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RECENT ADVANCEMENT IN ECHOCARDIOGRAPHIC EVALUATION OF CARDIAC TAMPONADE

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Abstract : Cardiac tamponade is a dangerous condition when fluid builds up in the pericardial sac and causes the heart to malfunction, remains a diagnostic challenge due to its varied clinical presentation. Echocardiography plays a pivotal role in its timely detection and management. This review aims to summarize recent advancements in echocardiographic techniques for the evaluation of cardiac tamponade.

Recent studies have highlighted the utility of various echocardiographic modalities, like transthoracic echocardiography (TTE), transesophageal echocardiography (TEE), and point-of-care ultrasound (POCUS), in enhancing diagnostic accuracy and guiding therapeutic interventions. Novel techniques such as speckle tracking echocardiography (STE) and three-dimensional echocardiography have shown promise in providing detailed information about cardiac mechanics and facilitating early recognition of tamponade physiology.

Furthermore, advancements in imaging technology, such as contrast-enhanced echocardiography and strain imaging, have enabled better visualization of pericardial effusion and assessment of myocardial function under tamponade conditions. Integration of echocardiography with additional imaging techniques like magnetic resonance imaging and computed tomography, has further enhanced diagnostic precision in complex cases.

In addition to diagnostic capabilities, recent studies have focused on the prognostic value of echocardiographic parameters in predicting outcomes and guiding therapeutic strategies in cardiac tamponade. Real-time monitoring of hemodynamic parameters using echocardiography has emerged as a valuable tool in guiding pericardiocentesis and assessing response to therapy.

Overall, recent advancements in echocardiographic evaluation have significantly improved our understanding of cardiac tamponade pathophysiology and enhanced diagnostic and therapeutic approaches. However, to confirm these results in larger cohorts and investigate the possible contribution of developing technologies to better outcomes for patients with cardiac tamponade, more study is necessary.

IndexTerms **- Echocardiography; Cardiac Tamponade; Ultrasound; Pericardium**

1.INTRODUCTION

1.1 Cardiac Tamponade

A decrease in the ventricles' capacity to fill diastolically characterises a pericardial syndrome known as cardiac tamponade. This reduces cardiac output and, if treatment is not received, usually leads to the signs and symptoms of cardiac arrest. Percutaneous cardiac procedures, malignancies, infectious/inflammatory conditions, mechanical problems from myocardial infarction, and aortic dissection are the primary causes of cardiac tamponade.

Cardiac tamponade is a medical emergency characterized by the compression of the heart due to the accumulation of fluid or blood in the pericardial sac. Timely diagnosis and intervention are crucial for patient outcomes. Echocardiography plays a pivotal role in the assessment of cardiac tamponade, providing real-time imaging and hemodynamic data. Recent advancements in echocardiographic techniques have significantly enhanced the accuracy and efficiency of diagnosing and managing this condition.

A dangerous disease known as cardiac tamponade can arise from an abrupt and/or severe build-up of liquid in the area around the heart. This fluid build-up prevents the heart chambers from filling properly, causing abnormal hemodynamics, which can ultimately result in cardiac arrest and hypotension. As a result, it is a potentially fatal illness that needs to be identified as quickly as feasible in order to receive the appropriate care.

1.2 ECHOCARDIOGRAPHY

Ultrasound is used in echocardiography, commonly referred to as cardiac ultrasound, to check the heart. It is a kind of ultrasound used in medicine that might be Doppler or conventional ultrasound. An echocardiogram, cardiac echo, or just an echo is the term used to describe the visual representation created by this method.

If there is any suspicion of cardiac tamponade, an echocardiogram should be performed right away.
It is easy to obtain the first five signals using M-mode and 2D echocardiography. A Doppler examination will be necessary for the assessment of flow pattern variability.

Throughout the whole diastole, diastolic filling is continuously impaired. Both the effusion's size and distribution may fluctuate. Given the relative stiffness of the pericardium, the duration of cardiac tamponade is determined by the rate at which pericardial fluid accumulates(acute or subacute). Fast pericardial fluid accumulation results in a sharp increase in pericardial pressure, (blood, for instance, in the event of hemopericardium in aortic dissection) can swiftly result in cardiac tamponade. Conversely, pericardial fluid that slowly builds up can be asymptomatic, and higher levels can cause cardiac tamponade. (Figure: 1)

The last-drop phenomenon of cardiac tamponade, the way that little volumes of pericardial fluid can cause tamponade, and the significant relief that can be obtained from aspirating small volumes of fluid during urgent pericardiocentesis are all covered in this topic. In clinical practice, moderate to large circumferential pericardial effusions are typically the source of cardiac tamponade; however, loculated effusions may also produce cardiac tamponade in some situations (such as following cardiac surgery or chest trauma).

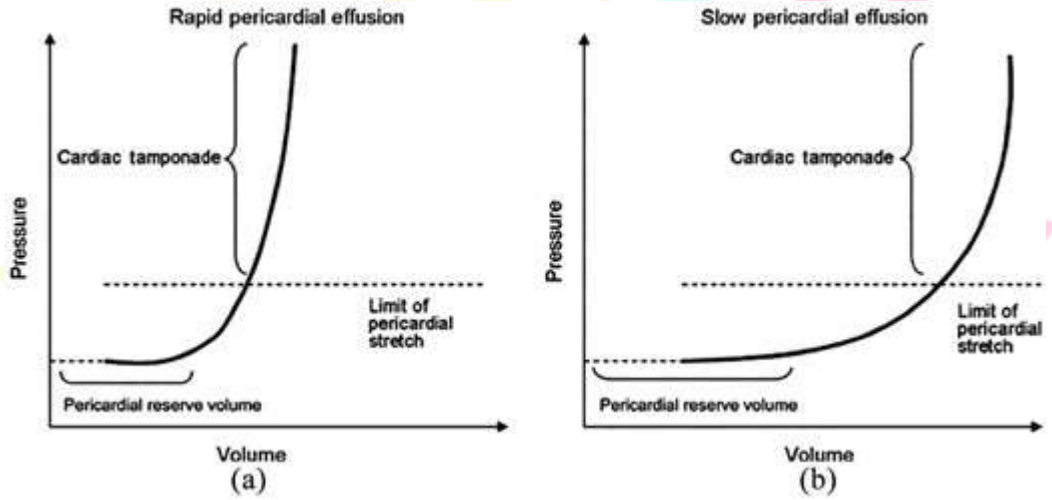

Fig: 1

2.Diagnosis of cardiac tamponade

Echocardiography

A resident of cardiology working in the direction of a senior heart specialist conducted the transthoracic or transoesophageal echocardiographic evaluation. The decision about the type of evaluation—transthoracic or transoesophageal—was made by the on-duty staff and took into account the clinical circumstances.
When one of the following was observed in addition to clotting or a effusion in pericardial region, echocardiography was deemed positive for tamponade: a swinging heart, atrial or collapse of ventricles, and greater respiratory variation in the tricuspid or mitral valve flow velocities.

The clinical diagnosis of cardiac tamponade is made based on a suspicious history and symptoms (often orthopnea developing from dyspnea on exertion, chest pain and/or fullness, high jugular venous pressure at bedside examination, pulsus paradoxus, reduced heart sounds, and often hypotension) are taken into consideration. Echocardiogram testing should be performed to validate the clinical suspicion of cardiac tamponade.
In urgent or emergency situations, echocardiography can be performed at the patient's bedside. It can show signs of moderately large or large circumferential pericardial effusion, abnormal respiratory variation in the dimensions of the right and left ventricles, and in the flow velocities of the tricuspid and mitral valves, which are typically associated with inferior vena cava plethora.
See Figure 2

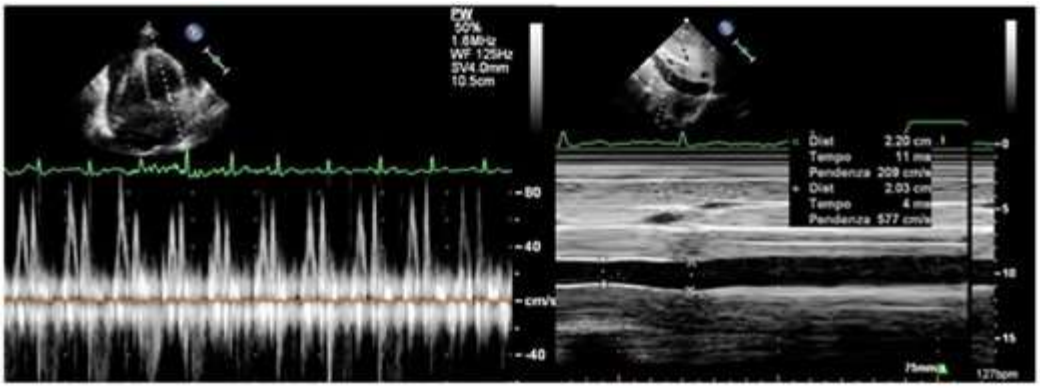

Fig: 2

3.Technological Advancements:-

1. Point-of-care Ultrasound (POCUS): POCUS has emerged as a valuable tool for rapid assessment of cardiac tamponade, especially in critical care settings and emergency departments. Its portability and ease of use enable prompt evaluation at the bedside, facilitating early diagnosis and intervention.
2. Transesophageal Echocardiography (TEE): TEE offers superior image quality compared to transthoracic echocardiography (TTE), particularly in patients with suboptimal acoustic windows. Recent improvements in TEE technology, including higher frequency probes and advanced imaging modalities such as 3D echocardiography, enhance visualization of cardiac structures and aid in the precise localization and quantification of pericardial effusion.
3. Speckle Tracking Echocardiography (STE): STE provides quantitative assessment of myocardial deformation parameters, including strain and strain rate. This technique enables the detection of subtle changes in cardiac function associated with cardiac tamponade, such as regional wall motion abnormalities, even before overt hemodynamic compromise occurs.
4. Doppler Echocardiography: Doppler echocardiography plays a crucial role in assessing hemodynamic consequences of cardiac tamponade, including intracardiac pressures, filling dynamics, and the presence of respiratory variation in blood flow velocities. Recent advancements in Doppler techniques, such as tissue Doppler imaging and pulse wave Doppler, improve the accuracy of hemodynamic assessment and aid in differentiating cardiac tamponade from other causes of hemodynamic instability.

3.1 2D Echocardiography and M-Mode

(i) Quantitative and qualitative assessment of pericardial fluid
In light of the previous remarks regarding PEff, an evaluation that is both quantitative and qualitative can be made.

(ii) Collapse of cardiac chambers
Right atrial (RA) and ventricular collapse is a common indicator of severe hemodynamic dysfunction linked to cardiac tamponade. When pressures of the internal chambers are less than pressure of pericardial region, this happens during the heart's relaxation phase. During the cardiac cycle, atrial and ventricular collapses happen at distinct times. When cardiac tamponade increases, atrial collapse typically happens before ventricular collapse.

Systole is when right atrial collapse is most frequently seen. At this stage, intracavity pressure is likewise reduced. Furthermore, research has demonstrated that the timing of atrial collapse it is exceeding one-third of the cardiac cycle in duration—is a nearly perfect predictor of clinical cardiac tamponade, with a sensitivity and specificity of approximately 100%. (Figure 3). Even though it has been documented, isolated right atrial collapse as a single chamber collapse occurs more frequently than left atrial collapse.

It is typically observed in conjunction with RA collapse and cardiac tamponade (Figure3)
Cardiac tamponade is more sensitive and specific when both atria collapse.

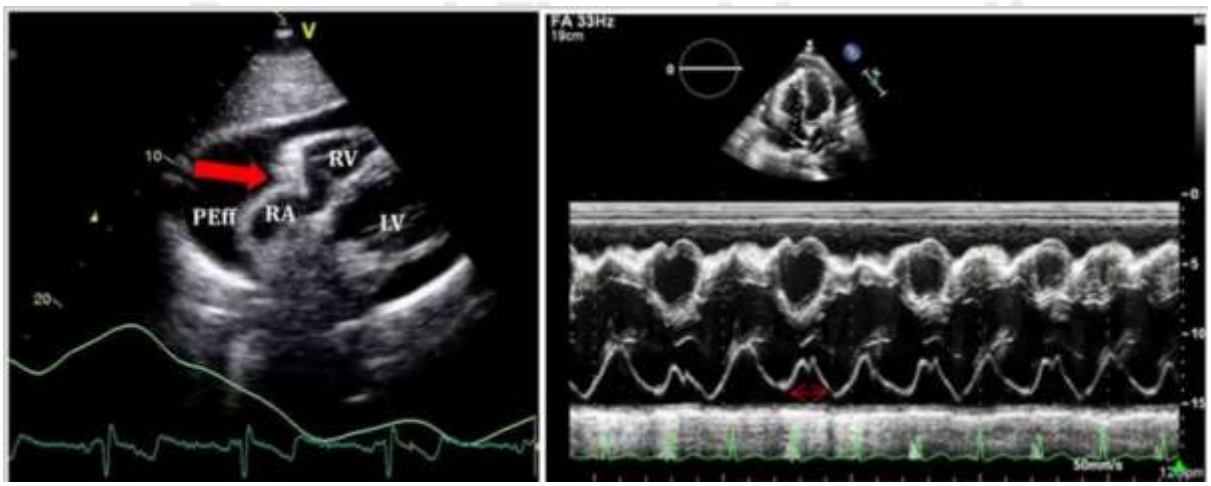

Figure 3

The patient is seen in the left subcostal view with symptoms of right atrial (RA) collapse and a large pericardial effusion. The collapse time over a third of the systole is displayed in the right image.

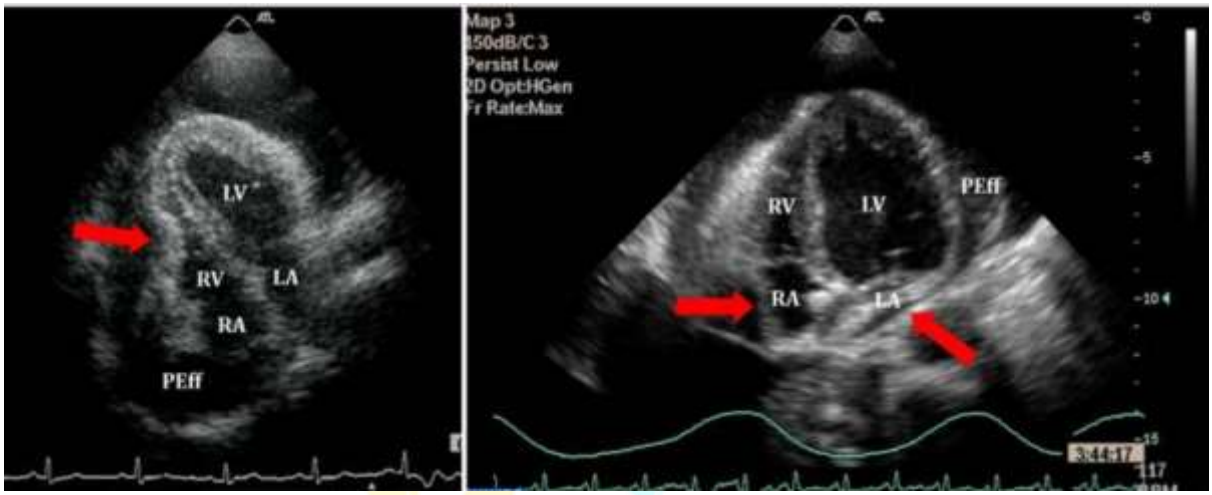

Figure 4

A patient with cardiac tamponade exhibits the collapse of right ventricles (left) in begining diastole (end of T wave); RV collapse (both atria collapse) in a separate patient presenting with symptoms of tamponade.

It's possible that none of these echocardiographic indicators of cardiac tamponade exist.
when there are congenital or hereditary cardiac disorders that would boost RV diastolic pressures, such as pulmonary hypertension, positive pressure ventilation, severe left ventricular failure, or other circumstances where baseline right ventricular diastolic pressures are elevated.
On different side, in settings like hypovolemia where baseline intracavitary pressures are lower, if the right chambers collapse, happen quicker than anticipated. Despite these drawbacks, there is a 90% negative predictive value if no cardiac chamber collapses.

(iii) Variability of diastolic ventilator size with respiratory cycle
M-mode is a useful technique to analize growing ventricular dependence along the respiratory cycle in both the long and short parasternal axis when cardiac tamponade is present. RV filling rises during inspiration, but LV size falls during diastole.

(see Figure5) The situation that exists during expiry is the opposite. In the absence of tamponade, this physiological event can vary the cardiac output by no more than 5%.

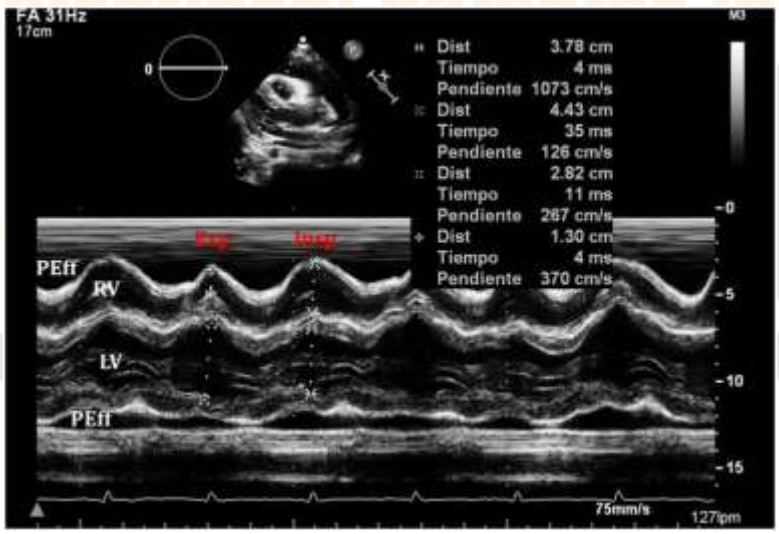

Figure 5

Reduced left ventricular diameter and increased diastolic diameter of the right ventricle (RV) during inspiration during expiration are signs of an exacerbated ventricular interdependence after severe pericardial effusion.

(iv) Assessment of IVC

On 2D echocardiography, an adult-sized heart's hepatic and IVC dilation (>20 mm) is a reliable indicator of tamponade.(Figure 6). It is known as IVC plethora, this is a very sensitive (92%), if not particularly specific, a sign of heart tamponade. A characteristic sign is a reduction in the IVC's physiological collapsibility after inspiration.Most cases of significant PEff will have a calibre reduction of less than 50% in M-mode through the IVC. (Fig: 6).

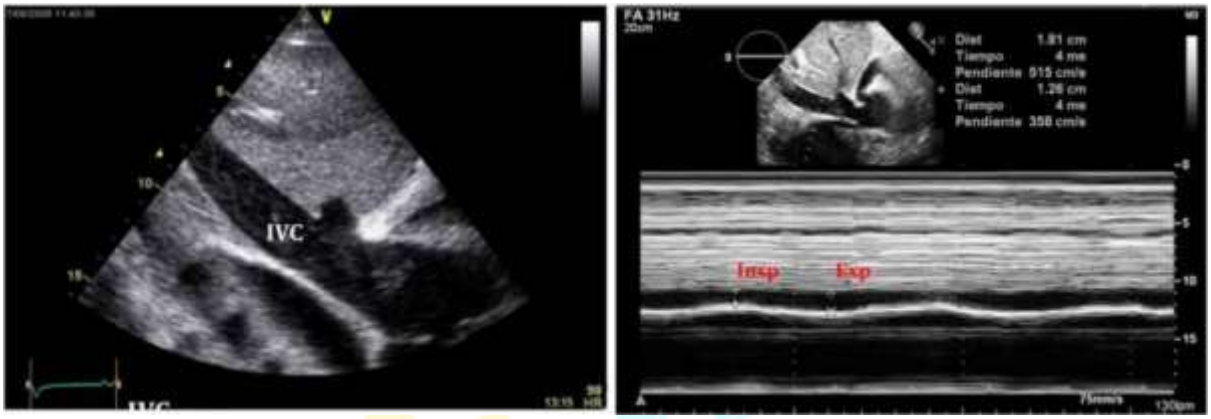

Fig: 6

An picture of a patient with a large pericardial effusion usually shows a left inferior vena cava (IVC) plethora. During inspiration, less than 50% of IVC collapse (right).

(v) Septal “bounce”

An inspiratory "bounce" of the interventricular septum towards the left ventricle is a typical, albeit non-specific, finding in cardiac tamponade (Figure 7). This aberrant movement of the interventricular septum will be visible as an M-mode over the parasternal long axis.
When there is LV hypertrophy or elevated LV filling pressure, it could not be present.

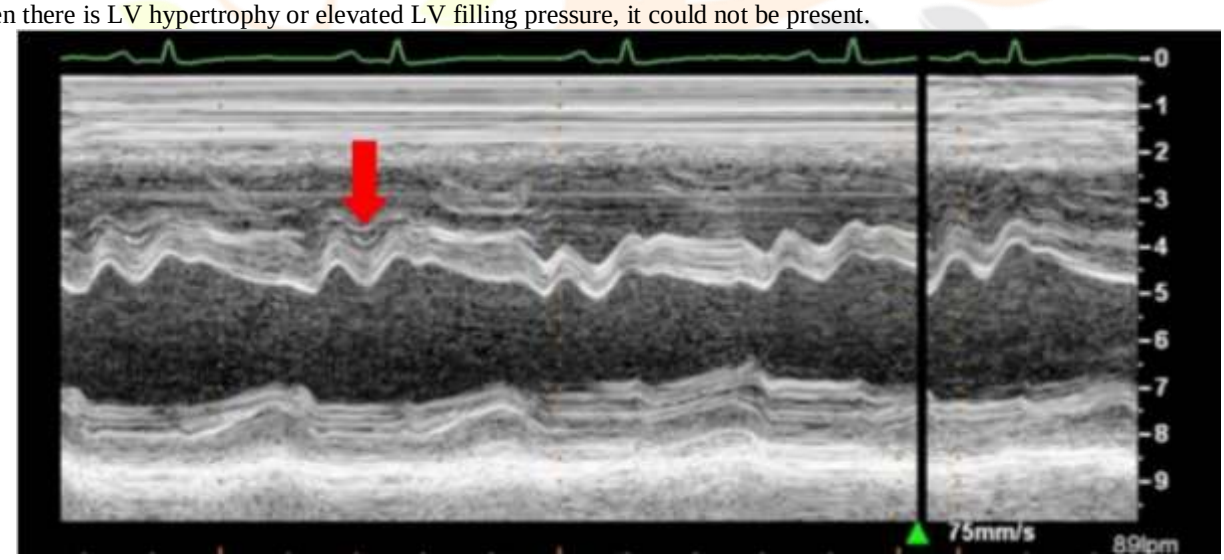

Fig 7

In the early diastole, the interventricular septum moves in an irrational manner, as indicated by the arrow, which may indicate higher right ventricle filling pressures.

Doppler Echocardiography Doppler echocardiography plays a crucial role in assessing hemodynamic consequences of cardiac tamponade, including intracardiac pressures, filling dynamics, and the presence of respiratory variation in blood flow velocities. Recent advancements in Doppler techniques, such as tissue Doppler imaging and pulse wave Doppler, improve the accuracy of hemodynamic assessment and aid in differentiating cardiac tamponade from other causes of hemodynamic instability.
Pulse-containing waves Doppler is crucial when assessing respiratory variations in transvalvular flows in cardiac tamponade patients. The doppler peak velocities of the tricuspid and pulmonary valves rise during inspiration, yet the mitral and aortic valves of healthy people breathing on their own show a decrease in these same velocities, they decrease. As was previously indicated in this paper, a normal variation of 5% or so in cardiac output is associated with a regular breathing cycle. A typical peak E-wave fluctuation of up to 10% reflects this volatility.

These Doppler velocity differences are more pronounced in cardiac tamponade.

4.Clinical Implications:

1. Early Diagnosis and Risk Stratification: Advanced echocardiographic techniques enable early diagnosis of cardiac tamponade and facilitate risk stratification based on the severity of hemodynamic compromise. Timely recognition of high-risk patients allows for prompt intervention, such as pericardiocentesis or surgical decompression, thereby improving outcomes.

2. Monitoring Response to Therapy: Echocardiography provides real-time monitoring of hemodynamic changes in response to therapeutic interventions. Serial echocardiographic assessments help evaluate the efficacy of pericardial drainage and guide further management decisions.
3. Integration with Multimodal Imaging: Integration of echocardiography combining other imaging techniques, such magnetic resonance imaging (MRI) and computed tomography (CT), offers comprehensive evaluation of cardiac tamponade, especially in complex cases or when additional information is needed for surgical planning.

When cardiac tamponade is diagnosed, a high-risk patient is identified, who has a higher chance of problems during follow-up and a non-viral aetiology. It is best to admit the patient for therapy and observation.

Pericardiocentesis is the only treatment that is certain to work, and depending on the clinical presentation, it should be done immediately.

5.Analysis

In this research, we looked at the accuracy of echocardiography in diagnosis of people. who had heart surgery in the past. Out of 8974 patients, 105 had a cardiac tamponade, with a 30-day death rate of 8.6%. With a 77% chance of confirming the identification of cardiac tamponade and an 88% probability of ruling it out, echocardiography's overall diagnostic accuracy was judged sufficient. Our data did, however, indicate that TTE and TEE were not very good at differentiating between individuals who had an early cardiac tamponade and those who did not over the first 24 hours following heart surgery. With a 76% and 83% likelihood that the cardiologist could perform a TTE this ability gradually grew throughout the course of the first 24-72 postoperative hours and the 72 hours after surgery, respectively.

As far as we are aware, this research presents the most extensive sample size on the diagnostic capabilities of echocardiography following heart surgery. This stands in conflict to earlier studies that included participants who underwent routine echocardiography. This affects the tamponade risk a priori and, as a result, the echocardiography's diagnostic capabilities.

6.Challenges and Future Directions:

1. Standardization of Techniques: Despite technological advancements, variability in echocardiographic techniques and interpretations remains a challenge. Standardization of imaging protocols and interpretation criteria is essential to ensure consistency and accuracy in diagnosing cardiac tamponade.
2. Training and Education: Adequate training and proficiency in advanced echocardiographic techniques are crucial for clinicians involved in the diagnosis and management of cardiac tamponade. Continuing medical education programs and hands-on training courses play a vital role in enhancing the skills of healthcare providers in this field.
3. Incorporation of Artificial Intelligence (AI): The integration of AI algorithms with echocardiographic imaging holds promise for automated image analysis, pattern recognition, and decision support in the diagnosis of cardiac tamponade. Additional investigation is required to confirm the precision and practical application of AI-based approaches in clinical practice.

7.CONCLUSION

Recent advancements in echocardiographic evaluation have revolutionized the diagnosis and management of cardiac tamponade, offering enhanced imaging capabilities and precise hemodynamic assessment. These technological innovations enable early diagnosis, risk stratification, and monitoring of therapeutic response, ultimately improving patient outcomes. Continued research, standardization of techniques, and integration of AI hold the key to further advancements in this field.

Within the first four weeks following heart surgery, echocardiography's overall diagnostic accuracy is deemed satisfactory in patients suspected of having cardiac tamponade. Only 58% of predictions were positive, the diagnostic accuracy is subpar in the first 24 hours following surgery. Therefore, a high clinical suspicion may lead to an emergency re-examination if tamponade is seen during the first stages of the healing process. More extensive cohort prospective studies are still needed to determine the diagnostic accuracy of transthoracic and transoesophageal echocardiography in individuals who have had heart surgery.

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