

Safety and Outcomes of Left Parasternal Approach Ultrasound-Guided Pericardiocentesis Performed by Emergency Physicians: An 11-Year Experience

Osman Adi

osman.adi@gmail.com

Hospital Raja Permaisuri Bainun

Mahathar Abd. Wahab

Hospital Kuala Lumpur

Chan Pei Fong

Hospital Raja Permaisuri Bainun

Hidayah Shafie

Hospital Kuala Lumpur

Farah Nuradhwa Apoo

Manchester Royal Infirmary

Tan Wan Chuan

Hospital University Tunku Abdul Rahman, Jalan Hospital, UTAR

Mohd Al Johari Linul Afiq

Hospital Kuala Lumpur

Azma Haryaty Ahmad

Hospital Raja Permaisuri Bainun

Asri Ranga

Hospital Serdang

Guido Tavazzi

University of Pavia, Fondazione IRCCS Policlinico S. Matteo

Gabriele Via

Istituto Cardiocentro Ticino – Ente Ospedaliero Cantonale

Research Article

Keywords: pericardiocentesis, tamponade, ultrasound, point-of-care ultrasound, echocardiography, ultrasound-guided procedures

Posted Date: August 25th, 2026

DOI: <https://doi.org/10.21203/rs.3.rs-10531075/v1>

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Additional Declarations: No competing interests reported.

Abstract

Aims. Ultrasound-guided pericardiocentesis has largely replaced blind techniques because of its greater safety. No consensus exists regarding the optimal approach. Ultrasound guided pericardiocentesis via in-plane parasternal approach techniques with high-frequency probes offer real-time visualization of needle trajectory. Evidence on this approach remains limited across both emergency medicine and other clinical settings. We evaluated the safety, feasibility, efficacy, and clinical outcomes of an in-plane, left parasternal, medial-to-lateral approach for pericardiocentesis.

Methods & Results. A observational cohort study including adult patients diagnosed with cardiac tamponade in the emergency department was conducted over 11 years (2014–2024) across two tertiary care hospitals. The primary outcome was procedural success rate. Secondary outcomes included procedure times, skin-to-pericardium distance, clinical and haemodynamic changes, procedure-related complications, and 72-hour mortality.

Among the 201 adult patients enrolled, the procedure achieved 100% success rate with only two complications (1%). Pericarditis was the most common cause of cardiac tamponade (45.8%), followed by sepsis, malignancy, procedure-related complications, myocardial disease, autoimmune disease, and trauma. The 72-hour in-hospital mortality rate was 15.9%, exclusively attributable to the underlying diseases. The mean time from needle puncture to fluid aspiration was 1 minute 51 seconds, while the mean procedural time was 5 minutes 46 seconds. Skin-to-pericardium distance was shorter than with a hypothetical subcostal approach. Hemodynamic parameters improved significantly after the procedure. No procedure-related deaths or major adverse events occurred.

Conclusion. The emergency ultrasound guided pericardiocentesis via an in-plane left parasternal approach is a safe, rapid technique for emergency pericardiocentesis, offering a shorter needle trajectory and improved needle control through continuous real-time visualization throughout the entire procedure.

INTRODUCTION

Ultrasound-guided pericardiocentesis has largely replaced “blind” landmark-based techniques because of its superior safety profile and lower complication rates. Under ultrasound guidance, the preferred access site is typically the location where the largest pericardial fluid collection can be reached through the shortest distance from the skin. While Advanced Cardiac Life Support (ACLS) guidelines recommend a parasternal approach, the American College of Advanced Trauma Life Support (ATLS) recommendations prefer a subxiphoid approach [1]. In a large Mayo Clinic study by Tsang et al. evaluating 1,127 pericardiocentesis, the apical approach (63%) was most commonly used, followed by the subxiphoid (18%) and left parasternal (7%) approaches [2]. Several studies have identified the subxiphoid approach as the preferred technique, reporting success rates exceeding 90% [3–5]

Two ultrasound-guided pericardiocentesis techniques have been described: the *out-of-plane* approach using an echocardiography or curvilinear probe, and the *in-plane* approach using a high-frequency probe.

The out-of-plane technique permits simultaneous cardiac monitoring during the procedure but may limit needle-tip visualization because of lower image resolution.

In contrast, the *in-plane* technique provides high-resolution imaging of superficial structures, enabling continuous visualization of the needle tip and trajectory, with improved needle control. Maggiolini et al. reported no inadvertent cardiac chamber puncture in 161 real-time echo-guided procedures with a probe-mounted needle [6]. Similar findings, including high success and minimal complications, were reported in pediatric and smaller adult studies [7–10]. Most studies using the in-plane technique employed either the subxiphoid [7,8] or apical approach [6,9]. In 2018, we reported an emergency ultrasound guided pericardiocentesis via left parasternal approach in 11 patients [10]. Otherwise, *the in-plane parasternal approach has only been described anecdotally* [11–13]. Of note, no substantial data on pericardiocentesis performed by emergency physicians have been published so far beyond mere case reports [11,13–16].

Expanding on our previous report [10], we studied in a significantly larger cohort of the emergency ultrasound guided pericardiocentesis via left parasternal approach or treating clinically and ultrasound-confirmed cardiac tamponade.

METHODS

Study Design and Study Setting

This observational cohort study included a subset of all consecutive patients who underwent pericardiocentesis in the emergency departments of two tertiary urban government hospitals (Hospital Raja Permaisuri Bainun, Ipoh, and Hospital Kuala Lumpur, Malaysia) over 11 years (2014–2024), selected by reviewing the patients' data and ultrasound dataset.

The study was conducted in accordance with the principles of Good Clinical Practice, the Declaration of Helsinki, and international standards governing clinical research. Ethical approval was obtained from the Medical Research and Ethics Committee of the Malaysian Ministry of Health.

Patient Population

All patients with point-of-care ultrasound confirmation of cardiac tamponade who underwent real-time using emergency ultrasound guided pericardiocentesis via left parasternal approach were selected. Patients younger than 18 years and those who underwent non-ultrasound-guided or non-parasternal pericardiocentesis were excluded.

Objective

The objective of this study was to evaluate the feasibility, safety, technical performance, and clinical outcomes of emergency ultrasound guided pericardiocentesis via left parasternal approach in patients

with tamponade.

Interventions

Data of all consecutive patients admitted to the emergency departments with suspected pericardial tamponade were reviewed. Patients with confirmed tamponade who underwent ultrasound-guided pericardiocentesis were further evaluated, and only those treated using the IP-LP-ML technique were included. In both participating centers, all patients presenting with shock undergo a point-of-care ultrasound examination, including focused cardiac, inferior vena cava (IVC), aortic, and lung ultrasound as part of the shock assessment protocol, and the choice of the specific pericardiocentesis approach is based on the attending physician's individual preference and clinical judgment. The diagnosis of tamponade was made according to well-established criteria [17] by emergency physicians with at least 5 years of experience in critical care sonography and ultrasound-guided procedures. Since 2012, the two participating hospitals have been accredited as WINFOCUS (World Interactive Network Focused on Critical Ultrasound) international training centers.

Pericardiocentesis was performed by the treating emergency physician using the original eight-step standardized emergency ultrasound guided pericardiocentesis via left parasternal approach previously described by our group[10]. [Figures 1–2; **Supplemental Video Files 1–4**]. Pericardiocentesis was considered successful when direct needle entry into the pericardial space and catheter placement with fluid drainage were visualized. A report sheet with clinical, procedural, and ultrasound data was generated.

Measures and Outcomes

The *primary outcome* was procedural success. *Secondary outcomes* included time from needle puncture to first fluid aspiration, procedure duration (from puncture to catheter in place), skin-to-pericardium distance, volume of pericardial fluid evacuated, clinical and haemodynamic changes, procedure-related complications, and 72-hour mortality. For comparative purposes, the skin-to-pericardium distance was also measured in a subcostal view for a subset of the studied population.

The separation between the 2 pericardial layers at the point of maximal fluid accumulation and the amount of fluid drained were also assessed.

Patient demographics, clinical data, and echocardiographic findings were obtained from the medical records.

Statistical Analysis

Patient demographics were summarized using descriptive statistics. Normally distributed variables were reported as mean $\pm$ standard deviation (SD), whereas non-normally distributed variables were expressed

as median and interquartile range (IQR). Paired sample t-test was used to compare the means of normally distributed samples, while the Wilcoxon signed-rank test was used for nonparametric samples. Statistical significance was defined as $p < 0.05$. Data analysis was performed using IBM SPSS Statistics for Windows, Version 21.0 (IBM Corp., Armonk, NY, USA).

RESULTS

During the study period, 950 patients were diagnosed with cardiac tamponade and were submitted to ultrasound-guided pericardiocentesis. Of these, 201 were treated using the emergency ultrasound guided pericardiocentesis via left parasternal approach. Patients were predominantly male (121; 60%), with a mean age of 57 ± 15 years (range 42–72). Pericarditis was the most common cause of cardiac tamponade (45.8%), followed by sepsis (15.9%), malignancy (12.4%), procedure-related complications (10.4%), cardiac disease (9%), autoimmune disease (4%), and trauma (2.5%). Thirty-two patients (15.9%) died despite the treatment within 72 hours, because of progression of their underlying medical conditions.

Patient demographics and clinical characteristics are summarized in Table 1.

Table 1 Baseline characteristics of the study population.	
Variable	Distribution
<i>Demographics</i>	
Age, years $\pm$ SD (range)	57 ± 15 (42–72)
Males, n (%)	121 (60%)
Females, n (%)	80 (40%)
<i>Pericardial Effusion Causes, n (%)</i>	
Pericarditis	92 (45.8%)
Sepsis	32 (15.9%)
Malignancy	25 (12.4%)
Complications from procedure	21 (10.4%)
Heart problem	18 (9.0%)
Autoimmune	8 (4.0%)
Trauma	5 (2.5%)

The procedural success rate was 100%, with two complications reported (1%). One patient developed a left-sided pneumothorax requiring percutaneous drainage, while another sustained a right ventricular

wall puncture, which didn't lead to hemopericardium. Both patients were discharged well without the need for further interventions.

The mean time from pericardial puncture to fluid aspiration was 1 minute 51 seconds (± 31 seconds), while mean catheter placement time was 3 minutes 55 seconds (± 35 seconds), resulting in a mean total procedural time of 5 minutes 46 seconds (± 56 seconds). First-pass success was recorded in 186 patients (92.5%), 2 attempts were needed in 5 patients (2.5%), and multiple attempts were needed for 10 patients (5%).

The median skin-to-parietal pericardial distance was 1.9 cm (IQR 1.6–2.0 cm) in the parasternal approach, while the skin-to-pericardium distance measured in the same patients in the subcostal window along a hypothetical ideal needle trajectory was 3.0 cm (IQR 3.0–4.0 cm), with a difference of 1.1 cm between the two medians ($p < 0.05$).

The median pericardial effusion size was 19 mm (IQR 17–22 mm). Small effusions (≤ 20 mm) were present in 139 patients (69.2%), whereas 62 (30.8%) had large effusions (> 20 mm). Median drainage volume was 87.5 mL/h (IQR 50–125 mL/h) during the first 4 hours and 59.4 mL/h (IQR 37.5–81.3 mL/h) over the subsequent 16 hours.

Hemodynamic parameters improved significantly after the procedure (MAP: 60 ± 15 vs 87 ± 14 mmHg; HR: 114 ± 21 vs 92 ± 11 beats/min; $p < 0.001$ for both).

Study results are summarized in Table 2.

Table 2
Study results

Variable	Distribution	
Procedure success, n (%)	201 (100%)	
Complications, n (%)	2 (1%)	
72 hour mortality, n (%)	32 (15.9%)	
Number of attempts = 1, n (%)	186 (92.5%)	
Number of attempts = 2, n (%)	5 (2.5%)	
More than 2 attempts, n (%)	10 (5.0%)	
Mean time for pericardial puncture & fluid aspiration, seconds $\pm$ SD	1 minute 51 seconds ($\pm$ 31 seconds)	
Mean time for catheter placement, seconds $\pm$ SD	3 minutes 55 seconds ($\pm$ 35 seconds)	
Mean procedural time, seconds $\pm$ SD	5 minutes 46 seconds ($\pm$ 56 seconds).	
Median distance from skin to parietal pericardium, cm $\pm$ IQR (parasternal approach, n = 201)	1.9cm (1.6-2.0 cm)	
Median distance from skin to parietal pericardium, cm $\pm$ IQR (Subcostal approach, n = 134)	3.0cm (3.0-4.0cm)	
Median Pericardial effusion size	19mm (IQR 17–22 cm).	
> 20mm, n (%)	62 (30.8%)	
20mm or less, n (%)	139 (69.2%)	
Median drainage for first 4 hours, cm $\pm$ IQR	87.5 ml/hour (50–125 ml/hour)	
Median drainage for the next 16 hours, cm $\pm$ IQR	59.4 ml/hour (37.5–81.3 ml/hour)	
MAP pre-procedure, mmHg $\pm$ SD	60 mmHg $\pm$ 15 mmHg	P < 0.05
MAP post- procedure, mmHg $\pm$ SD	87 mmHg $\pm$ 14 mmHg	
HR pre-procedure, beats/minute $\pm$ SD	114 beats/minute $\pm$ 21	P < 0.05
HR post-procedure, beats/minute $\pm$ SD	92 beats/minute $\pm$ 11	

DISCUSSION

To our knowledge, this represents the largest reported series of ultrasound-guided in-plane parasternal pericardiocentesis in patients with cardiac tamponade. In this observational cohort of 201 patients, the emergency ultrasound guided pericardiocentesis via left parasternal approach *achieved a 100% success rate* and demonstrated a *favourable safety profile*, with only two complications (1%) [Fig. 3]. These results are in line with other studies of in-plane ultrasound-guided techniques reporting complication rates of 1–5% [6,7,18]. This real-time guidance in-plane approach has also been shown to outperform static ultrasonography-guided techniques, generally associated with lower success rates (93%) and higher rates of major complications [18].

The *efficacy* of this pericardiocentesis technique was extremely satisfactory. Patients with cardiac tamponade are hemodynamically unstable and prone to rapid decompensation. Prompt pericardiocentesis is therefore lifesaving, with removal of as little as 10–20 mL often sufficient to produce clinical benefit. In our cohort, needle insertion and initial fluid aspiration were achieved in a mean time of 1 minute and 51 seconds, resulting in immediate haemodynamic improvement. The needle first-pass rate was, in fact, 92.5%, which was comparable with other ultrasound-guided pericardiocentesis [2,5,18].

The whole procedure, including catheter insertion following the pericardial puncture, was also short, taking on average 5 minutes 46 seconds.

In this study, the median skin-to-pericardium distance was 19 mm, significantly shorter than with a hypothetical subcostal approach. This short trajectory enabled optimal visualization of superficial structures with the high-frequency probe. Longer skin-to-pericardium distances have been associated with higher complication rates. In a retrospective ED study by Stolz, the subxiphoid approach had a mean distance of 56 mm and a predicted complication rate of 80%, compared with 27 mm and 20% for the parasternal approach [1].

Three main factors likely contribute to the safety, efficacy, and speed of the emergency ultrasound guided pericardiocentesis via left parasternal approach (i) superior needle control through continuous visualization of the needle tip and trajectory, minimizing injury to the lung, vessels, and myocardium; (ii) added procedural safety from direct visualization of the guidewire and agitated saline within the pericardial space; and (iii) shorter procedural time due to the reduced skin-to-pericardium distance and high first-pass success rate.

Continuous needle visualization enhances procedural safety by reducing the risk of cardiac wall injury, a feared complication, particularly in centers without cardiac surgery backup. Our results are consistent with previous evidence: no detectable significant cardiac wall injuries are reported using real-time needle visualization during pericardiocentesis, regardless of approach [6–9]. In contrast, earlier ultrasound-guided studies without real-time needle tracking reported rates of relevant cardiac injury up to 10% [2–5].

The optimal drainage site is where the pericardial effusion is largest and is closest to the skin [9]. In addition to providing a stable surface for optimal probe positioning and needle–probe alignment, the left

parasternal area offers the shortest access route to the pericardium; in this study, the median skin-to-pericardium distance was only 1.9 cm, and this certainly facilitated the procedure. Although larger effusions (> 20 mm) are technically easier to drain because of greater needle maneuverability and lower risk of cardiac puncture [9], pericardial fluid collections cause tamponade regardless of their size, as their hemodynamic effect is correlated more with the speed of fluid accumulation than with the amount [19,20]. Real-time needle visualization with the left parasternal approach enables safe drainage of small effusions. Notably, 69% of effusions in this cohort measured ≤ 20 mm [Figure 3].

This study has several limitations. First, from a technical perspective, small or loculated post-cardiac surgery effusions may not be amenable to a parasternal approach because of their posterior location or because access may be limited by hyperinflated lungs, left-sided pneumothorax, subcutaneous emphysema, or post-surgical dressings. Furthermore, this approach may be impractical during cardiac arrest, as it could interfere with ongoing cardiopulmonary resuscitation maneuvers. However, none of these situations occurred in our emergency medicine patient cohort.

Second, the follow-up was limited to 72 hours and based solely on medical records. As patients were transferred to inpatient wards after the procedure, delayed complications such as infection, catheter dislodgement, or recurrent effusion may have been missed. The observed 15.9% mortality rate was attributed to progression of the underlying disease; however, because post-mortem examinations were not routinely performed, minor procedure-related complications cannot be entirely excluded.

Finally, the study was conducted in two tertiary centers staffed by emergency physicians experienced in critical care ultrasound, ultrasound-guided procedures, and the left parasternal approach. Therefore, these findings may not be generalizable to settings lacking similar expertise.

CONCLUSIONS

Data from this observational cohort of emergency department patients with cardiac tamponade demonstrate that real-time ultrasound-guided pericardiocentesis using the in-plane left parasternal ultrasound guided from medial-to-lateral is feasible, safe, rapid, and effective. Compared with previously reported ultrasound-guided techniques, this approach may offer several practical advantages.

Declarations

Ethics approval and consent to participate

The study was approved by Medical Research and Ethics Committee of Malaysia Ministry of Health was granted and obtained from the patient's parents before enrolment in the study

Funding information

Authors received no funding for this study from any institution/ individual.

Consent for publication

Consent for publication was obtained and with permission from Director of Health , Ministry of Health , Malaysia.

Availability of data and materials

The materials are available from the corresponding author on reasonable request.

COI Statement: all authors declare they have no conflict of interest as concerns this manuscript.

Acknowledgements

The authors would like to thank Ipoh Emergency Critical Care Society (IECCS), Clinical Research Centre (CRC) HRPB, Ipoh, and Hospital Kuala Lumpur, for their support. The study has been approved by the Ministry of Health of Malaysia.

Authors' contribution

AO, MAW, GV , GT and CPF was involved in the initial conception and drafting of the manuscript. All authors contributed to the image interpretation, writing and revision of the manuscript.

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Figures

Step 1 - Patient positioning and ergonomics
The operator stands on the patient's right side, with the ultrasound machine positioned contra-laterally, allowing both the operator's hands and the ultrasound screen to remain within the same line of sight.
Step 2 - Patient and ultrasound preparation
The skin overlying the chest wall is cleaned and draped in a sterile fashion, and the ultrasound probe is covered with a sterile sheath.
Step 3 - Visualization of ultrasound landmarks
A high-frequency probe is used to identify the sternum, internal thoracic vessels, lung sliding, pericardial effusion, and the right ventricular wall. The needle insertion site, intended needle trajectory, and the distance from the skin to the pericardium are then identified.
Step 4 - Ultrasound settings optimization
The depth and focal zone are adjusted to magnify the area of interest and optimize image resolution, so that only the intercostal muscles, pericardial effusion, and right ventricular wall remain visible.
Step 5 - Needle insertion
The needle is introduced using a medial-to-lateral approach at an approximately 45-degree angle and advanced through the chest wall into the pericardial space. The needle is maintained in-plane with the ultrasound beam to allow continuous visualization of its trajectory and precise control of the needle tip.
Step 6 - Aspiration and microbubble test confirmation
Aspiration of 10–20 mL of fluid confirms entry into the pericardial effusion. As additional confirmation, while maintaining the same needle and probe position, 5 mL of an agitated saline–air mixture is injected as a contrast medium. This produces a “rocket flare” appearance on the ultrasound image, followed by opacification of the pericardial space.
Step 7 - Wire and catheter positioning
While maintaining the ultrasound probe in the same position, a guide-wire is advanced into the pericardial space and visualized under ultrasound guidance. A single-lumen catheter is then inserted using the Seldinger technique.
Step 8 - Pericardial drainage and monitoring
Fluid is aspirated until improvement in clinical and physiological parameters is achieved, at the operator's discretion, without necessarily draining the entire effusion. The catheter is then left on passive drainage, with ongoing clinical monitoring and repeated ultrasound assessments according to the patient's clinical condition.

Figure 1

Description of the 8-step in-plane left parasternal medial-to-lateral (IP-LP-ML) technique for emergency pericardiocentesis, from patient positioning to pericardial fluid drainage.

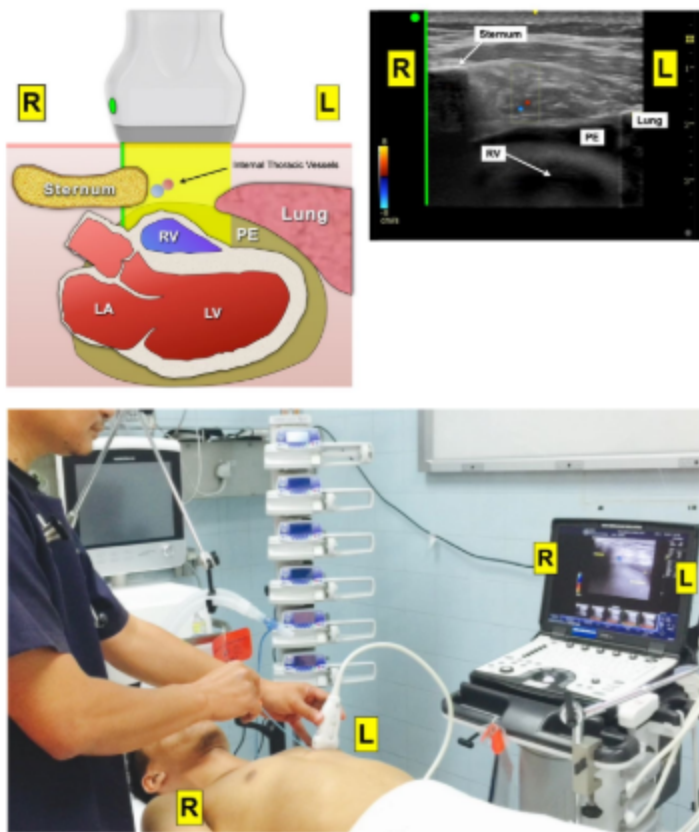


Figure 2

In-plane left parasternal medial-to-lateral (IP-LP-ML) approach for pericardial drainage. The upper panel provides a side-by-side comparison between the anatomical structures and the corresponding ultrasound view of the selected left parasternal intercostal space over the cardiac area of the left hemithorax. The lower panel illustrates the procedural ergonomics, with the operator positioned on the patient's right side and the ultrasound machine on the opposite side, allowing both the operator's hands and the ultrasound screen to remain within the same line of sight. For ease of orientation, "L" and "R" indicate the patient's left and right sides, respectively. This ultrasound image orientation (opposite to the conventional echocardiographic orientation used with phased-array probes) maintains anatomical side consistency between the patient and the ultrasound display, thereby facilitating intuitive and accurate needle guidance.

LEFT PARASTERNAL ULTRASOUND-GUIDED PERICARDIOCENTESIS WITH MEDIAL-TO-LATERAL IN-PLANE APPROACH: 11 YEARS OF EXPERIENCE



Osman Adi, Mahathar Abd. Wahab, Chan Pei Fong, Hidayah Shafie, Farah Nuradhwa Apoo, Tan Wan Chuan, Mohd Al Johari Linul Afiq, Azma Haryaty Ahmad, Asri Ranga, Guido Tavazzi, Gabriele Via.

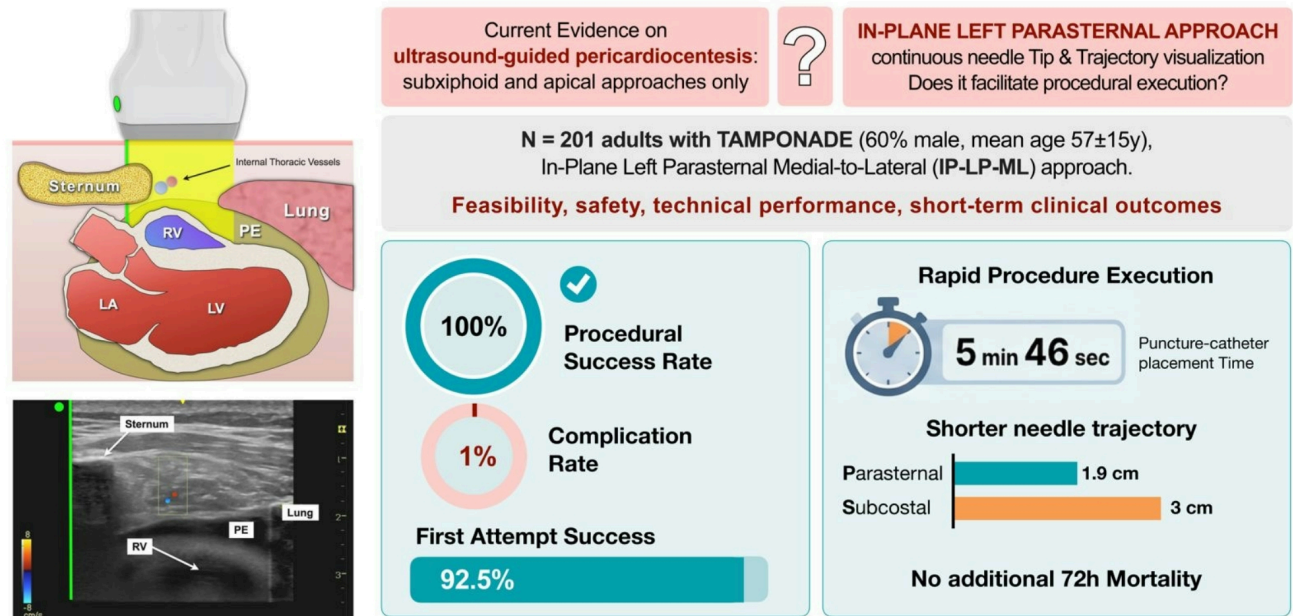


Figure 3

Infographic summary of the study

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