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Comparative Perioperative Outcomes Among Pericardioperitoneal, Pleuropericardial and Regular Pericardial Window Procedures: A Retrospective Cohort Study

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ABSTRACT

Background

Pericardial window procedures are commonly performed for the management of recurrent or symptomatic pericardial effusion. Multiple surgical approaches are currently utilized, including pericardioperitoneal window (PPW), pleuropericardial window (PLW), and regular subxiphoid pericardial window procedures. However, comparative data evaluating perioperative outcomes among these techniques remain limited. This study aimed to compare perioperative outcomes and postoperative complications across the three surgical approaches.

Methods

A retrospective exploratory cohort study was conducted in Jordan University Hospital and King Abdullah University Hospital, including patients who underwent surgical pericardial window creation. Patients were divided into three groups: PPW, PLW, and regular pericardial window. Baseline characteristics, perioperative variables, postoperative complications, and length-of-stay outcomes were analyzed descriptively and comparatively. Continuous variables were reported as median [IQR], and categorical variables as n/N (%). Fisher's exact and Wilcoxon rank-sum tests were used where appropriate. Effect estimates were reported with 95% confidence intervals.

Results

The study cohort included 28 patients, of whom 5 underwent PPW, 7 underwent PLW, and 16 underwent regular pericardial window procedures. Median age was 55 [38–65] years in the PPW group, 52 [29–55] years in the PLW group, and 52 [36.5–58] years in the regular pericardial window group. Early 30-day complications occurred in 3/5 (60.0%) PPW patients, 5/7 (71.4%) PLW patients, and 1/16 (6.2%) regular pericardial window patients. Acute complications occurred in 40.0%, 57.1%, and 12.5% of patients, respectively. PLW demonstrated numerically shorter hospital length of stay, shorter ICU stay, lower estimated blood loss, and shorter chest tube duration compared with PPW, while the regular pericardial window group demonstrated the lowest documented early complication rate. However, no continuous perioperative outcome demonstrated a statistically conclusive difference across groups. Long-term outcomes were limited by sparse follow-up documentation.

Conclusions

In this exploratory three-group retrospective cohort study, no definitive superiority of any individual surgical approach was established. The regular pericardial window group demonstrated the lowest documented early complication rate, whereas PLW showed numerically favorable perioperative recovery characteristics in several outcomes. Interpretation of these findings is limited by the retrospective design, small sample size, baseline imbalance between groups, and incomplete long-term follow-up. Larger prospective multicenter studies are needed to better define comparative safety, recurrence risk, and long-term effectiveness among different pericardial window techniques.

Keywords: Pericardial Effusion; Pericardial Window; Pericardioperitoneal Window; Pleuropericardial Window; Perioperative Outcomes; Postoperative Complications; Retrospective Cohort Study

INTRODUCTION

Pericardial effusion is a clinically significant condition characterized by the pathological accumulation of fluid within the pericardial cavity, which under physiological conditions contains approximately 10–50 mL of serous fluid facilitating cardiac motion [1]. The etiology of pericardial effusion is diverse, encompassing inflammatory and non-inflammatory causes such as malignancy, infection, autoimmune disorders, trauma, and post-cardiac surgical states. While many cases remain asymptomatic or are incidentally detected, progressive fluid accumulation can lead to cardiac tamponade, a life-threatening condition associated with hemodynamic compromise and high mortality if not promptly managed [1,2].

Management strategies for pericardial effusion depend on the underlying etiology, severity, and hemodynamic impact. Pericardiocentesis is widely considered the first-line intervention, particularly in emergent settings, due to its minimally invasive nature and high success rate. However, it is frequently associated with recurrence, especially in cases of malignant or chronic effusions, necessitating more definitive surgical approaches [1]. In this context, surgical creation of a pericardial window has emerged as a reliable method for continuous drainage and prevention of fluid reaccumulation, particularly in recurrent or loculated effusions where percutaneous techniques are insufficient [3].

Several surgical techniques have been developed for pericardial window creation, including pleuropericardial window (PLW), pericardioperitoneal window (PPW), and conventional or regular pericardial window procedures. The pleuropericardial window establishes communication between the pericardial and pleural cavities, facilitating effective drainage and demonstrating favorable perioperative outcomes in multiple settings. For example, & Özkan M reported a significant reduction in postoperative pericardial effusion following atrial septal defect closure when a pleuropericardial window was created [4]. Thoracoscopic PLW approaches have additionally been associated with low complication rates, shorter hospital stay, and low recurrence rates during follow-up [3].

The pericardioperitoneal window offers an alternative drainage route into the peritoneal cavity and may be particularly useful in refractory or recurrent effusions. Previous reports suggest that PPW can provide durable symptom relief and reduce the need for repeated interventions in selected patients with persistent effusions [5]. In parallel, conventional or regular pericardial window procedures remain widely used in routine clinical practice because of their technical familiarity, accessibility, and effectiveness in rapidly relieving tamponade physiology and symptomatic effusions [6]. Traditional subxiphoid approaches in particular have demonstrated durable drainage and acceptable recurrence rates across multiple etiologies [7].

In addition to therapeutic considerations, the technical complexity and relative rarity of specialized pericardial window procedures pose challenges in clinical practice. Limited exposure to PPW and PLW during surgical training may affect procedural familiarity and decision-making, further emphasizing the importance of comparative evidence and standardized surgical selection strategies [5].

Given the variability in patient presentation, underlying etiologies, and procedural approaches, there remains a critical need to better understand the comparative perioperative outcomes associated with different surgical drainage techniques. Although prior studies have evaluated individual surgical approaches, few investigations have directly compared multiple pericardial window strategies within a single institutional cohort. Furthermore, regional data from Middle Eastern populations remain scarce.

Therefore, this study aimed to perform a comprehensive retrospective analysis comparing perioperative outcomes among three surgical approaches for pericardial effusion drainage: pleuropericardial window, pericardioperitoneal window, and regular pericardial window procedures. By evaluating complications, perioperative recovery parameters, recurrence, and mortality, this study seeks to provide clinically relevant insights that may guide surgical decision-making and optimize patient outcomes.

METHODS

Study Design

This study is an exploratory retrospective cohort study comparing perioperative and postoperative outcomes among three surgical approaches for pericardial effusion drainage: pericardioperitoneal window, pleuropericardial window, and regular pericardial window. Because the study was retrospective and procedure allocation was not randomized, all comparisons were interpreted as observational and hypothesis-generating rather than causal.

Study Cohort

The analytical cohort included 28 patients who underwent surgical drainage of pericardial effusion in Jordan University Hospital and King Abdullah University Hospital. Patients were categorized according to procedure type into one of three groups: pericardioperitoneal window, pleuropericardial window, or regular pericardial window.

The final cohort included 5 patients in the pericardioperitoneal group, 7 patients in the pleuropericardial group, and 16 patients in the regular pericardial window group.

Exposure Definition

The exposure of interest was the procedure type. The three procedure groups were defined as: Pericardioperitoneal window, pleuropericardial window, and regular pericardial window. All analyses were performed using these three procedure groups. No multivariable adjustment was performed because of the small sample size and sparse event counts.

Outcome Definitions

The primary outcome was early postoperative complications occurring within 30 days after surgery.

Secondary binary outcomes included acute complications, transfusion, documented mortality, recurrence of pericardial effusion, reintervention, readmission, procedural success, respiratory complications, infection, suspected infection, and bleeding.

Continuous perioperative and postoperative outcomes included hospital length of stay, ICU length of stay, estimated blood loss, operative time, drain output during the first 24 hours, total drain output, and chest tube duration.

Follow-up duration was assessed as an outcome ascertainment variable rather than a treatment efficacy outcome because long-term follow-up documentation was limited.

Data Preparation and Quality Control

Data were extracted retrospectively from available clinical records and organized into a structured analysis dataset. Variables included demographic characteristics, comorbidities, indication for surgery, procedural details, postoperative outcomes, complications, length of stay, recurrence, reintervention, readmission, mortality, procedural success, and follow-up duration.

Data cleaning was performed before analysis. Numeric variables were standardized to clinically consistent units. Hospital and ICU length of stay were recorded in days, operative time in minutes, blood loss and drain output in milliliters, symptom-to-surgery duration in days, and follow-up duration in months. Binary variables were coded as 1 for event present and 0 for event absent.

Missing, unclear, or uncertain values were retained as missing and were not assumed to represent the absence of an event.

Quality-control checks included procedure group classification, duplicate patient identifiers, binary variable coding, numeric-unit consistency, implausible age or BMI values, hospital length of stay shorter than ICU length of stay, blood loss range issues, symptom-to-surgery range issues, follow-up range issues, and logical inconsistencies between procedural success, recurrence, reintervention, and mortality.

Final quality-control results are summarized in Supplementary Table 2.

Handling of Missing Data

Missing data were reported for each variable. No statistical imputation was performed because of the small sample size, retrospective design, and sparse event counts.

Analyses were performed using available cases for each outcome; therefore, denominators varied across outcomes. Outcomes with substantial missingness, extremely small evaluable denominators, or no valid comparison across groups were interpreted descriptively only.

Statistical Analysis

Continuous variables were summarized as median and interquartile range. Categorical and binary variables were summarized as counts and percentages.

For binary outcomes, overall comparisons across the three procedure groups were performed using Fisher's exact test when estimable. For continuous outcomes, Kruskal-Wallis tests were used for overall comparisons across groups when data were available.

Because of the small cohort size and sparse outcomes, p-values were interpreted cautiously. The analysis was considered exploratory and hypothesis-generating. No conclusion of superiority, equivalence, or non-inferiority was made.

Ethical Considerations

Ethical approval was obtained from Jordan University Hospital IRB, code: 10/2025-27514 and King Abdullah University Hospital, code:11/2025-187-7. Data were anonymized, and confidentiality was maintained; no incentives were provided. Artificial intelligence (Chatgpt4, DeepSeek) was used to proofread the manuscript part after fulfilling its writing just to correct methods of scientific writing, but original writing, analysis, and interpretation are human-led.

RESULTS

Study Cohort and Baseline Characteristics

The final cohort included 28 patients: 5 in the pericardioperitoneal window group, 7 in the pleuropericardial window group, and 16 in the regular pericardial window group.

Baseline characteristics are summarized in Table 1.

Variable	Overall	Pericardioperito n eal window	Pleuropericardia l window	Regular pericardial window	Missing, n	p-value
Age, years	52 [36.5, 58]	55 [38, 65]	52 [29, 55]	52 [36.5, 58]	0	0.868
BMI, kg/m²	29 [24.3, 31.2]	22.5 [19.76, 28.05]	30.15 [29, 41.5]	28.54 [24, 31]	8	0.166
Symptom-to-surgery time, days	14 [3, 45]	13 [3.34, 284.25]	14 [3, 180]	13.5 [2.25, 37.5]	5	0.814
Previous pericardiocentesi s, count	1 [0, 1]	1 [0, 1]	0 [0, 1]	1 [0, 1]	5	0.788
Female sex	17/28 (60.7%)	2/5 (40.0%)	5/7 (71.4%)	10/16 (62.5%)	0	0.664
Smoker	7/28 (25.0%)	2/5 (40.0%)	1/7 (14.3%)	4/16 (25.0%)	0	0.709
History of malignancy	9/28 (32.1%)	1/5 (20.0%)	2/7 (28.6%)	6/16 (37.5%)	0	0.867
Stage IV/metastatic disease	5/7 (71.4%)	0/1 (0.0%)	1/1 (100.0%)	4/5 (80.0%)	21	0.647
Hypertension	12/27 (44.4%)	2/5 (40.0%)	1/7 (14.3%)	9/15 (60.0%)	1	0.246
Diabetes mellitus	7/27 (25.9%)	2/5 (40.0%)	1/7 (14.3%)	4/15 (26.7%)	1	0.840
CKD/ESRD	3/27 (11.1%)	0/5 (0.0%)	0/7 (0.0%)	3/15 (20.0%)	1	0.651
COPD	1/27 (3.7%)	0/5 (0.0%)	0/7 (0.0%)	1/15 (6.7%)	1	1.000
IHD/CAD	1/27 (3.7%)	1/5 (20.0%)	0/7 (0.0%)	0/15 (0.0%)	1	0.386
Heart failure	1/27 (3.7%)	1/5 (20.0%)	0/7 (0.0%)	0/15 (0.0%)	1	0.386
Autoimmune disease	2/27 (7.4%)	0/5 (0.0%)	2/7 (28.6%)	0/15 (0.0%)	1	0.150
Indication:idiopathic	7/28 (25.0%)	2/5 (40.0%)	3/7 (42.9%)	2/16 (12.5%)	0	0.227
Indication:malignant	10/28 (35.7%)	0/5 (0.0%)	2/7 (28.6%)	8/16 (50.0%)	0	0.227
Indication:other/ unspecified	6/28 (21.4%)	2/5 (40.0%)	2/7 (28.6%)	2/16 (12.5%)	0	0.227
Indication:traumatic	3/28 (10.7%)	1/5 (20.0%)	0/7 (0.0%)	2/16 (12.5%)	0	0.227
Indication:uremic	2/28 (7.1%)	0/5 (0.0%)	0/7 (0.0%)	2/16 (12.5%)	0	0.227

Table 1: Baseline Characteristics by Procedure Group

Note: Values are presented as median [IQR] for continuous variables and n/N (%) for categorical variables. For categorical variables, denominators reflect the number of evaluable patients for that variable, with missing values reported separately. PPW = pericardioperitoneal window; PLW = pleuropericardial window; CKD/ESRD = chronic kidney disease/end-stage renal disease; COPD = chronic obstructive pulmonary disease; IHD/CAD = ischemic heart disease/ coronary artery disease. Stage IV/metastatic disease status had substantial missingness and should be interpreted descriptively only.

Baseline characteristics by procedure group. The median age was similar across groups: 55 years [IQR, 38–65] in the pericardioperitoneal group, 52 years [IQR, 29–55] in the pleuropericardial group, and 52 years [IQR, 36.5–58] in the regular pericardial window group.

BMI was numerically higher in the pleuropericardial group, with a median of 30.15 kg/m² [IQR, 29–41.5], compared with 22.5 kg/m² [IQR, 19.76–28.05] in the pericardioperitoneal group and 28.54 kg/m² [IQR, 24–31] in the regular pericardial window group.

Female sex was present in 2 of 5 patients (40.0%) in the pericardioperitoneal group, 5 of 7 patients (71.4%) in the pleuropericardial group, and 10 of 16 patients (62.5%) in the regular pericardial window group.

History of malignancy was documented in 1 of 5 patients (20.0%) in the pericardioperitoneal group, 2 of 7 patients (28.6%) in the pleuropericardial group, and 6 of 16 patients (37.5%) in the regular pericardial window group.

Hypertension was documented in 2 of 5 patients (40.0%) in the pericardioperitoneal group, 1 of 7 patients (14.3%) in the pleuropericardial group, and 9 of 15 evaluable patients (60.0%)

in the regular pericardial window group. CKD/ESRD was documented only in the regular pericardial window group, occurring in 3 of 15 evaluable patients (20.0%).

Indication categories differed numerically across groups. Malignant indication was present in 0 of 5 patients in the pericardioperitoneal group, 2 of 7 patients (28.6%) in the pleuropericardial group, and 8 of 16 patients (50.0%) in the regular pericardial window group. Idiopathic indication was present in 2 of 5 patients (40.0%), 3 of 7 patients (42.9%), and 2 of 16 patients (12.5%), respectively.

Stage IV or metastatic disease status had substantial missingness and was interpreted descriptively only.

Primary Outcome and Evaluable Secondary Binary Outcomes

Primary and evaluable secondary binary outcomes are summarized in Table 2A.

Outcome	PPW	PLW	Regular	Overall Fisher p	Missing, n
Early 30-day complications	3/5 (60.0%)	5/7 (71.4%)	1/16 (6.2%)	0.0018	0
Acute complications	2/5 (40.0%)	4/7 (57.1%)	2/16 (12.5%)	0.0572	0
Transfusion	1/5 (20.0%)	1/7 (14.3%)	3/16 (18.8%)	1.000	0

Table 2A: Primary and Evaluable Secondary Binary Outcomes

Note: Values are presented as n/N (%). The primary outcome was early 30-day postoperative complications. The overall p-value was calculated using Fisher's exact test across the three procedure groups. PPW = pericardioperitoneal window; PLW = pleuropericardial window. All comparisons are exploratory.

Primary outcomes

Early 30-day complications occurred in 3 of 5 patients (60.0%) in the pericardioperitoneal group, 5 of 7 patients (71.4%) in the pleuropericardial group, and 1 of 16 patients (6.2%) in the regular pericardial window group.

The overall Fisher exact test showed a statistically significant difference across the three groups ($p = 0.0018$). The lowest documented early complication rate was observed in the regular pericardial window group.

This finding should be interpreted cautiously because of the retrospective design, small subgroup sizes, and potential differences in documentation, patient selection, and case mix. The result indicates an association in documented early complications across groups, not definitive procedural superiority.

Evaluable Secondary Binary Outcomes

Acute complications occurred in 2 of 5 patients (40.0%) in the pericardioperitoneal group, 4 of 7 patients (57.1%) in the pleuropericardial group, and 2 of 16 patients (12.5%) in the regular pericardial window group. The overall Fisher exact p-value was 0.0572.

This showed a numerical trend toward fewer documented acute complications in the regular pericardial window group, but the result did not meet conventional statistical significance.

Transfusion was required in 1 of 5 patients (20.0%) in the pericardioperitoneal group, 1 of 7 patients (14.3%) in the pleuropericardial group, and 3 of 16 patients (18.8%) in the regular pericardial window group. There was no clear difference across groups ($p = 1.000$).

Sparse or Descriptive Binary Outcomes

Sparse and descriptive binary outcomes are summarized in Table 2B.

Outcome	Pericardioperito n eal window	Pleuropericardia l window	Regular pericardial window	Overall Fisher p-value	Missing, n	Interpretation
Documented mortality	1/3 (33.3%)	0/3 (0.0%)	1/5 (20.0%)	1.000	17	Descriptive only due to missingness
Recurrence	0/1 (0.0%)	1/2 (50.0%)	0/3 (0.0%)	0.500	22	Descriptive only due to sparse follow-up
Reintervention	0/4 (0.0%)	1/6 (16.7%)	0/5 (0.0%)	1.000	13	Descriptive only
Readmission	0/4 (0.0%)	1/6 (16.7%)	0/6 (0.0%)	1.000	12	Descriptive only
Procedural success	2/3 (66.7%)	3/4 (75.0%)	4/5 (80.0%)	1.000	16	Descriptive only
Respiratory complication	1/1 (100.0%)	3/3 (100.0%)	0/1 (0.0%)	0.400	23	Descriptive only; extremely sparse denominator

Infection	1/1 (100.0%)	1/1 (100.0%)	0/1 (0.0%)	1.000	25	Descriptive only; extremely sparse denominator
Suspected infection	Not evaluable	Not evaluable	0/1 (0.0%)	Not estimable	27	Not estimable / not evaluable
Bleeding	Not evaluable	Not evaluable	0/1 (0.0%)	Not estimable	27	Not estimable / not evaluable

Table 2B: Sparse or Descriptive Binary Outcomes

Note: Values are presented as n/N (%). Outcomes in this table had substantial missingness, sparse evaluable denominators, or were not estimable. They should be interpreted descriptively only. Absence of documented events should not be interpreted as absence of true events. P-values in this table are exploratory only and should not be interpreted inferentially because of sparse evaluable denominators. PPW = pericardioperitoneal window; PLW = pleuropericardial window.

Documented mortality was available in a limited number of patients. Mortality was documented in 1 of 3 evaluable patients (33.3%) in the pericardioperitoneal group, 0 of 3 evaluable patients in the pleuropericardial group, and 1 of 5 evaluable patients (20.0%) in the regular pericardial window group.

Recurrence was documented in 0 of 1 evaluable patient in the pericardioperitoneal group, 1 of 2 evaluable patients (50.0%) in the pleuropericardial group, and 0 of 3 evaluable patients in the regular pericardial window group.

Reintervention occurred in 0 of 4 evaluable patients in the pericardioperitoneal group, 1 of 6 evaluable patients (16.7%) in the pleuropericardial group, and 0 of 5 evaluable patients in the regular pericardial window group.

Readmission occurred in 0 of 4 evaluable patients in the pericardioperitoneal group, 1 of 6 evaluable patients (16.7%) in the pleuropericardial group, and 0 of 6 evaluable patients in the regular pericardial window group.

Procedural success was documented in 2 of 3 evaluable patients (66.7%) in the pericardioperitoneal group, 3 of 4 evaluable patients (75.0%) in the pleuropericardial group, and 4 of 5 evaluable patients (80.0%) in the regular pericardial window group.

Respiratory complications and infection were limited by extremely small evaluable denominators. Suspected infection and bleeding were not estimable because the pericardioperitoneal and pleuropericardial groups had no evaluable patients for these outcomes.

Overall, mortality, recurrence, reintervention, readmission, procedural success, respiratory complications, infection, suspected infection, and bleeding were interpreted descriptively only because of substantial missingness, sparse denominators, or lack of estimability.

Length of Stay and Continuous Perioperative Outcomes

Length-of-stay and continuous perioperative outcomes are summarized in Table 3.

Outcome	Pericardioperitoneal, n	Pericardioperitoneal median [IQR]	Pleuropericardial, n	Pleuropericardial median [IQR]	Regular pericardial window, n	Regular pericardial window median [IQR]	Kruskal-Wallis p	Missing, n
Hospital LOS, days	4	13 [8.5, 33]	4	9 [6.5, 20.5]	12	9.5 [7, 13.5]	0.635	8
ICU LOS, days	3	2 [2, 4]	4	1 [1, 2]	10	5 [4, 7]	0.0519	11
Blood loss, mL	5	150 [150, 350]	7	50 [10, 400]	9	10 [5, 380]	0.332	7
Readmission	5	55 [45, 90]	7	60 [60, 90]	0	Not available	Not applicable	16
Procedural success	3	50 [0, 200]	5	100 [100, 300]	6	225 [100, 600]	0.324	14
Respiratory complication	2	325 [100, 550]	3	200 [100, 1000]	3	300 [50, 800]	0.955	20
Infection	3	4 [3, 10]	5	1 [1, 3]	11	4 [3, 5]	0.427	9

Table 3: Length of Stay and Continuous Perioperative Outcomes

Note: Values are presented as median [IQR]. LOS = length of stay; ICU = intensive care unit. The Kruskal-Wallis test was used for overall comparisons across procedure groups when data were available across the groups. Operative time was not available in the regular pericardial window group; therefore, no valid three-group comparison was performed for operative time. All comparisons are exploratory.

Hospital length of stay did not differ clearly across groups. Median hospital LOS was 13 days [IQR, 8.5–33] in the pericardioperitoneal group, 9 days [IQR, 6.5–20.5] in the pleuropericardial group, and 9.5 days [IQR, 7–13.5] in the regular pericardial window group (Kruskal-Wallis p = 0.635).

ICU length of stay was numerically longest in the regular pericardial window group. Median ICU LOS was 2 days [IQR, 2–4] in the pericardioperitoneal group, 1 day [IQR, 1–2] in the pleuropericardial group, and 5 days [IQR, 4–7] in the regular pericardial window group. The overall comparison approached but did not meet conventional statistical significance (Kruskal-Wallis p = 0.0519).

Estimated blood loss was numerically lowest in the regular pericardial window group. Median estimated blood loss was 150 mL [IQR, 150–350] in the pericardioperitoneal group, 50 mL [IQR, 10–400] in the pleuropericardial group, and 10 mL [IQR, 5–380] in the regular pericardial window group. The overall comparison was not statistically conclusive (p = 0.332).

Operative time was available in the pericardioperitoneal and pleuropericardial groups only. Median operative time was 55 minutes [IQR, 45–90] in the pericardioperitoneal group and 60 minutes [IQR, 60–90] in the pleuropericardial group. Operative time was not available in the regular pericardial window group; therefore, no valid three-group comparison was performed for this variable.

Drain output during the first 24 hours was 50 mL [IQR, 0–200] in the pericardioperitoneal group, 100 mL [IQR, 100–300] in the pleuropericardial group, and 225 mL [IQR, 100–600] in the regular pericardial window group (p = 0.324).

Total drain output was available in a small number of patients and was interpreted descriptively. Median total drain output was 325 mL [IQR, 100–550] in the pericardioperitoneal group, 200 mL [IQR, 100–1000] in the pleuropericardial group, and 300 mL [IQR, 50–800] in the regular pericardial window group (p = 0.955).

Chest tube duration was shortest numerically in the pleuropericardial group. Median chest tube duration was 4 days [IQR, 3–10] in the pericardioperitoneal group, 1 day [IQR, 1–3] in the pleuropericardial group, and 4 days [IQR, 3–5] in the regular pericardial window group (p = 0.427).

Overall, no continuous perioperative outcome demonstrated a statistically conclusive difference across the three groups.

Follow-Up Ascertainment

Follow-up ascertainment is summarized in Supplementary Table 1.

Variable	Pericardioperitoneal, n	Pericardioperitoneal median [IQR]	Pleuropericardial, n	Pleuropericardial median [IQR]	Regular pericardial window, n	Regular pericardial window median [IQR]	Kruskal-Wallis p	Missing, n
Follow-up duration, months	1	6 [6, 6]	0	Not available	4	18 [12, 42]	Not applicable	23

Supplementary Table 1: Follow-up Ascertainment

Note: Values are presented as median [IQR]. Follow-up duration was documented in only 5 of 28 patients. No follow-up duration was documented in the pleuropericardial group; therefore, no valid three-group comparison was performed for follow-up duration. Follow-up duration was used to assess outcome ascertainment rather than treatment efficacy. Long-term outcomes should be interpreted descriptively only.

Follow-up duration was documented in only 5 of 28 patients. Follow-up was available in 1 patient in the pericardioperitoneal group, with a documented duration of 6 months. No follow-up duration was documented in the pleuropericardial group. Follow-up was documented in 4 patients in the regular pericardial window group, with a median duration of 18 months [IQR, 12–42].

Because follow-up documentation was sparse, long-term outcomes including mortality, recurrence, reintervention, readmission, and procedural success were interpreted descriptively only. The absence of documented events should not be interpreted as absence of true events.

Quality-Control Summary

Final quality-control checks identified no critical data-quality issues. All quality-control checks had zero flagged rows, and the dataset proceeded to exploratory statistical analysis.

Final quality-control summary is summarized in supplementary table 2.

QC check	Flagged rows
Invalid three-group procedure classification	0
Duplicate patient ID	0
Binary text/pre-conversion issues	0
Binary coding issues after conversion	0

Numeric text/unit contamination issues	0
Age issues	0
BMI issues	0
Hospital LOS < ICU LOS conflicts	0
Blood loss range issues >5000 or <0	0
Blood loss high review >2000	0
Symptom-to-surgery range issues	0
Follow-up range issues	0
Success logical conflicts	0
Recurrence/reintervention conflicts	0

Supplementary Table 2: Final QC Summary

Note: Final quality-control decision: PASS. No critical data-quality issues were identified after final review. The dataset proceeded to three-group exploratory statistical analysis. LOS = length of stay; ICU = intensive care unit

Overall Results Summary

In this exploratory three-group retrospective cohort, early 30-day complications differed significantly across the three procedure groups, with the lowest documented complication rate observed in the regular pericardial window group. Acute complications showed a similar numerical pattern, although the overall comparison was borderline and not statistically conclusive.

Hospital LOS did not differ clearly across groups. ICU LOS was numerically longest in the regular pericardial window group and approached conventional statistical significance, but this finding should be interpreted cautiously. Estimated blood loss was lowest numerically in the regular pericardial window group, while chest tube duration was shortest numerically in the pleuropericardial group. None of the continuous perioperative outcomes demonstrated a definitive statistically conclusive difference.

Long-term outcomes were limited by sparse follow-up documentation and were interpreted descriptively only. Given the retrospective design, small subgroup sizes, sparse denominators, and incomplete follow-up, no conclusion of superiority, equivalence, or non-inferiority can be made.

DISCUSSION

Surgical pericardial window creation remains an established therapeutic strategy for recurrent or clinically significant pericardial effusion, particularly when percutaneous drainage techniques are either insufficient or associated with high recurrence rates. This approach is especially relevant in malignant pericardial effusion, a potentially life-threatening condition frequently associated with advanced malignancy and cardiac tamponade. Early surgical series demonstrated that pericardial window procedures provide durable symptomatic relief with acceptable perioperative morbidity and low recurrence rates, thereby establishing surgical drainage as a standard therapeutic option in selected patients [1].

Multiple surgical approaches are currently utilized for pericardial drainage, including pleuropericardial window (PLW), pericardioperitoneal window (PPW), and conventional or regular pericardial window procedures. Previous reports have demonstrated that PPW is both safe and effective in the management of recurrent or malignant pericardial effusion, particularly in reducing recurrent tamponade physiology [5,8]. Similarly, PLW approaches have been associated with favorable perioperative recovery profiles and low recurrence rates, particularly when performed thoracoscopically [3]. Conventional pericardial window procedures continue to be widely used because of their technical familiarity, accessibility, and broad applicability across different clinical settings [6]. Traditional subxiphoid drainage procedures have additionally demonstrated acceptable recurrence rates and durable symptomatic relief in patients with both malignant and nonmalignant effusions [7,11].

Nevertheless, comparative evidence directly evaluating perioperative and postoperative outcomes among these three surgical techniques remains limited. In the present exploratory retrospective cohort, early 30-day complications differed significantly across the three groups, with the lowest documented complication rate observed in the regular pericardial window group. Acute complications demonstrated a similar numerical pattern, although the overall comparison did not reach conventional statistical significance. These findings should be interpreted cautiously given the retrospective design, small subgroup sizes, and potential differences in patient selection, baseline characteristics, and documentation practices.

Interestingly, although the regular pericardial window group demonstrated the lowest documented early complication rate, ICU length of stay was numerically longest in this group. This may reflect differences in underlying disease severity, perioperative clinical status, or indication complexity rather than procedural factors alone. The regular pericardial window group also included a greater proportion of patients with malignancy and CKD/ESRD, suggesting potential baseline differences that may have influenced postoperative recovery.

Among the alternative surgical approaches, PLW demonstrated numerically shorter ICU stay, shorter hospital length of stay, shorter chest tube duration, and lower estimated blood loss compared with PPW. These trends may suggest potential perioperative recovery advantages associated with pleural

drainage pathways and are broadly consistent with previous literature describing favorable recovery profiles following pleural-based drainage procedures [3]. However, none of these differences reached statistical significance, and the small cohort size substantially limited statistical precision.

Long-term outcomes including recurrence, reintervention, readmission, and mortality could not be reliably assessed because follow-up documentation was incomplete across all groups. This represents an important limitation, as long-term durability and recurrence prevention remain among the most clinically relevant determinants of procedural success when selecting a surgical drainage strategy. Prior studies comparing surgical windows with pericardiocentesis have demonstrated lower recurrence rates following surgical drainage procedures, albeit with greater procedural invasiveness and bleeding risk [1,11]. However, robust comparative long-term evidence between individual surgical window techniques remains scarce.

LIMITATIONS

This study has several important limitations that should be considered when interpreting its findings. First, the sample size was very small and markedly imbalanced across the three groups (PPW, n=5; PLW, n=7; regular pericardial window, n=16), resulting in limited statistical power and unstable effect estimates. Second, baseline differences between groups, particularly with respect to malignancy and CKD/ESRD, introduce substantial potential for confounding by indication. Because of the small sample size, multivariable adjustment for these potential confounders was not feasible; therefore, the observed differences in outcomes, including the statistically significant difference in early 30-day complications, cannot be attributed to the surgical technique alone. The definition and components of early 30-day complications should also be interpreted within the context of these baseline differences and potential unmeasured confounders. Third, substantial missing follow-up data limited reliable assessment of clinically important long-term outcomes, including recurrence, reintervention, readmission, and mortality, and may have introduced attrition bias. Finally, the single-center observational design and small cohort limit the generalizability of the findings. Accordingly, the apparent advantage of the regular pericardial window with respect to early complications should not be interpreted as evidence of procedural superiority, while the numerical findings observed with PPW or PLW should be considered hypothesis-generating. Larger prospective, preferably multicenter studies with standardized patient selection, clearly defined outcomes, and adequate longitudinal follow-up are needed to determine whether any pericardial window technique offers clinically meaningful advantages over the others.

Despite these limitations, this study represents one of the few three-group comparative analyses evaluating PPW, PLW, and regular pericardial window procedures within a single institutional cohort. Standardized data cleaning, structured quality-control procedures, and consistent outcome reporting improved methodological transparency and internal consistency.

Several limitations should be acknowledged. First, the retrospective single-center design introduces potential selection bias and confounding by indication. Second, the modest sample size limits statistical power and restricts definitive comparative conclusions. However, the relatively small cohort partially reflects the rarity of specialized procedures such as PPW and PLW. Third, incomplete follow-up data limited interpretation of long-term outcomes including recurrence and procedural durability. Finally, baseline differences in comorbidities and indication profiles across groups may have influenced perioperative outcomes.

Overall, this exploratory three-group study did not establish definitive superiority of any individual surgical approach. The regular pericardial window group demonstrated the lowest documented early complication rate, whereas PLW showed numerically favorable perioperative recovery characteristics in several continuous outcomes. Given the limitations of the current dataset, procedural selection should remain individualized according to patient characteristics, underlying pathology, anatomical considerations, and surgical expertise. Larger prospective multicenter studies with standardized follow-up are needed to better define comparative safety, recurrence risk, and long-term effectiveness among different surgical pericardial window techniques.

CONCLUSION

In this retrospective exploratory cohort study, perioperative outcomes were compared among pericardioperitoneal window (PPW), pleuropericardial window (PLW), and regular pericardial window procedures for the management of pericardial effusion. Early postoperative complications differed across the three groups, with the lowest documented complication rate observed in the regular pericardial window group. In contrast, PLW demonstrated numerically favorable perioperative recovery parameters, including shorter ICU and hospital length of stay, shorter chest tube duration, and lower estimated blood loss compared with PPW. However, none of the continuous perioperative outcomes demonstrated statistically conclusive differences.

Interpretation of these findings is limited by the retrospective single-center design, small subgroup sizes, baseline differences between groups, and incomplete long-term follow-up data. Consequently, no definitive conclusions regarding superiority, equivalence, or non-inferiority among the three surgical approaches can be established.

Overall, PPW, PLW, and regular pericardial window procedures all appear to represent clinically acceptable surgical strategies for the management of symptomatic or recurrent pericardial effusion. Procedural selection should remain individualized according to patient characteristics, underlying etiology, anatomical considerations, surgeon experience, and institutional expertise. Further prospective multicenter studies with larger sample sizes and standardized long-term follow-up are required to better define comparative safety, recurrence risk, and long-term procedural durability among different pericardial window techniques.

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SUPPLEMENTARY MATERIAL QUESTIONNAIRE

"Comparative Analysis of Perioperative Outcomes Between Pericardioperitonial and Pleuropericardial Window Procedures: A Retrospective Cohort Study"

Preoperative Data

1. Demographics Age Sex Body Surface Area (BSA) BMI Smoking status (Pack-years) Alcohol consumption

2. Medical History Comorbidities (HTN, DM, CKD, COPD, Cancer, Autoimmune diseases, etc.) History of previous cardiac surgery or intervention History of malignancy (type, stage) Number of previous pericardiocentesis procedures Time from symptom onset to surgical intervention

3. Indications for Surgery Year of the surgery Malignant pericardial effusion Infectious pericarditis (TB, viral, bacterial) Autoimmune Uremic pericarditis Idiopathic Post-cardiac surgery (e.g., Dressler's syndrome) Traumatic hemopericardium

4. Imaging and Laboratory Findings Echo findings (tamponade, effusion size in cc, fibrin strands) CT/MRI findings if available (loculated fluid, thickening) Preoperative pericardial fluid analysis (if tapped before surgery) Lab tests (WBC, CRP, ESR, Creatinine, Troponin, NT-proBNP) Intraoperative Data

5. Surgical Details Type of procedure: pericardial window vs pleuropericardial window Surgical approach: subxiphoid, thoracoscopic, thoracotomy Type of anesthesia Use of cardiopulmonary bypass (CBP) if any Aortic cross-clamp time (if applicable) Partial vs. complete pericardiectomy Operative time (in minutes) Estimated blood loss (EBL) Need for transfusion Concomitant procedures (e.g., lung biopsy, pleural drainage, cardiac surgery) Postoperative Data

6. Immediate Postoperative Course ICU length of stay Hospital length of stay Chest tube duration Drain output (first 24h, total) Early complications (within 30 days): Infection (wound, pneumonia, mediastinitis) Bleeding requiring reoperation Arrhythmias (e.g., atrial fibrillation) Dressler syndrome Cardiac tamponade Pericardial constriction Respiratory complications (atelectasis, pleural effusion) Renal injury Stroke

7. Late/Post-discharge Follow-Up Follow-up duration (months) Mortality (30-day and long-term) Recurrence of pericardial effusion Readmission rate Need for re-intervention (repeat pericardiocentesis or surgery) Success rate (defined as symptom relief + no recurrence at 6–12 months) Quality of life (if available, e.g., via SF-36 or EQ-5D)

*Optional Advanced Variables Pathology results of pericardial tissue Microbiological cultures from pericardial fluid Cytology (for malignant cases) Immunohistochemistry (if TB or autoimmune is suspected) Pericardial fluid ADA, LDH, glucose, protein (for TB or malignancy differentiation).