion in most of the cases was dark bloody serosanguinous (Table 1).

Free circumferential effusion was reported in 71.9% of the cases (92/128). In the rest of the cases (28.1%), the pericardial effusion was capsulated.

The preinterventional ejection fraction was determined echocardiographically with value between 30-40% (mean: 35%, SD: ± 2). Directly after pericardiocentesis, there was a significant improvement of the ejection fraction to 40-55% (mean: 45%, SD: ± 5; $p < 0.05$). The mean percentage increase of the EF following pericardial effusion drainage was 10%.

According to the approach of collections, the drains were applied anteriorly (preventricular) in 39 of 128 (30.5%), retroventricularly in 33 (25.8%), and infracardiac in 56 (43.8%). Recurrence rate of pericardial effusion post removal of drain was 4.7% (6/128).

Complete drainage was achieved in retroventricular and infracardiac positioning of the catheter ($p < 0.05$) in comparison to the preventricular position of the catheter. The mean dwell time of the drains was 36 h (24–72 h) of the drains. Recorded complications included: asymptomatic, minimal, self-limiting pneumothorax and pneumomediastinum 2.3% (3/128); sinus tachycardia 3.9% (5/128); blockage of the drain and failed evacuation with surgical interference in (1.6%) 2/128 due to coagulation of the hemopericardium.

Discussion

The most frequent etiology of pericardial effusion nowadays is postoperative. This is due to the increase in number of surgical procedures performed for cardiovascular disorders [6]. The decision for pericardiocentesis should be taken based on the clinical status of the patient [7–10]. Ideally, the pericardial drainage should fulfil several criteria: easily performed with low level of morbidity and mortality; drain should achieve full drainage of the effusion; and sample attained from the effusion for possible cytological or microbiological analysis.

Table 1 Summary of the population and the results of the study

Number of patients	128
Age	66.5 years (range 54–74, SD: 5.5)
Gender: male: female	82:46
Mean days postoperative	5 days (1–18 days, SD: 2.5)
Pre-interventional ejection fraction	30–40%
Post-interventional ejection fraction	40–55%
Mean percentage of increase of EF post pericardial drainage	10%
CT morphology of the pericardial effusion	
Capsulated	36/128 (28.1%)
Circumferential	92/128 (71.9%)
Volume of pericardial effusion	80–900 ml, mean: 260 ml SD: ± 70
Color of effusion	
Bloody	83/128 (64.8%)
Serosanguinous	39/128 (30.5%)
Serous	6/128 (4.7%)
Position of drainage	
Preventricular	39/128 (30.5%)
Retroventricular	33/128 (25.8%)
Infracardiac	56 (43.8%)

Success of the drainage can be predicted based on the effusion density as measured on CT examination. High density of the effusion is most likely to represent blood clot, which is highly resistant for drainage. This requires in most of the cases surgical/thoracoscopic interference to relieve the cardiac tamponade [5].

In the current study, the pericardiocenteses and application of pericardial drain was technically successful in all patients. Significant increase of the ejection fraction was achieved after alleviation of the tamponading effect of the pericardial effusion. Complete drainage was achieved in retroventricular and infracardiac positioning of the catheter in comparison to the preventricular position of the catheter. This could be related to the accumulation of the fluid in the dependent parts (retro and infracardiac) by the effect of gravity in recumbent patients, with subsequent improved drainage of the pericardial fluid by positioning the draining catheters in these dependent locations.

Pilot studies published in the early 1980s showed echo-guided pericardial drainage to be a safe and effective procedure [6, 7]. Compared with blind pericardial drainage, image-guided pericardial drainage showed a markedly lower rate of complications (4.7% vs. 20%). Blind drainage of pericardial effusion was accompanied with a relatively high mortality rate (6%). The CT guidance provides proper planning and optimal guidance for drainage placement for and allows early detection of associated complications. The incidence of minor complications was 2.3% in our patient group, which required conservative treatment. In the literature, the most reported complications were pneumothoraces [7–10]. The usage of pericardial decompression presented an attractive alternative in the past due to reduced recurrence rates associated with this method.

Pericardial fenestration under thoracoscopy represents an alternative option for pericardial drainage. Another alternative is the balloon pericardiostomy, in which the small tear is performed in the pericardium and then dilated with a balloon to drain the fluid into the thoracic cavity directly or the fluid is drained externally using a catheter. To assist adherence of the layers of the pericardium, it is recommended to perform drainage of the effusion completely as previously defined. This also will help to prevent further fluid accumulation. In case of failed pericardiocentesis or if it is not applicable, it is possible to perform windowing of the pericardium either surgically or using thoracospcopy. The current study had limitations being retrospective, single-center case series review.

In conclusion, postoperative pericardial effusions could be safely and effectively relieved by CT-guided pericardiocenteses. CT-guided drainage of postoperative pericardial effusion is a minimally invasive technique for the release of the tamponade effect of the effusion and improvement of cardiac output.

Compliance with Ethical Standards

Conflict of interest The authors state the fact that this article is not under consideration for publication elsewhere or any part of it has been sent elsewhere, and there is no conflict of interest. The

Publication is approved by all authors. There are no conflicts of interest. We also agree the regulations of copyright of the publisher.

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