Original Article

Artificial intelligence-assisted peri-operative echocardiography: a multicentre observational study

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Summary

Introduction Point-of-care transthoracic echocardiography performed by anaesthetists can influence peri-operative management but is constrained by time, the need for measurements and advanced skill requirements. Artificial intelligence-driven analysis may streamline this assessment and yield benefits to clinicians and patients.

Methods In this prospective multicentre observational study, adult patients who were referred for pre-operative echocardiography were enrolled. Anaesthetists certified in echocardiography acquired a predefined 12-view protocol. The same studies were uploaded to the US2.AI cloud platform, which generated measurements and categorical classifications for 10 key echocardiographic parameters. Manual measurements by clinicians served as the reference standard.

Results Of 206 enrolled patients, 202 (98%) with adequate image quality were analysed. Agreement between artificial intelligence- and clinician-derived continuous measurements was good to excellent for most parameters, with intraclass correlation coefficient values 0.605–0.956 ($p < 0.001$). Left ventricular ejection fraction was strongly correlated ($r = 0.845$, $p < 0.001$) with a mean difference of -1.9%. The US2.AI software classified left ventricular systolic function correctly in 180/201 (91%) patients and left ventricular diastolic dysfunction in 193/201 (96%) patients. Correlations for right ventricular size and function, and right atrial size were strong ($r = 0.860$, 0.743 and 0.842, all $p < 0.001$) with small mean differences. The US2.AI software identified all patients with pulmonary hypertension ($n = 10$) and severe aortic stenosis ($n = 6$) correctly. Agreement for inferior vena cava collapsibility ($r = 0.641$) and cardiac output ($r = 0.675$) was moderate with low mean bias. Cohen's κ for categorical classifications was statistically significant for all parameters ($p < 0.001$).

Discussion Using a limited predefined image sequence, anaesthetists can obtain most information essential for peri-operative decision-making. Agreement between US2.AI and clinicians was high for 10 echocardiographic parameters. These findings support integrating US2.AI into peri-operative echocardiography workflows, with further studies needed to assess its impact on clinical outcomes.

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Introduction

In busy peri-operative clinical settings, the need for transthoracic echocardiography can delay surgery. Peri-operative echocardiography performed by anaesthetists has aided pre-operative assessment in various contexts [1, 2]. Subramaniam et al. observed that focused peri-operative echocardiography led to either simplification (omission of extensive monitoring) or escalation (addition of inotropes, vasopressors, volume infusions or advanced monitoring) in many patients [3]. The European Society of Anaesthesiology and Intensive Care guidelines now recommend that trained anaesthetists perform point-of-care ultrasound for cardiac issues in urgent situations [4]. While trials have not yet shown improved outcomes, pre-operative echocardiography has often prompted diagnostic and management changes [5–7]. Visual estimation remains the most common echocardiographic method [8], with quantitative measurements regarded as an advanced assessment [9].

Artificial intelligence has advanced echocardiography by automating routine measurements, increasing diagnostic accuracy and reducing inter-observer variability [10, 11]. Most research focuses on automating measures of left ventricular systolic function and parameters related to diastolic dysfunction, left atrial structure and right ventricular function [10]. The US2.AI software is a US Food and Drug Administration-approved, vendor-neutral platform which automates cardiac ultrasound analysis, providing measurements and reports instantaneously without human input. Trained on extensive datasets and validated externally, it classifies systolic and diastolic dysfunction precisely [12, 13]. Although promising in cardiology populations, its effectiveness in peri-operative settings remains largely unstudied.

This study aimed to assess the diagnostic accuracy and agreement of US2.AI software with expert clinicians for 10 key echocardiographic parameters in the peri-operative setting. We hypothesised that an artificial intelligence-based algorithm could measure 10 key parameters precisely and reliably from limited image sequences obtained by anaesthetists, with diagnostic agreement comparable with measurements performed by clinicians.

Methods

This was a multicentre, prospective observational study of adult patients scheduled for elective surgery at five tertiary hospitals between March and May 2025. Ethical approval was obtained from the respective institutional review board before enrolment. All patients provided informed consent in accordance with institutional protocols.

This study involved consecutive patients scheduled for surgery who required pre-operative echocardiography based on clinical indications. Inclusion criteria included: adult patients capable of undergoing echocardiographic examination on the day of surgery; patients willing to provide informed consent; and outpatients or inpatients scheduled for elective surgery. Pregnant people; patients with poor-quality echocardiographic images (such as inability to derive more than seven of the predefined 10-parameters); and those admitted to the intensive care unit for mechanical ventilation with vasoactive support were not studied.

The study involved a predefined 12-image transthoracic echocardiographic sequence. The same images were measured by two methods: manual measurement by an expert clinician certified in echocardiography to assess 10 parameters; and uploading the same images to US2.AI for analysis. The study investigators participated in a dedicated online training session to familiarise themselves with the US2.AI software. Each study was analysed by the local clinician, who was blinded to the artificial intelligence-generated measurements but not to patient clinical status, reflecting real-world practice. No intervention by clinicians was made during the US2.AI measurements. This was an external validation study for US2.AI, which is US Food and Drug Administration-approved software [14]. The US2.AI output had no impact on patient care pathways.

During the procedure, the investigator (an anaesthetist certified in echocardiography by either the American Society of Echocardiography or the European Association of Cardiovascular Imaging with a minimum of 5 years' experience) performed echocardiography. A predefined 12-image/loop sequence was used for image acquisition, capturing images and Doppler measurements in the following views: parasternal long-axis; apical four-, two-, five-chamber and long-axis; and subcostal (online Supporting Information Figure S1). The analysis included 10 parameters of left and right ventricular function, and valvular abnormalities such as aortic valve stenosis and haemodynamic parameters (see online Supporting Information Figure S2). Clinicians assessed 10 parameters: left ventricular ejection fraction; left ventricular diastolic function; left ventricular size; right ventricular size; tricuspid annular plane systolic excursion; right atrial area; inferior vena cava diameter measured in the subcostal long axis; pulmonary hypertension; aortic valve stenosis; and left ventricular outflow tract stroke volume. These parameters

were measured and categorised wherever applicable according to standardised guidelines [15–18]. Each echocardiogram had only one reference report. If initial recordings were suboptimal in quality, they were repeated. Persistent poor-quality images led to patients being omitted from analysis.

The consistency of continuous measurements from two different methods was evaluated using a two-way random-effects intra-class correlation to assess absolute agreement across single measures. To explore the relationship between the two methods, Pearson's correlation coefficient and linear regression were used. Agreement for continuous measures was assessed using Bland–Altman analysis. For categorical outcomes, Cohen's κ was used to assess agreement between methods. A p value < 0.05 indicated statistical significance. Statistical analysis was performed using RStudio Desktop (RStudio Team 2025, Boston, MA, USA).

No formal a priori sample size calculation was performed. This multicentre pilot validation study focused on the feasibility and agreement of artificial intelligence-assisted echocardiographic quantification vs. the reference standard in routine clinical acquisitions. The target sample of approximately 200 patients was selected a priori to enable stable estimation of agreement and reliability, rather than hypothesis testing of clinical outcomes. This size aligns with recommendations for method comparison studies, balancing the precision of agreement estimates with the feasibility of multicentre data harmonisation and expert review. Findings will inform workflow integration, highlight measurement domains requiring refinement and guide the design of a precision-based sample-size calculation for a future definitive prospective study.

Results

During the study period from March to May 2025, 206 patients undergoing different surgeries were enrolled across five centres. Four patients were not included due to poor image quality with fewer than seven predefined parameters obtained. The final analysis included 202 patients (Table 1). Parameters measured included: left ventricular systolic and diastolic function together with left ventricular and right atrial size (n = 201); right ventricular size (n = 199); aortic stenosis assessment (n = 193); and right ventricular function, cardiac output and pulmonary hypertension assessment (n = 188) (Fig. 1). In 168 patients, at least one echocardiographic abnormality was present (online Supporting Information Figures S3–S6).

Table 1 Characteristics of the study population of 202 patients undergoing echocardiographic examination before surgery. Values are number (proportion) or mean (SD).

Female	61 (30%)
Age; y	55 (14)
Body surface area; m^2	1.7 (0.2)
Comorbidities	
Hypertension	145 (72%)
Type 2 diabetes mellitus	122 (60%)
Coronary artery disease	108 (54%)
Chronic kidney disease	8 (4%)
Surgical categories	
Cardiac	102 (51%)
Orthopaedic	26 (13%)
Laparoscopic	15 (7%)
Urological	28 (14%)
Gynaecological	18 (9%)
Neurosurgery	13 (6%)

There was good agreement between clinician-assessed and US2.AI measurements across several parameters, with interclass correlation coefficient values ranging from 0.605 to 0.956 (Table 2). Left ventricular ejection fraction was normal in 145 (72%) patients, mildly abnormal in 37 (18%), moderately abnormal in 17 (8%) and severely abnormal in 2 (1%) patients. Left ventricular size was abnormal in 22 (11%) patients. Left ventricular size was classified correctly in 193 (96%) patients, overclassified in 5 (2%) patients, and under classified in three (1%) patients. Diastolic function was classified as normal in 131 (65%) patients and abnormal in 14 (7%). In patients with reduced ejection fraction or suspected cardiac disease, diastolic dysfunction grades 1, 2 and 3 were noted in 36 (18%), 5 (2%) and 16 (8%) patients, respectively.

There was a strong and statistically significant correlation with minimal mean differences within acceptable limits of agreement across various parameters of left ventricular function between the clinician-performed and US2.AI measurements for left ventricular function (online Supporting Information Figure S7). Left ventricular ejection fraction showed a correlation coefficient of 0.845 (p < 0.001) and a mean difference of -1.9% between the two methods. For left ventricular systolic function, 180 (90%) of cases were correctly classified by the US2.AI method when compared with clinician-performed studies, while 8 (4%) were over-classified and 13 (6%) were under-classified. For left ventricular diastolic dysfunction, 193 (96%) of cases were classified correctly by the US2.AI method when

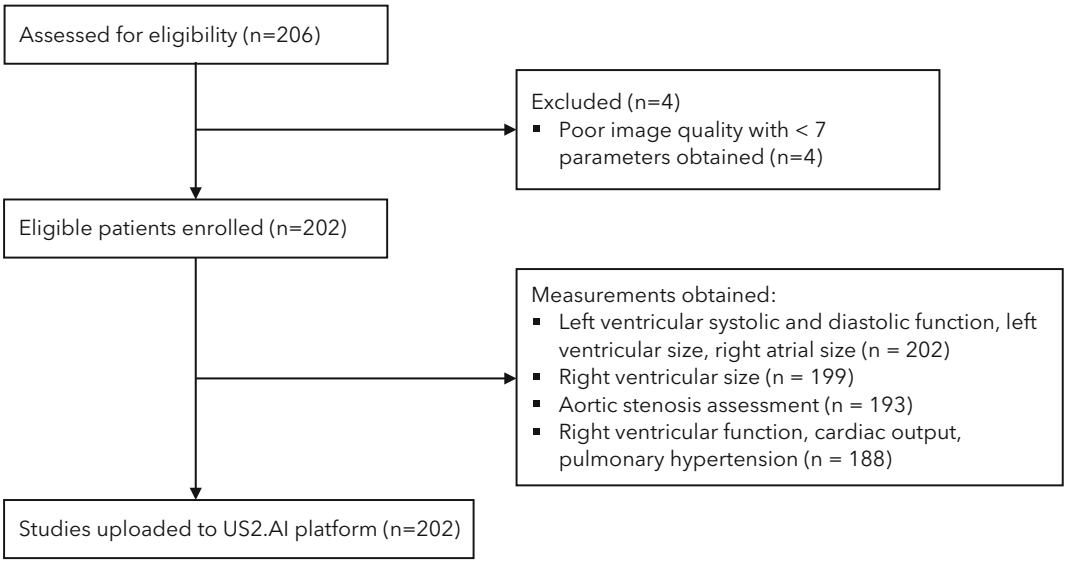

Figure 1 Study flow diagram.

Table 2 Intra-class correlation to assess reliability between clinician- and US2.AI-assessed measurements.

	Interclass correlation (95%CI)	p value
Left heart assessment		
Left ventricular ejection fraction; %	0.833 (0.761–0.881)	< 0.001
E/A ratio	0.956 (0.942–0.967)	< 0.001
E/e' mean	0.944 (0.927–0.958)	< 0.001
Indexed left atrial volume; $ml.m^{-2}$	0.753 (0.579–0.845)	< 0.001
Right heart assessment		
Right heart internal basal diameter during diastole; mm	0.856 (0.812–0.890)	< 0.001
Tricuspid annular plane systolic excursion; mm	0.736 (0.663–0.795)	< 0.001
Right atrial area; cm^2	0.827 (0.758–0.875)	< 0.001
Valvular assessment		
Left ventricular outflow tract; mm	0.596 (0.394–0.725)	< 0.001
Indexed aortic valve area; $cm^2.m^{-2}$	0.731 (0.654–0.792)	< 0.001
Pulmonary hypertension (tricuspid regurgitation maximum velocity; $m.s^{-1}$)	0.742 (0.712–0.783)	< 0.001
Haemodynamic assessment		
Indexed stroke volume; $ml.m^{-2}$	0.692 (0.565–0.780)	< 0.001
Cardiac index; $l.min.m^{-2}$	0.621 (0.479–0.723)	< 0.001
Inferior vena cava collapsibility index; %	0.605 (0.451–0.716)	< 0.001

compared with the clinician-assessed method, while 6 (3%) were over-classified and 2 (1%) were under-classified (online Supporting Information Tables S1 and S2).

For echocardiographic parameters of right heart assessment measured by clinicians, right ventricular size was abnormal in 7 (4%); right ventricular function was abnormal in 25 (13%); and right atrial size was abnormal in 6 (3%). There was a strong correlation between the clinician-performed and US2.AI measurements, with r values of 0.860, 0.743 and 0.842 for right ventricular size, right ventricular function and right atrial size, respectively (all $p < 0.001$). The mean difference between the two methods was minimal (online Supporting Information Figure S8). Pulmonary hypertension was suspected using

echocardiographic criteria for clinician-performed measurements in 10 (5%) patients, and US2.AI correctly identified this in all patients.

Mean (SD) clinician-assessed left ventricular outflow tract diameter was 19 (2.81) mm, while the US2.AI measurement was 20 (1.90) mm. Mean (SD) clinician-assessed left ventricular outflow tract velocity-time integral and aortic valve velocity-time integral were 18 (4.1) cm and 29 (6.2) cm, respectively; and these values were 18 (3.8) cm and 27 (5.5) cm with the US2.AI method. Mean (SD) aortic valve area and indexed aortic valve area were 2.13 (0.55) cm^2 and 1.2 (0.40) $cm^2.m^{-2}$ using clinician assessment vs. 2.02 (0.58) cm^2 and 1.19 (0.36) $cm^2.m^{-2}$ with US2.AI (online Supporting Information Figure S9) method. Aortic stenosis was classified as mild, moderate and severe in one, three and six patients, respectively. The US2.AI software diagnosed severe aortic stenosis in all six patients (see online Supporting Information Table S3).

There was a strong correlation between clinician- and US2.AI-assessed measurements for inferior vena cava collapsibility with an r value of 0.641 and a mean difference of 5.65%. Similarly, there was a strong correlation for indexed cardiac output with an r value of 0.675 and a mean difference of 0.23 $l.m^{-2}$ (online Supporting Information Figure S10). Across several echocardiographic parameters, Cohen's κ values were statistically significant ($p < 0.001$ for all parameters) (Tables 3 and 4).

Table 3 Cohen's κ to assess agreement between clinician- and US2.AI-assessment of echocardiographic parameters.

Variable	κ statistic (95%CI)	p value
Left ventricular systolic function	0.818 (0.746–0.891)	< 0.001
Left ventricular diastolic function	0.868 (0.800–0.937)	< 0.001
Left ventricular size	0.804 (0.672–0.935)	< 0.001
Right ventricular size	1.000 (1.000–1.000)	< 0.001
Right ventricular function	0.723 (0.575–0.871)	< 0.001
Right atrial size	1.000 (1.000–1.000)	< 0.001
Pulmonary hypertension	1.000 (1.000–1.000)	< 0.001
Aortic stenosis	0.980 (0.941–1.000)	< 0.001

Discussion

We have confirmed our hypothesis that the US2.AI software was able to analyse and measure 10 echocardiographic parameters that correlated strongly with clinician-derived measurements. The differences between the two methods were minimal with acceptable limits of agreement. This software could therefore identify and categorise most diagnoses, which have important implications for peri-operative prognostication, monitoring and management.

Pre-operative echocardiography performed by anaesthetists can affect management decisions [3, 5, 6]. However, existing studies have not shown a reduction in mortality, likely due to study design limitations and the predominant use of qualitative or limited quantitative methods rather than guideline-recommended quantitative assessment [5, 6]. Comprehensive evaluation requires multiple parameters and is difficult to apply in time-pressured clinical practice.

Table 4 Mean (SD) difference and limits of agreement between the clinician- and US2.AI-assessment of echocardiographic parameters.

	Mean (SD) difference	Limits of agreement	Range
Left ventricular ejection fraction; %	-1.90 (5.46)	-8.79–12.6	21.39
E/A	-0.03 (0.19)	-0.41–0.36	0.77
E/e'	0.21 (1.95)	-3.62–4.04	7.66
Indexed left atrial volume; $ml.m^{-2}$	-3.12 (5.98)	-14.85–8.61	23.46
Right ventricular internal diameter in diastole; mm	0.61 (3.07)	-5.41–6.63	12.04
Tricuspid annular plane systolic excursion; mm	0.20 (3.13)	-5.94–6.34	12.28
Left ventricular outflow tract; mm	-0.87 (1.7)	-4.21–2.47	6.68
Right atrial area; cm^2	-0.56 (1.71)	-3.91–2.79	6.70
Indexed aortic valve area; $cm^2.m^{-2}$	-0.05 (0.27)	-0.58–0.49	1.07
Indexed stroke volume; $ml.m^{-2}$	-2.61 (6.71)	-15.76–10.53	26.29
Cardiac index; $l.min^{-1}.m^{-2}$	-0.23 (0.58)	-1.37–0.91	2.28
Inferior vena cava collapsibility index; %	5.65 (13.84)	-21.47–32.77	54.24

Artificial intelligence can help automate key echocardiographic tasks with high precision. Typical workflows include view classification; segmentation; labelling; and quantification [10]. A convoluted neural network trained on 10,000 apical four-chamber videos predicted ejection fraction with a 4–6% error and detected heart failure with reduced ejection fraction [19]. In a randomised study of board-certified cardiologists adjudicating 3495 echocardiographic exams, artificial intelligence-guided initial ejection fraction assessment was non-inferior, and sometimes superior, to sonographer-guided assessment [20]. A validation study of US2.AI showed close agreement with local measurements, with mean absolute errors of 9–25 ml for left ventricular volume and 6–10% for ejection fraction [12]. Similarly, our study has shown strong agreement between clinician-measured and artificial intelligence-derived ejection fraction ($r = 0.845$, $p < 0.001$). The artificial intelligence algorithm classified left ventricular ejection fraction categories correctly in 90% of patients and identified left ventricular dilatation accurately in most patients. These findings are important prognostically, as chronic heart failure is associated independently with major adverse cardiovascular events, mortality and severe postoperative complications after non-cardiac surgery [21, 22].

Correct assessment of diastolic dysfunction requires multiple parameters and complex algorithms [16]. A validation study of US2.AI showed that the software measured various parameters correctly [13]. We have shown that US2.AI measured e', E/e', E/A, left atrial volume and tricuspid regurgitation velocity accurately, and assigned the correct diastolic dysfunction grade to > 92% of patients (online Supporting Information Appendices S1 and S2). This can be crucial for modifying intra-operative monitoring and management.

Grade 1 diastolic dysfunction is characterised by normal left atrial pressures and typically requires avoiding tachycardia and optimising left ventricular filling. In contrast, grades 2 and 3 diastolic dysfunction is preload-intolerant and requires careful diuretic titration and early vasopressor therapy for haemodynamic instability [23]. Appropriate diastolic dysfunction grading is prognostically important, as higher grades are associated with adverse short- and long-term outcomes across multiple surgical categories [24–27]. Rapid and accurate identification of diastolic dysfunction during pre-operative evaluation by anaesthetists has the potential to improve patient care.

Another important aspect of pre-operative echocardiographic assessment is evaluating right ventricular function and identifying patients living with pulmonary hypertension. A large body of literature indicated that patients with pre-operative right ventricular dysfunction have adverse postoperative outcomes [28–32]. We found a strong correlation between clinician-derived and US2.AI measurements, with r values of 0.860 for right ventricular size and 0.743 for right ventricular function. Mortality is very high (15–50%) for patients with pulmonary hypertension undergoing emergency surgery [33], and they experience a four-fold higher adjusted mortality even during elective procedures such as joint replacement [34]. It is useful, therefore, to evaluate and optimise patients with severe pulmonary hypertension [35] or refer them appropriately. In our study, the US2.AI software identified all 10 patients with severe pulmonary hypertension.

A meta-analysis of seven studies involving 29,327 patients showed that patients with aortic stenosis undergoing non-cardiac surgery have higher rates of adverse cardiovascular events than those without aortic stenosis [35]. A more recent and larger meta-analysis, including 14 studies and 2,885,254 patients, showed that patients with aortic stenosis undergoing non-cardiac surgery face a markedly elevated peri-operative risk [36]. The analysis found that individuals with severe aortic stenosis had an almost 10% mortality rate within 30 days of surgery. An overall absolute mortality rate of 3.8% across all severities of aortic stenosis in non-cardiac surgical patients highlights the considerable challenges involved in peri-operative management for this population [36]. Peri-operative risk is higher in symptomatic patients than in asymptomatic ones, especially among those with reduced left ventricular ejection fraction; more severe aortic stenosis; concomitant pulmonary hypertension; and in emergency vs. elective non-cardiac surgeries. Therefore, the American Heart Association guidelines recommend a heart team approach for managing this high-risk group [37].

Severe aortic stenosis assessment requires multiple views and Doppler assessments at an advanced skill level [18]. Krishna et al. showed that the US2.AI application could mimic closely human measurement of all relevant parameters during aortic stenosis severity assessment. They also concluded that this technology might reduce interscan variability, improve the interpretation and diagnosis of aortic stenosis and facilitate precise, reproducible identification and management of patients with aortic stenosis [38]. Our findings support those conclusions.

Most previous studies focused on a single aspect of automated echocardiographic measurements [12, 13, 39]. To our knowledge, this is one of the first multicentre studies to evaluate artificial intelligence-based comprehensive echocardiographic analysis of multiple echocardiographic parameters using a limited peri-operative acquisition

protocol performed by anaesthetists. Identifying patients at higher peri-operative risk can ensure appropriate expertise is allocated to these high-risk groups.

Two open-source models have been released that can perform multiple B-mode and Doppler measurements without human intervention: EchoNet [40]; and PanEcho [41]. EchoPrime, a multi-view, view-informed, video-based vision-language foundation model trained on 12 million videos, generates a comprehensive, clinical echocardiographic report [42]. These represent significant advances towards automating echocardiographic measurements, which must be validated across diverse patient populations before widespread clinical use, particularly in the pre-operative population which poses unique challenges for anaesthetists. Our study validates a clinically deployed and validated platform, whereas these open-source models have not yet been validated.

Our study has limitations. The report generation depends on image quality and no software is expected to produce reliable reports from poor-quality images. The study lacked image-quality control and instead we relied on at least seven of the 10 predefined parameters. Regarding valvular pathology, the software is currently applicable only to tricuspid regurgitation and aortic stenosis. Other valve abnormalities, such as mitral regurgitation, mitral stenosis and aortic regurgitation, were not assessed per the study protocol. The presence of significant pericardial effusion was also not studied. We did not measure the exact time required for a clinician to generate a report compared with the software; however, the software typically produces a report in < 2 min. Because this was a pilot multicentre validation study, the sample size was not powered for subgroup analyses or for detecting small differences between methods in clinical decision thresholds. These analyses will be incorporated in a future prospective trial with predefined non-inferiority margins and a formal precision-based sample size calculation for primary agreement endpoints.

With a limited predefined sequence of images, anaesthetists can extract most of the information essential for peri-operative decision-making. There was high agreement between the US2.AI software and clinicians for 10 echocardiographic parameters. Our findings support the integration of US2.AI into peri-operative echocardiography workflows, with further studies needed to evaluate its impact on clinical outcomes.

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Supporting Information

Additional supporting information may be found online via the journal website.

Appendix S1. Example US.AI2 output for a patient undergoing echocardiography due to breathlessness on exertion before laparoscopic hysterectomy.

Appendix S2. Example US.AI2 output for a patient undergoing echocardiography due to a murmur on auscultation before arteriovenous fistula formation.

Table S1. Comparison of left ventricular systolic function between clinician- and US2.AI-assessments.

Table S2. Comparison of left ventricular diastolic dysfunction between clinician- and US2.AI-assessments.

Table S3. Comparison of aortic stenosis identification and grading between clinician- and US2.AI-assessments.

Figure S1. Image acquisition sequence.

Figure S2. Sample measurements parameters by US.AI2 software.

Figure S3. Left ventricular assessment by US2.AI software.

Figure S4. Right heart assessment by US2.AI software.

Figure S5. Valve assessment by US2.AI software.

Figure S6. Haemodynamic parameter assessment by US2.AI software.

Figures S7–S10. Correlation and agreement of various parameters of: left ventricular function assessment; right heart function assessment; aortic valve assessment; and haemodynamic assessment.

Table S1 Comparison of left ventricular systolic function between clinician and US2.AI assessments.

US2.AI-assessed left ventricular systolic function	**Clinician-assessed left ventricular systolic function**				**Total**
	Severely abnormal	**Moderately abnormal**	**Mildly abnormal**	**Normal**	
Severely abnormal	2	1	0	0	3
Moderately abnormal	0	10	1	0	11
Mildly abnormal	0	6	29	6	41
Normal	0	0	7	139	146
Total	2	17	37	145	201

Table S2 Comparison of left ventricular diastolic dysfunction between clinician and US2.AI assessments.

US2.AI-assessed left ventricular diastolic dysfunction	**Clinician-assessed left ventricular systolic dysfunction**					**Total**
	Grade III	**Grade II**	**Grade I**	**Abnormal**	**Normal**	
Grade III	13	0	0	0	0	13
Grade II	0	5	0	0	0	5
Grade I	1	0	31	2	5	39
Abnormal	1	0	0	12	0	13
Normal	1	0	5	0	125	131
Total	16	5	36	14	130	201

Table S3 Comparison of aortic stenosis identification and grading between clinician and US2.AI assessments.

US2.AI assessed aortic stenosis	Clinician assessed aortic stenosis				Total
	Severe	Moderate	Mild	No	
Severe	6	1	0	0	7
Moderate	0	2	0	0	2
Mild	0	0	1	0	1
No	0	0	0	183	183
Total	6	3	1	183	193

Figure S1 Image acquisition sequence.

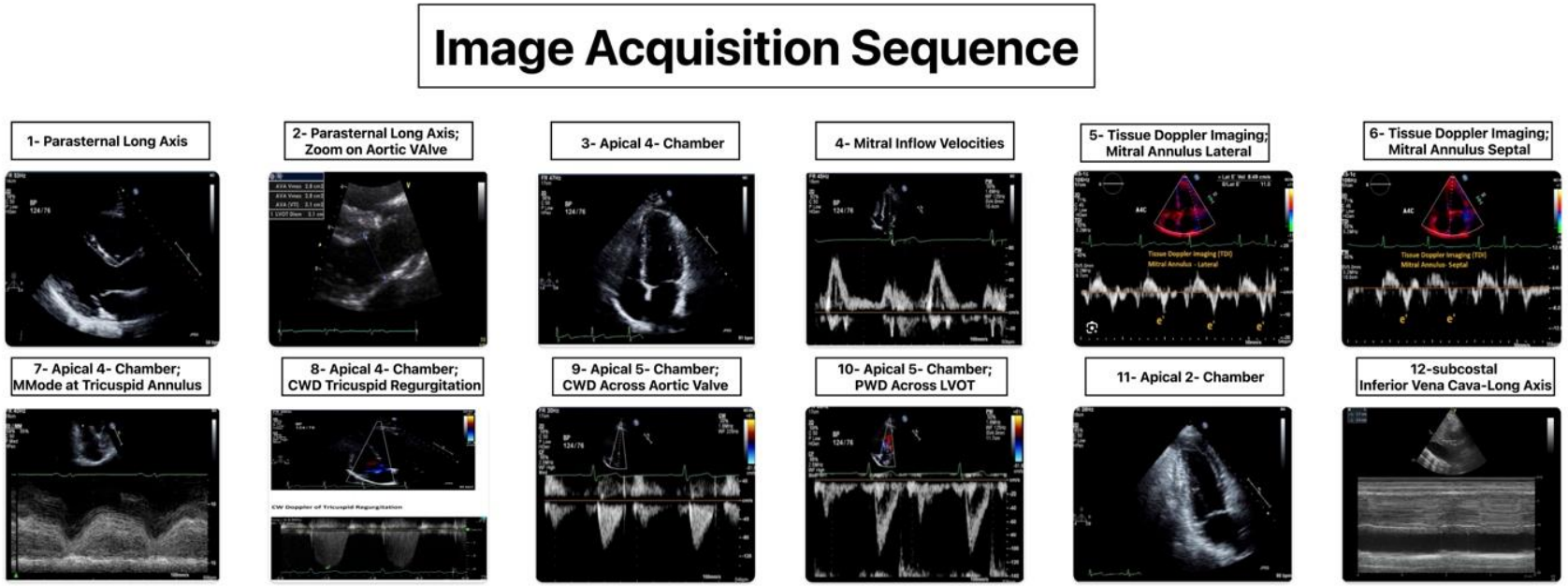


Figure S2 Sample measurements parameters by US.AI2 software. A) Measurement of left ventricular end systolic volume for left ventricular ejection fraction for systolic function assessment and left atrial end systolic volume for left ventricular diastolic function assessment in apical 2-chamber view. B) Measurement of mitral valve inflow velocities (E, A, E/A ratio) for left ventricular diastolic function assessment in apical 4-chamber view. C) Measurement of tissue Doppler velocities (e') at mitral annulus for left ventricular diastolic function assessment in apical 4-chamber view. D) Continuous wave Doppler measurement across aortic valve to assess aortic valve stenosis severity in apical 5-chamber view. E) Measurement of tricuspid regurgitation velocity to estimate systolic pulmonary artery pressure in apical 4-chamber view. F) Measurement of tricuspid annular plane systolic excursion for right ventricular systolic function assessment in apical 4-chamber view.

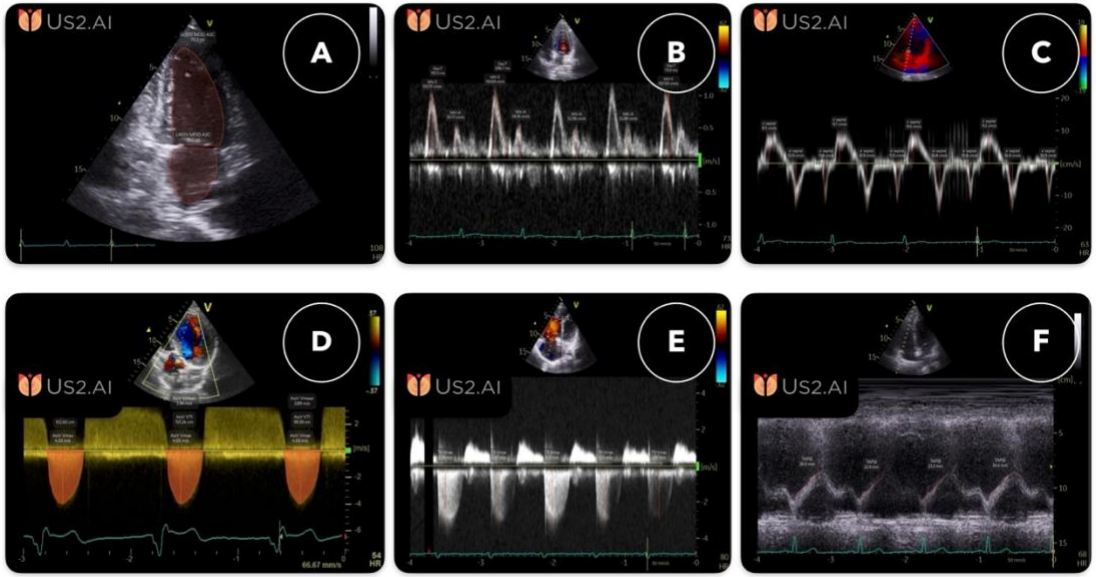


Figure S3 Left ventricular assessment by US2.AI software.

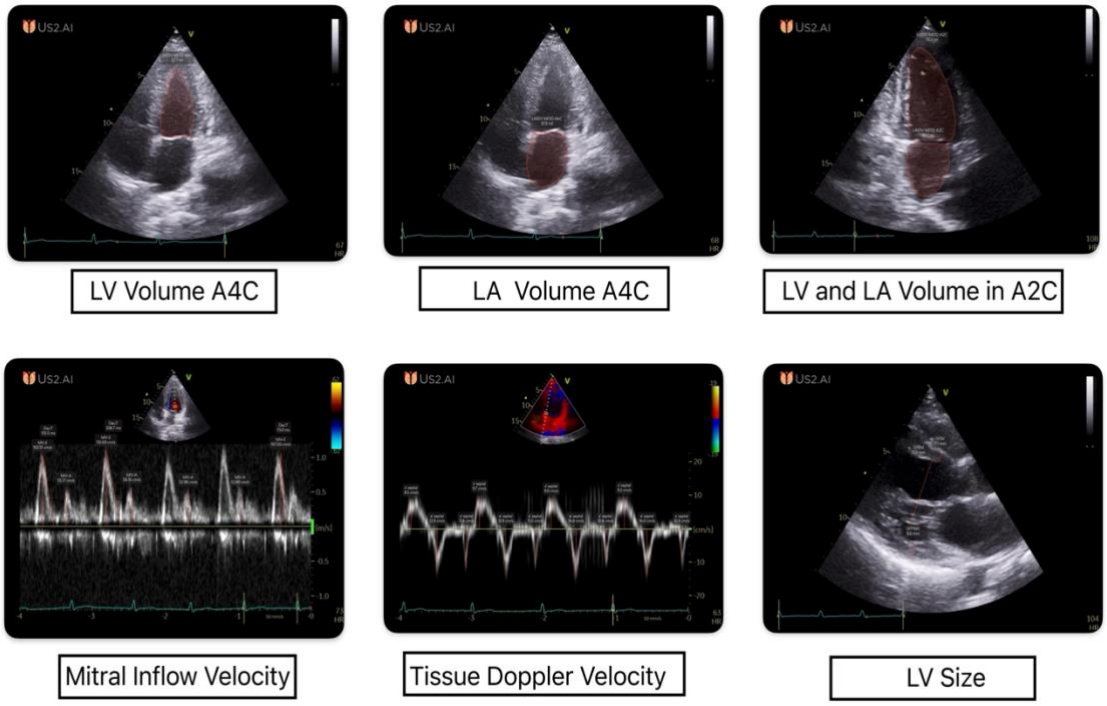


Figure S4 Right heart assessment by US2.AI software.

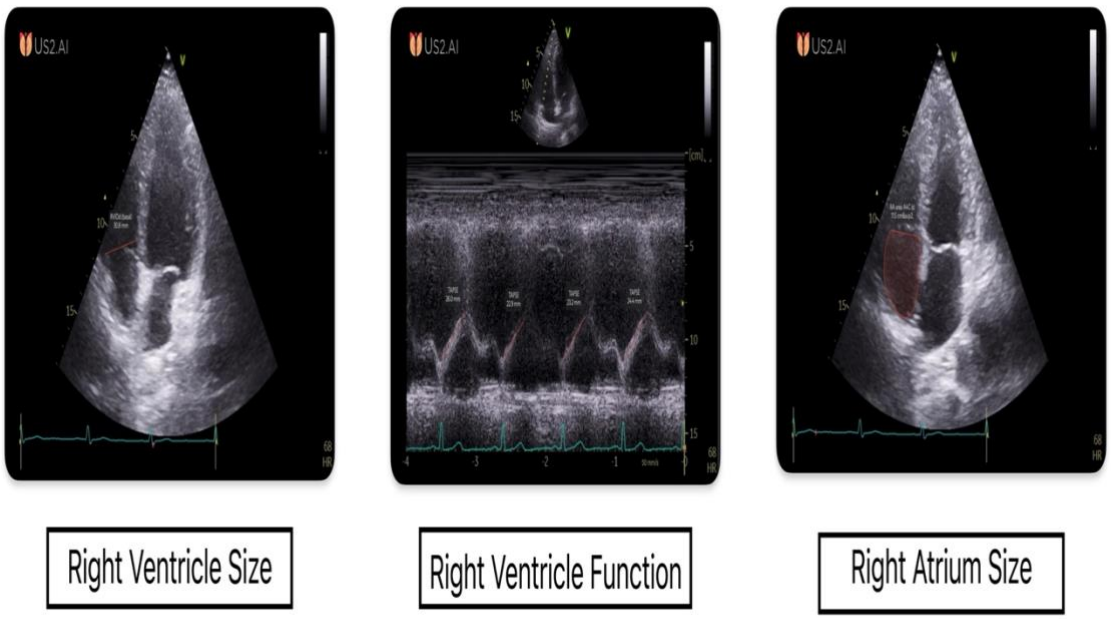
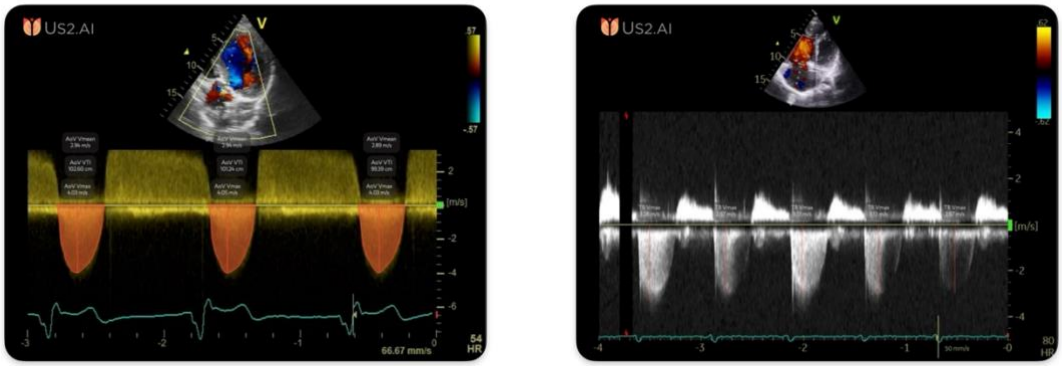


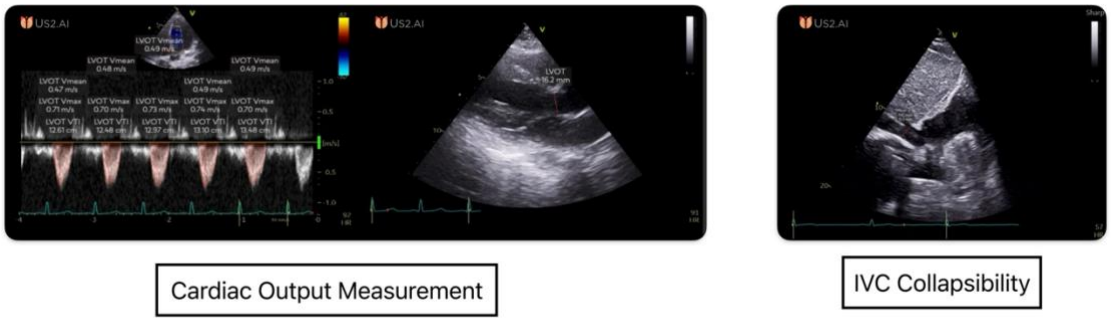
Figure S5 Valve assessment by US2.AI software.



Aortic Stenosis

Tricuspid Regurgitation

Figure S6 Haemodynamic parameter assessment by US2.AI software.



Cardiac Output Measurement

IVC Collapsibility

Figure S7 Correlation and agreement of various parameters of left ventricular function assessment A) Scatter plot with Pearson's correlation coefficient (r=0.848; p<0.001) for clinician assessed with US2.AI for left ventricular ejection fraction. B) Bland- Altman plot for left ventricular ejection fraction demonstrating mean difference -1.90% between clinician assessed and US2.AI method. C)Scatter plot with Pearson's correlation coefficient (r=0.945; p<0.001) for clinician assessed with US2.AI for E/e' ratio. D) Bland- Altman plot for E/e' demonstrating mean difference of 0.21 between clinician assessed and US2.AI method. E) Scatter plot with Pearson's correlation coefficient (r=0.957; p<0.001) for clinician assessed with US2.AI for E/A ratio. F) Bland- Altman plot for E/A ratio demonstrating mean difference -0.03 between clinician assessed and US2.AI method. G) Scatter plot with Pearson's correlation coefficient (r=0.803; p<0.001) for clinician assessed with US2.AI for indexed left atrial systolic volume. H) Bland- Altman plot for indexed left atrial systolic volume demonstrating mean difference -3.12 ml.m^{-2} between clinician assessed and US2.AI method.

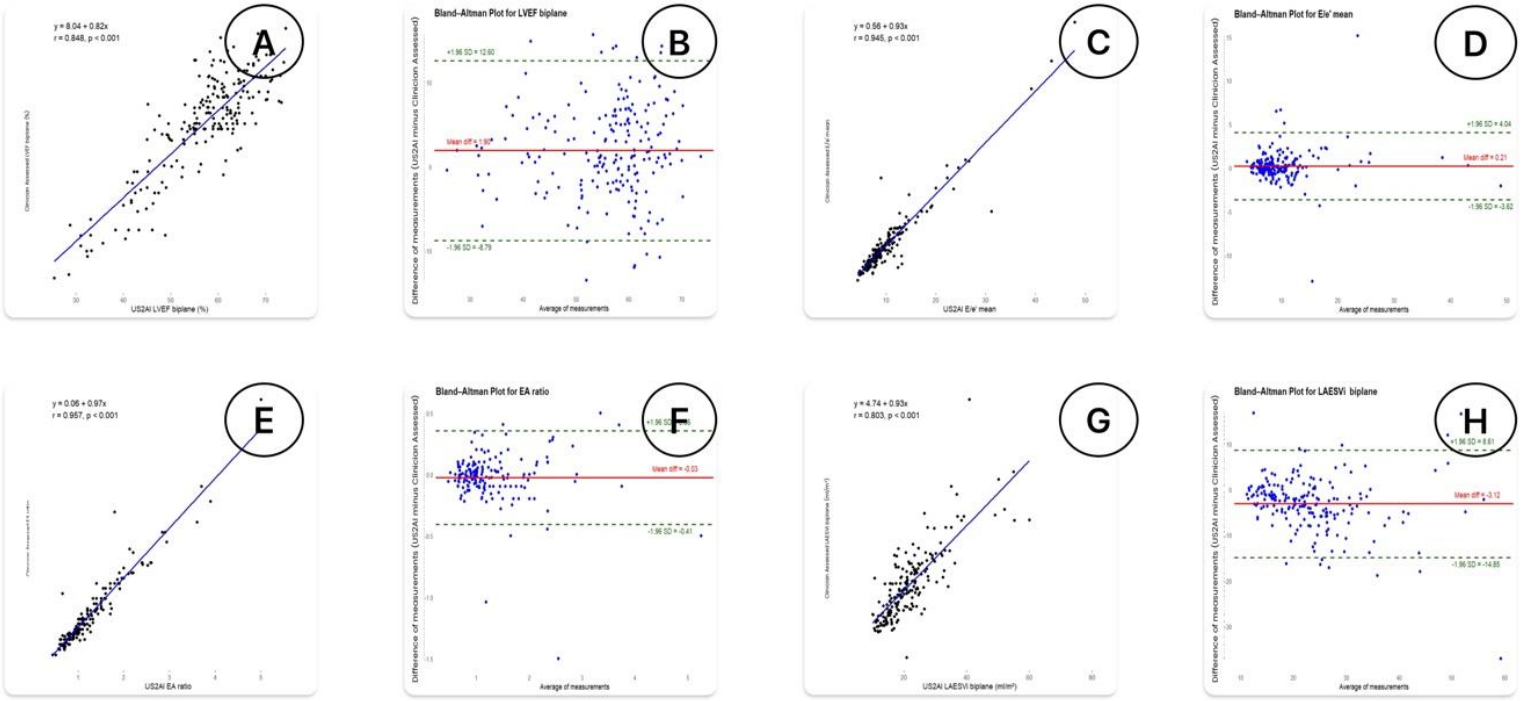


Figure S8 Correlation and agreement of various parameters of right heart function assessment. A) Scatter plot with Pearson's correlation coefficient (r=0.860; p<0.001) for clinician assessed with US2.AI for right ventricular size as assessed by right ventricular basal diameter. C) Bland-Altman plot for right ventricular size demonstrating mean difference 0.61mm between clinician assessed and US2.AI method. D) Scatter plot with Pearson's correlation coefficient (r=0.743; p<0.001) for clinician assessed with US2.AI for right ventricular function as measured by tricuspid annular plane systolic excursion. E) Bland- Altman plot for right ventricular function demonstrating mean difference between clinician assessed and US2.AI method 0.20 mm in tricuspid annular plane systolic excursion. F) Scatter plot with Pearson's correlation coefficient (r=0.842; p<0.001) for clinician assessed with US2.AI for right atrial area. G) Bland- Altman plot for right atrial area demonstrating mean difference -0.56 cm^2 between clinician assessed and US2.AI method.

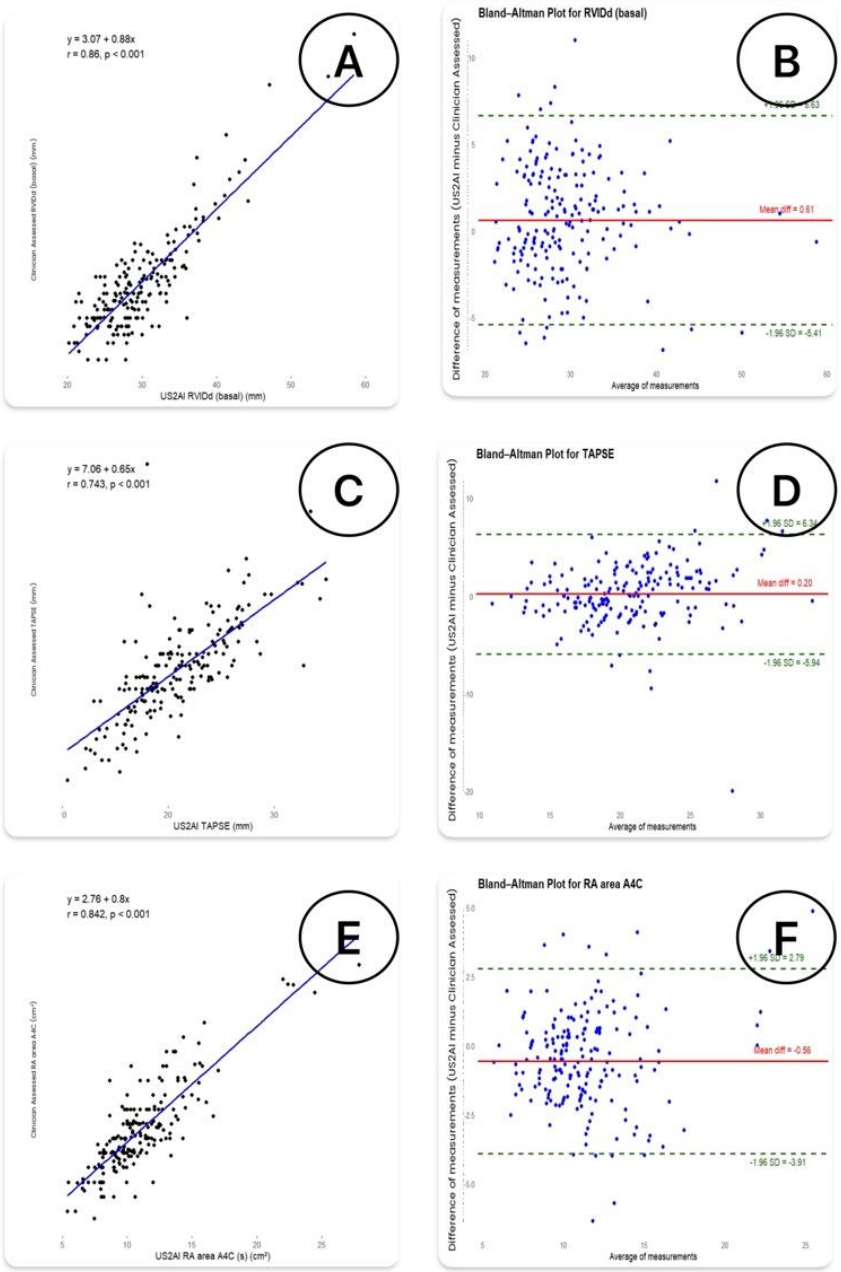


Figure S9 Correlation and agreement of various parameters of the aortic valve assessment. A) Scatter plot with Pearson's correlation coefficient (r=0.656; p<0.001) for clinician assessed with US2.AI for left ventricular outflow tract diameter measurement. B) Bland- Altman plot for left ventricular outflow tract diameter measurement demonstrating mean difference -0.87 mm between clinician assessed and US2.AI method. C) Scatter plot with Pearson's correlation coefficient (r=0.737; p<0.001) for clinician assessed with US2.AI for indexed aortic valve area. D) Bland- Altman plot for indexed aortic valve area demonstrating mean difference -0.05 $cm^2.m^{-2}$ between clinician assessed and US2.AI method.

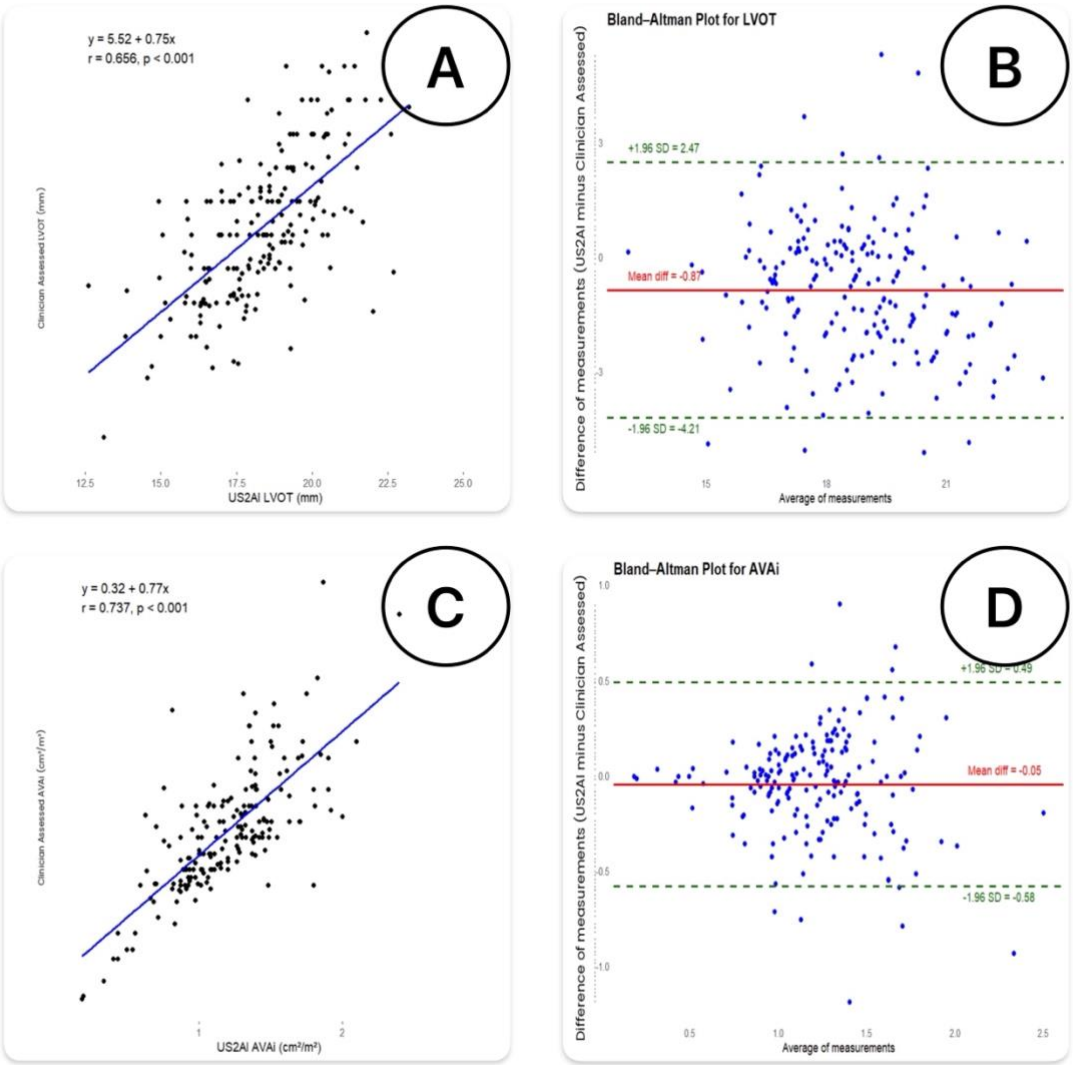
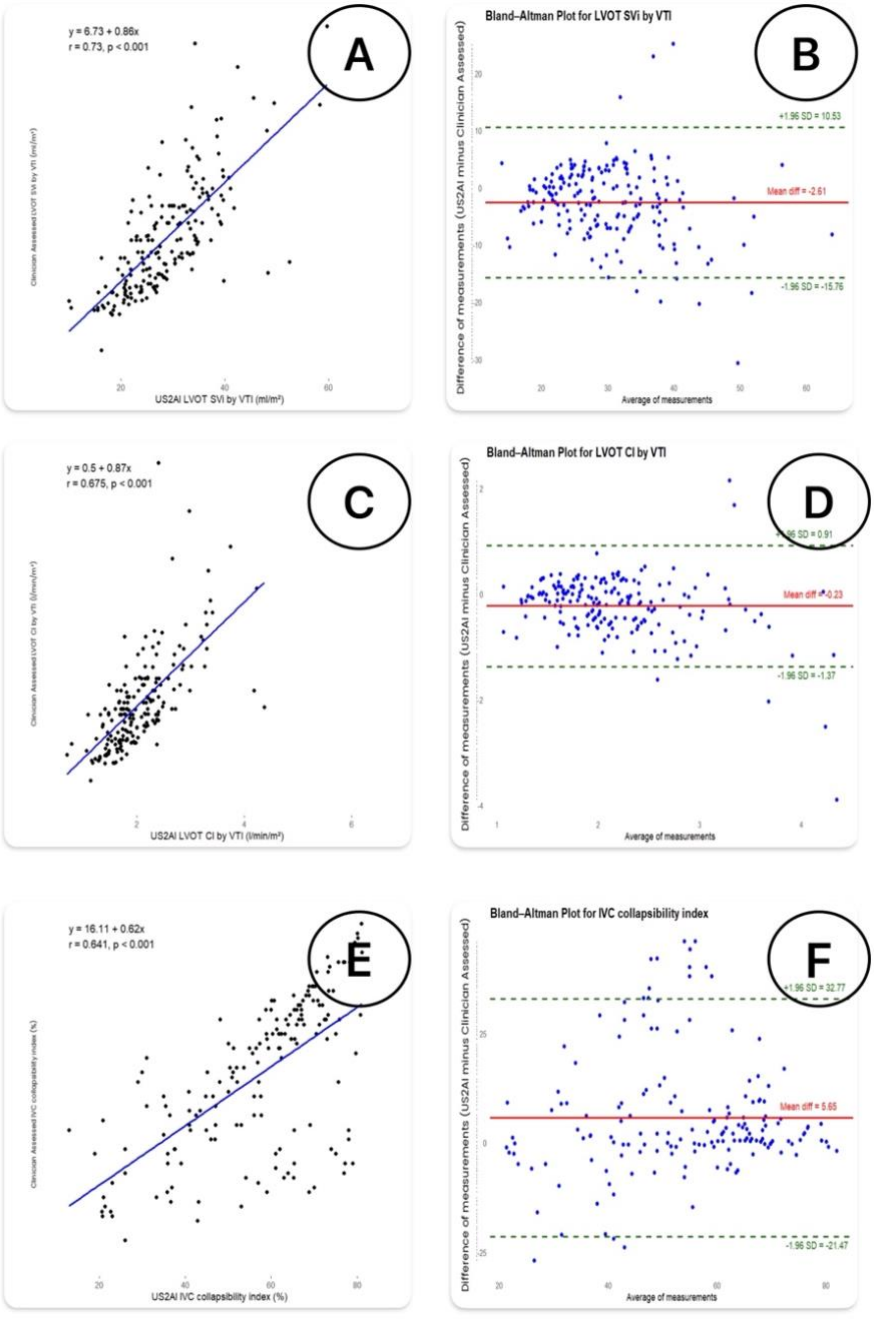


Figure S10 Correlation and agreement of various parameters of haemodynamic assessment. A) Scatter plot with Pearson's correlation coefficient (r=0.730; p<0.001) for clinician assessed with US2.AI for indexed left ventricular outflow tract stroke volume. B) Bland- Altman plot for indexed left ventricular outflow tract stroke volume demonstrating mean difference -2.61 ml.m^{-2} between clinician assessed and US2.AI method. C) Scatter plot with Pearson's correlation coefficient (r=0.675; p<0.001) for clinician assessed with US2.AI for indexed cardiac output. D) Bland- Altman plot for indexed cardiac output demonstrating mean difference -0.23 l.m^{-2} between clinician assessed and US2.AI method. E) Scatter plot with Pearson's correlation coefficient (r=0.641; p<0.001) for clinician assessed with US2.AI for inferior vena cava collapsibility index. F) Bland- Altman plot for inferior vena cava collapsibility index demonstrating mean difference 5.65% between clinician assessed and US2.AI method.



Appendix S1 Example US.AI2 output for a patient undergoing echocardiography due to breathlessness on exertion before laparoscopic hysterectomy.

First Name	-	Last Name	-
Visit Date	07/03/2025 03:58 PM	Gender	Female
Body Surface Area	1.6 m^2	Referral Reason	Dyspnea on Exertion Grade III Prior to Lap Hysterectomy
Age (on exam date)	55	Date of Birth	

Conclusions

- The left ventricular (LV) systolic function is classified as normal.
- The left ventricular (LV) diastolic function is normal.
- The left ventricular (LV) size is normal.
- The right ventricle (RV) global systolic function is normal.
- The right ventricle (RV) size is normal.
- The left atrial (LA) cavity size is normal.
- The right atrial (RA) cavity size is normal.

Main Findings

LV Systolic Function

The left ventricular (LV) systolic function is classified as normal, with a calculated left ventricle ejection fraction (LVEF) of 61.2 % by modified biplane Simpson's method.

LV Diastolic Function

The left ventricular (LV) diastolic function is normal. The E/A ratio is 1.0. The mitral valve E velocity (MV-E) measures at 75.20 cm/s. The septal E' velocity is 9.2 cm/s. The lateral E' velocity is 10.9 cm/s. The average E/e' ratio, which represents the ratio of mitral inflow velocity (E) to average mitral annular early diastolic velocity (e'), at both septal and lateral regions is 7.5. The left atrial end-systolic volume indexed to body surface area (LAESVi) measures 18.5 ml/m^2 by modified biplane Simpson's method.

LV Size

The left ventricular (LV) size is normal. With a left ventricular internal diameter in diastole (LVIDd) measuring 42.2 mm, a left ventricular end-diastolic volume (LVEDV) of 74.7 ml and a left ventricular end-systolic volume (LVESV) of 29.0 ml, both by modified biplane Simpson's method. When indexed to body surface area, the LV end-diastolic volume index (LVEDVi) is 47.8 ml/m^2, and the LV end-systolic volume index (LVESVi) is 18.5 ml/m^2, both of which are within normal limits.

RV Function

The right ventricle (RV) global systolic function is normal. Tricuspid annular plane systolic excursion (TAPSE) measuring 18.6 mm.

RV Size

The right ventricle (RV) size is normal, with right ventricular internal diameter in diastole (RVIDd) at the basal level measuring 28.7 mm.

LA Size

The left atrial (LA) cavity size is normal, with an indexed LA volume of 18.5 ml/m^2.

RA Size

The right atrial (RA) cavity size is normal, with a right atrial area measuring 10.1 cm^2. RA end-systolic volume indexed to body surface area (RAESVi) in the A4C view measuring 14.2 ml/m^2.

Measurements

Left Ventricle

Name	Value	Normal Ref. Range
LVEF MOD biplane	61.2 %	52.0 - 72.0
LVEF MOD A4C	65.3 %	55.2 - 73.3
LVEF MOD A2C	56.7 %	55.5 - 73.9
LVEDV MOD biplane	74.7 ml	62.0 - 150.0
LVEDVi MOD biplane	47.8 ml/m^2	34.0 - 74.0
LVEDV MOD A4C	76.9 ml	58.5 - 146.3
LVEDV MOD A2C	72.7 ml	54.0 - 142.3
LVESV MOD biplane	29.0 ml	21.0 - 61.0
LVESVi MOD biplane	18.5 ml/m^2	11.0 - 31.0
LVESV MOD A4C	26.7 ml	18.9 - 56.6
LVESV MOD A2C	31.5 ml	17.6 - 52.3
LVSV MOD biplane	45.7 ml	
LVSVi MOD biplane	29.3 ml/m^2	
LVCO MOD biplane	2.7 l/min	4.0 - 8.0
LVCI MOD biplane	1.8 $l/min/m^2$	2.5 - 4.0
IVSd	8.3 mm	6.0 - 10.0
LVIDd	42.2 mm	42.0 - 58.4
LVIDd index	27.0 mm/m^2	22.0 - 30.0
LVPWd	7.0 mm	6.0 - 10.0
LVIDs	27.1 mm	25.0 - 39.8
LVIDs index	17.4 mm/m^2	13.0 - 21.0
LV mass	96.2 g	88.0 - 224.0
LVMi	61.6 g/m^2	49.0 - 115.0
RWT	0.33	0.24 - 0.42

Left Ventricle - Doppler

Name	Value	Normal Ref. Range
MV-E	75.2 cm/s	46.0 - 112.0
MV-A	73.65 cm/s	35.0 - 98.0

E/A ratio	1.0	0.6 - 2.7
DecT	222.8 ms	112.8 - 296.4
e' septal	9.2 cm/s	5.0 - 17.0
e' lateral	10.9 cm/s	6.0 - 22.0
E/e' mean	7.5	4.0 - 12.0
s' septal	8.0 cm/s	6.0 - 11.0
a' septal	10.4 cm/s	6.0 - 13.0
s' lateral	10.1 cm/s	5.0 - 14.1
a' lateral	8.6 cm/s	5.0 - 15.0

Left Atrium

Name	Value	Normal Ref. Range
LAESVi MOD biplane	18.5 ml/m^2	16.0 - 34.0
LAESV MOD biplane	29.0 ml	29.5 - 70.3
LAESV MOD A4C	31.8 ml	25.2 - 70.0
LAESV MOD A2C	26.3 ml	27.6 - 75.0

Right Ventricle

Name	Value	Normal Ref. Range
RVIDd (basal)	28.7 mm	25.0 - 41.0
RV/LV ratio	0.68	< 1.0
TAPSE	18.6 mm	> 17.0

Right Atrium

Name	Value	Normal Ref. Range
RA area A4C (s)	10.1 cm^2	13.2 - 19.0

Left Ventricle Outflow Tract

Name	Value	Normal Ref. Range
LVOT Vmax	0.81 m/s	
LVOT VTI	18.29 cm	
LVOT Pmax	2.6 mmHg	
LVOT Pmean	1.31 mmHg	
LVOT SV by VTI	52.55 ml	
LVOT SVi by VTI	33.62 ml/m^2	
LVOT CO by VTI	3.15 l/min	4.0 - 8.0

LVOT CI by VTI	2.02 l/min/m^2	2.5 - 4.0
LVOT	19.1 mm	

Aortic Valve

Name	Value	Normal Ref. Range
AoV Vmax	1.17 m/s	< 2.5
AoV VTI	24.95 cm	
AoV Pmax	5.52 mmHg	
AoV Pmean	2.86 mmHg	
AVA	2.11 cm^2	
AVAi	1.35 cm^2/m^2	
Velocity ratio by Vmax	0.69	

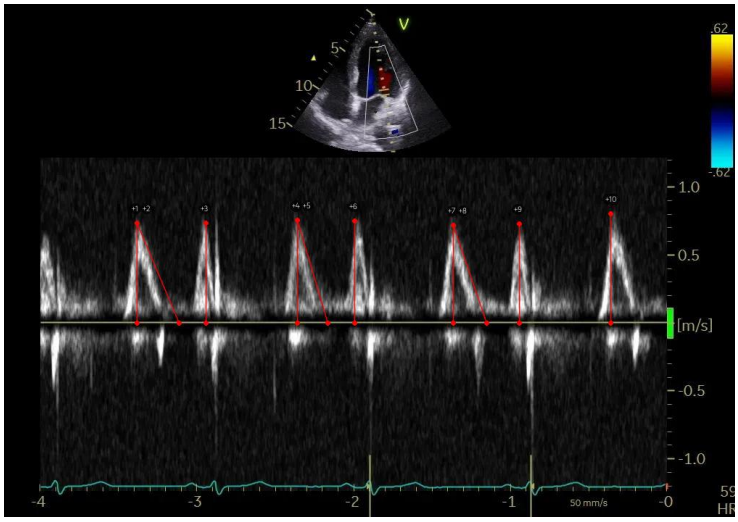
Tricuspid valve

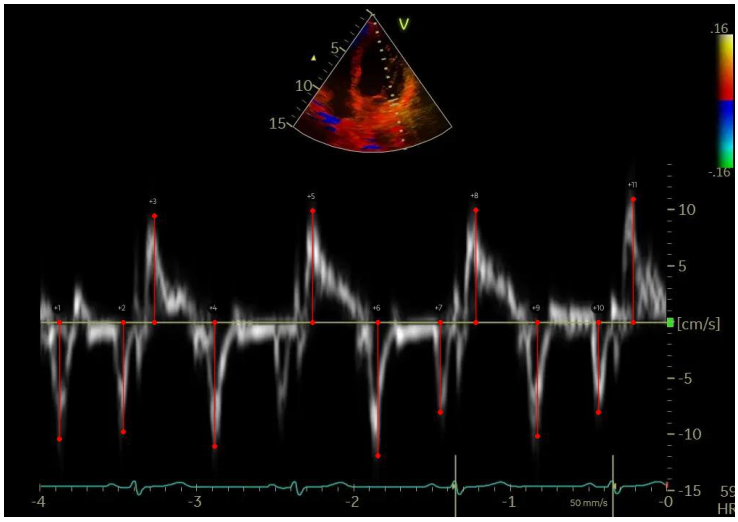
Name	Value	Normal Ref. Range
RAP	5.0 mmHg	

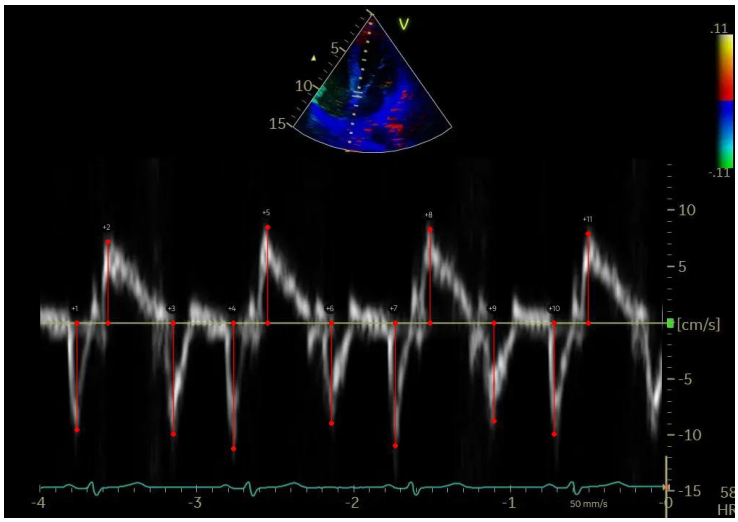
Other

Name	Value	Normal Ref. Range
IVC max	12.7 mm	< 21.0
IVC min	7.3 mm	
IVC collapsibility index	42.5 %	> 50.0

Images



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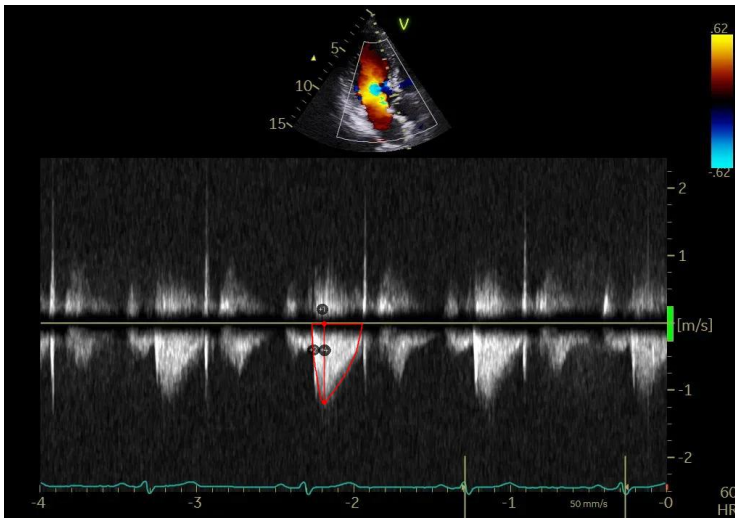
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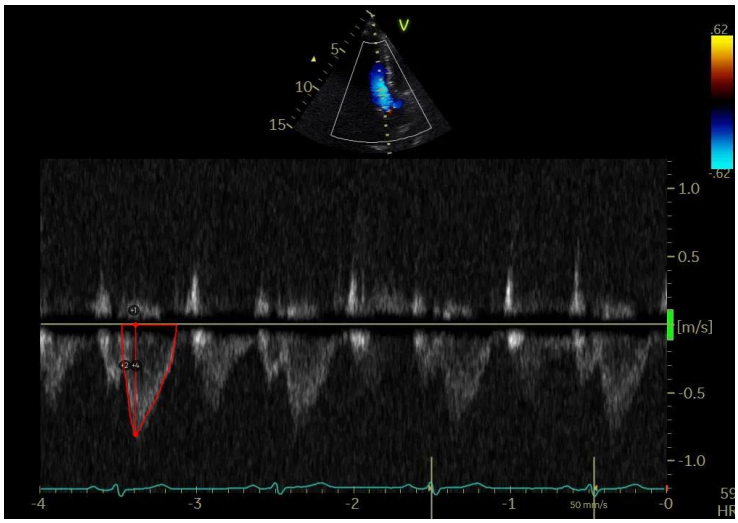
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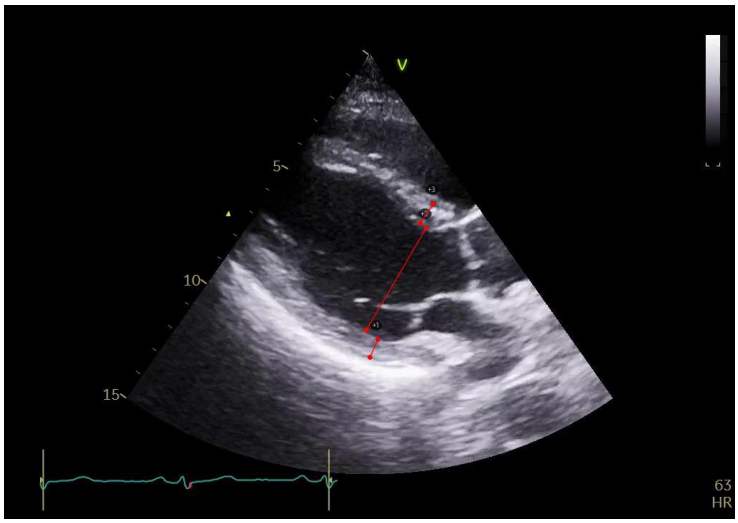
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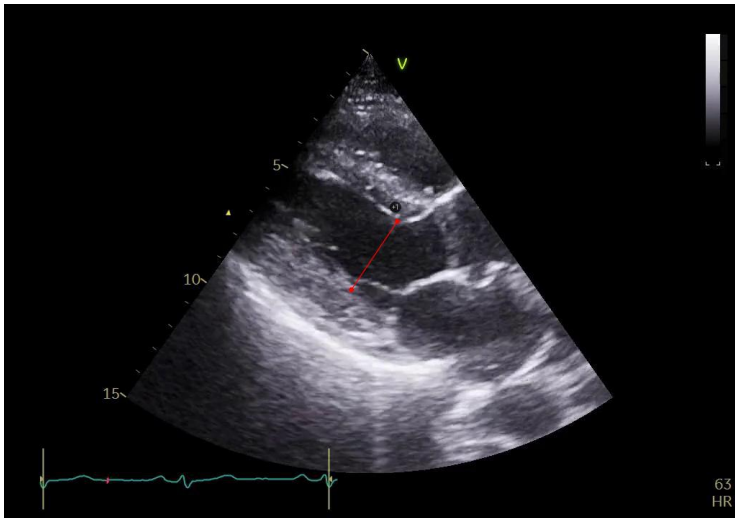
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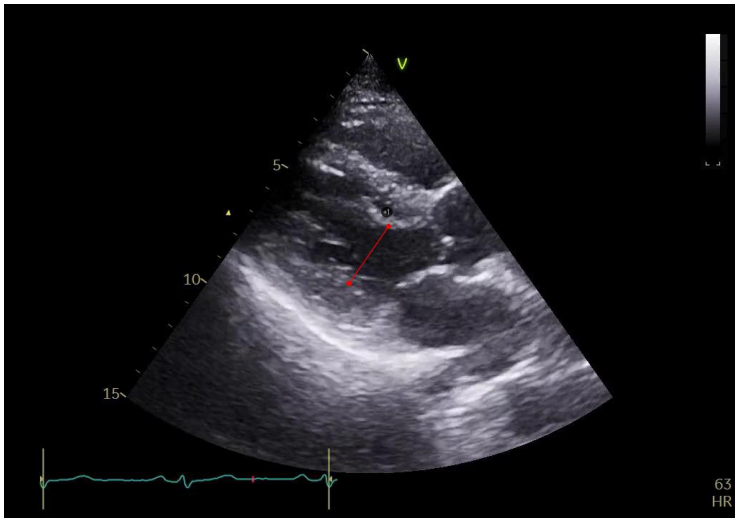
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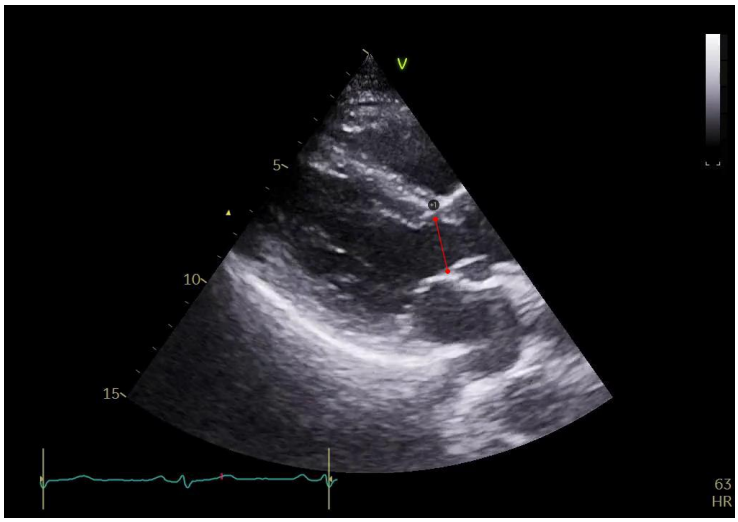
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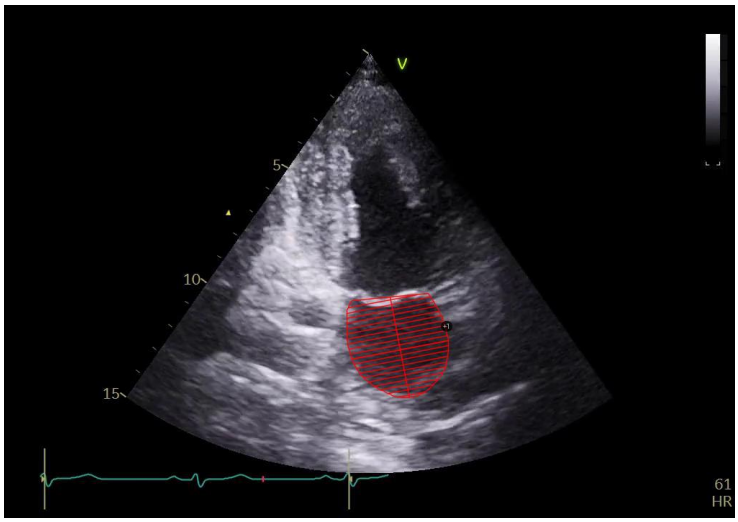
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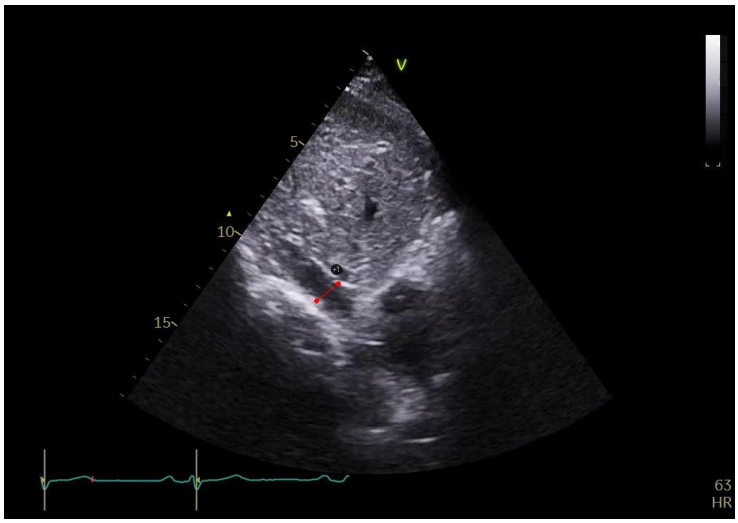
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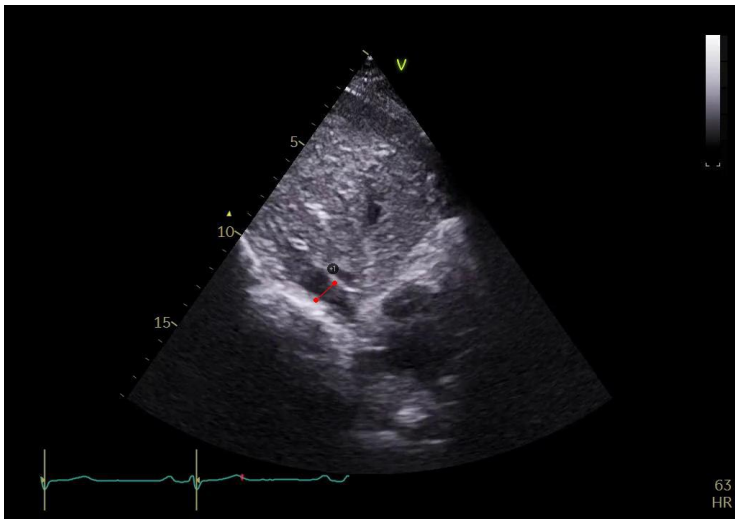
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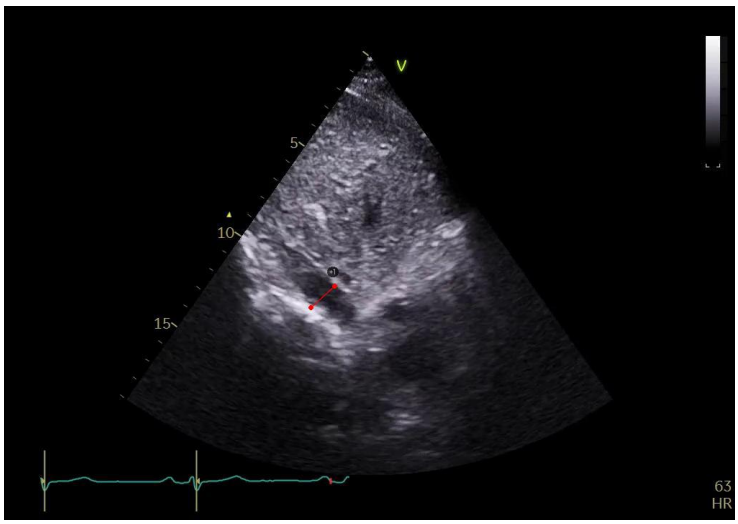
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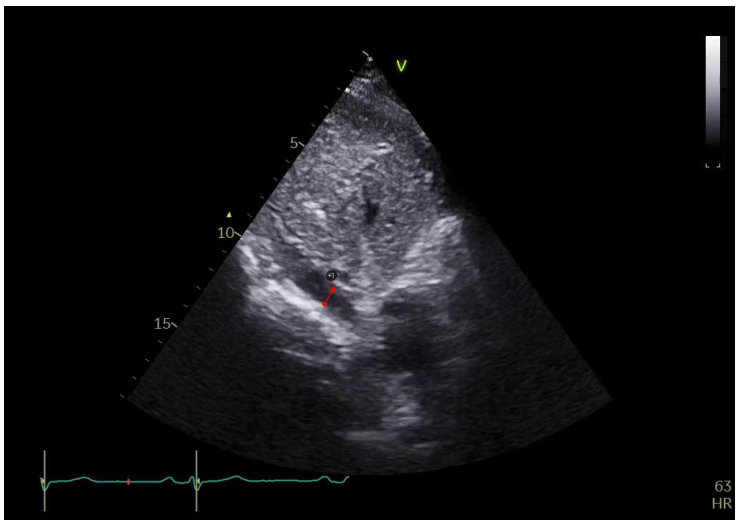
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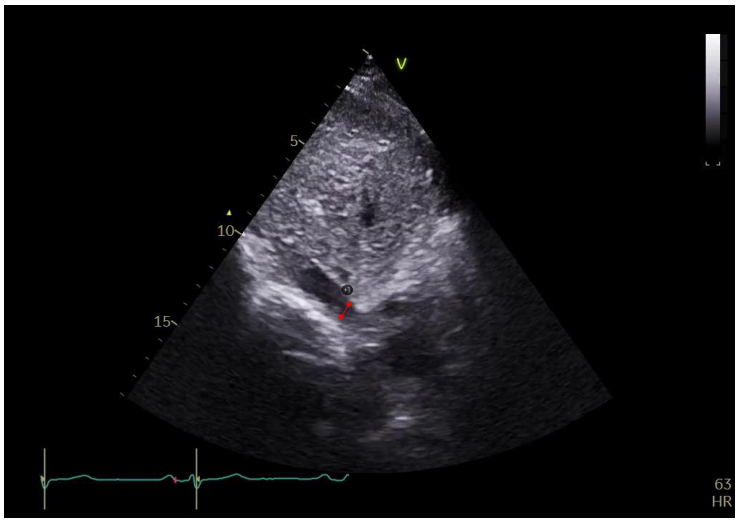
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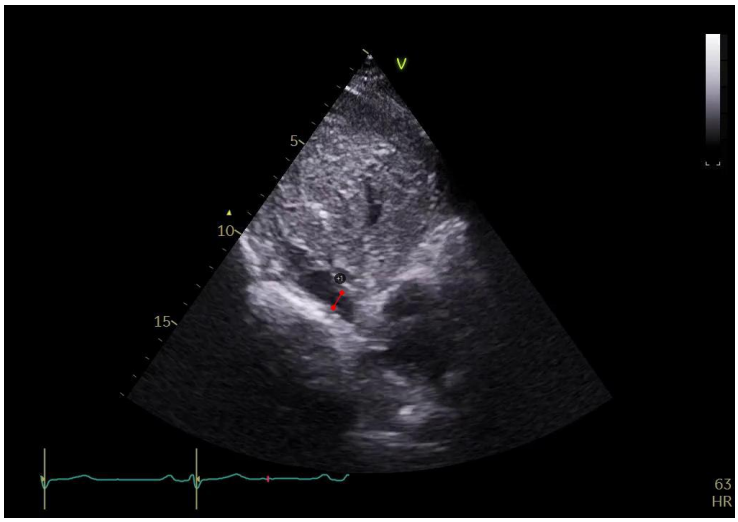
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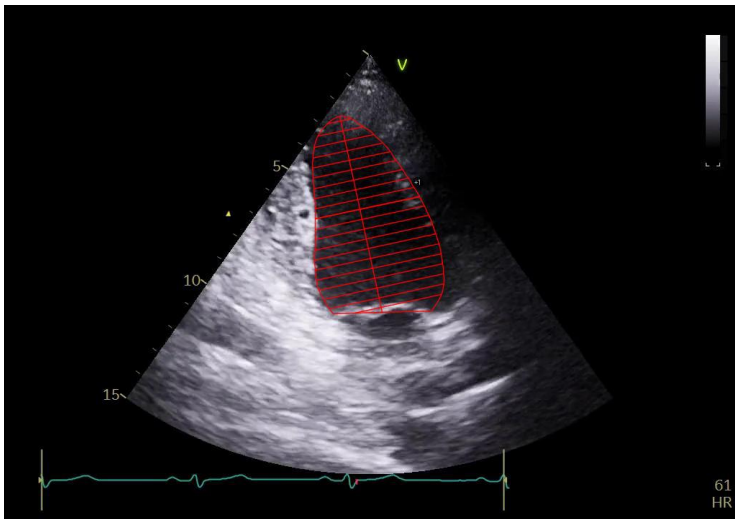
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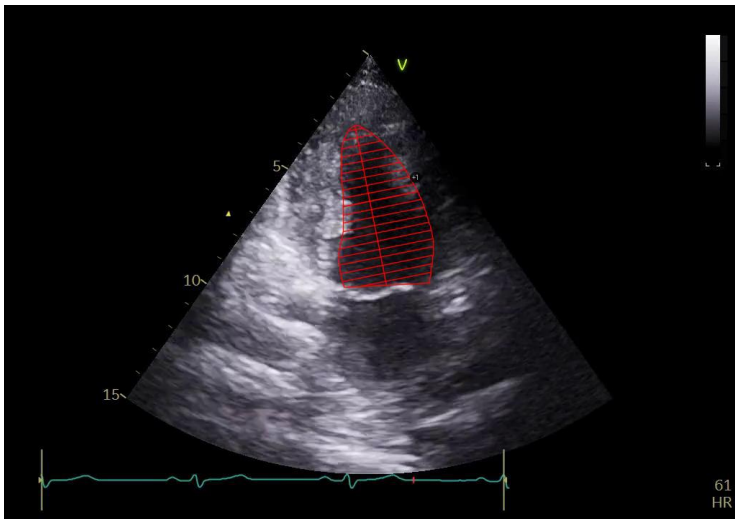
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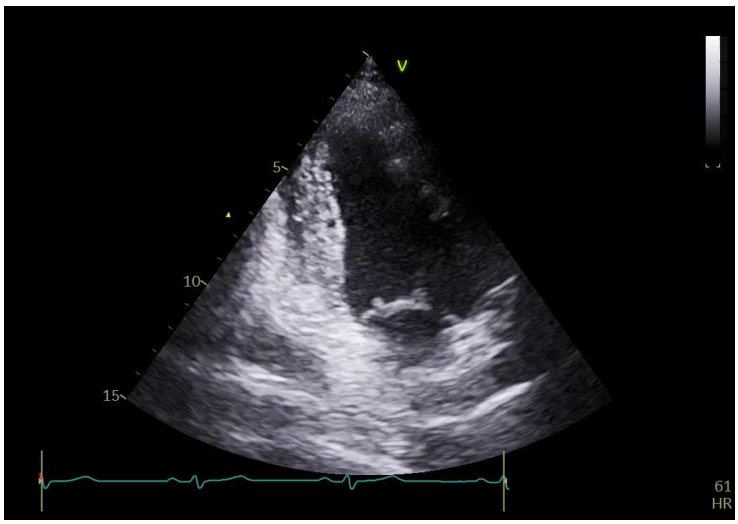
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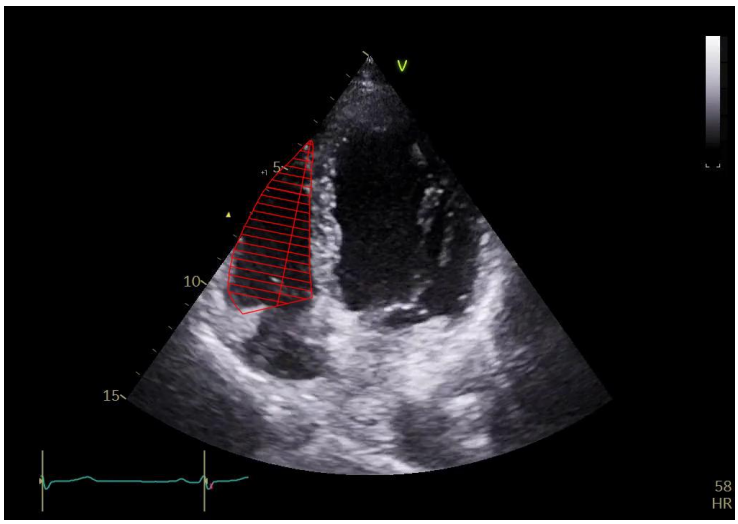
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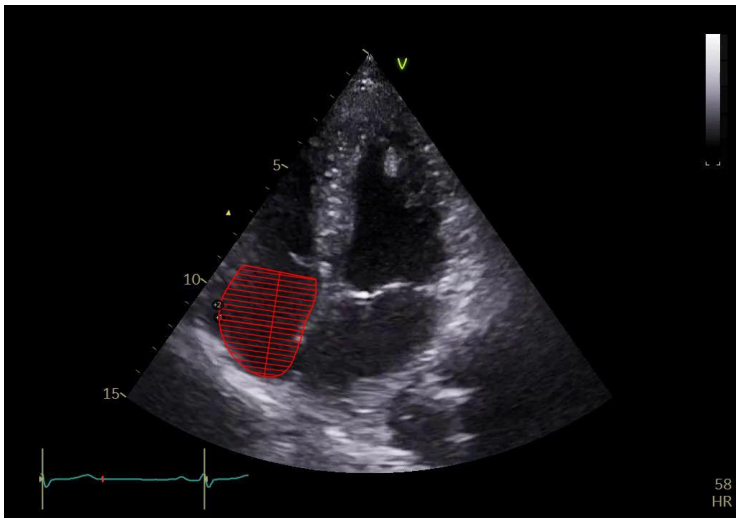
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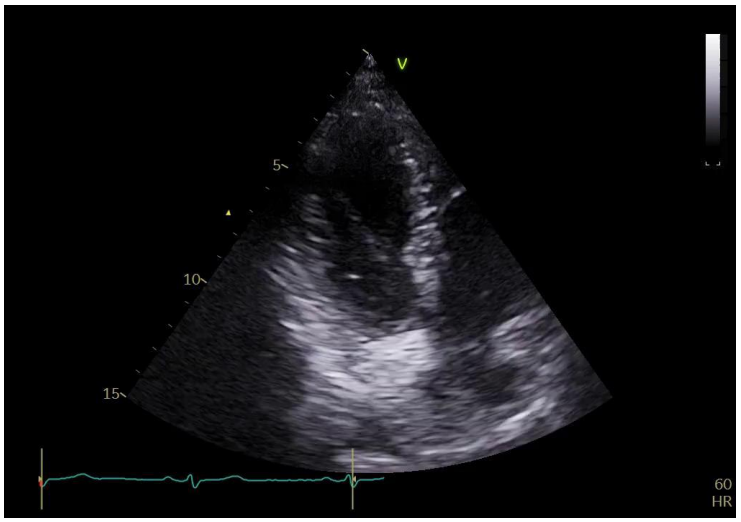
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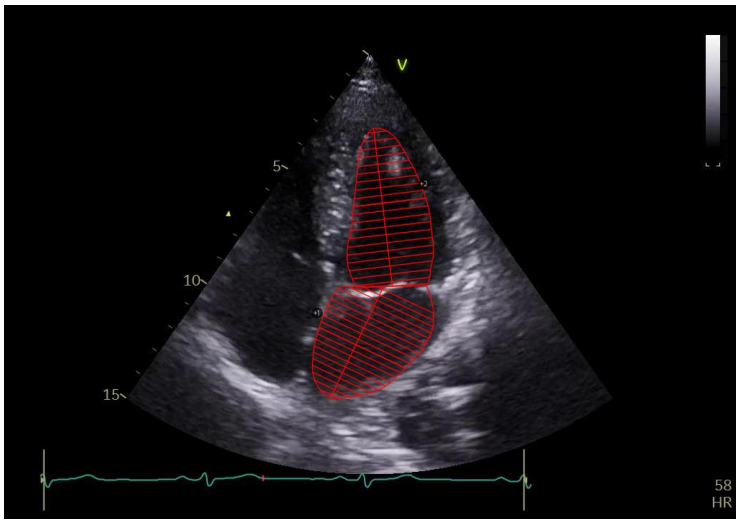
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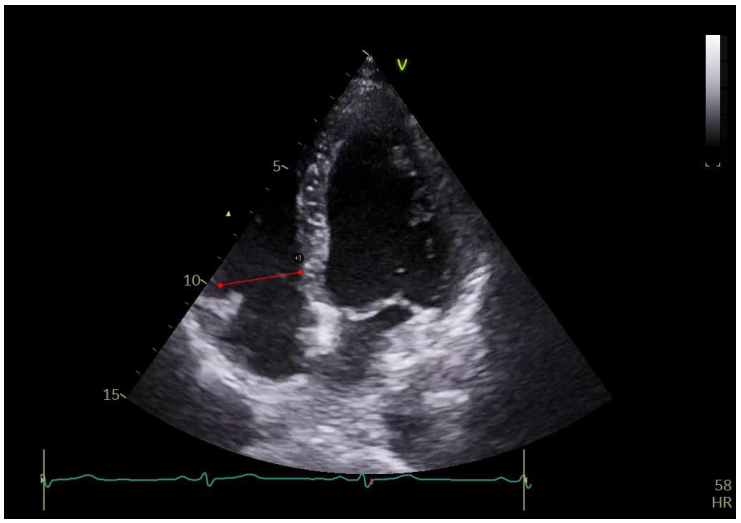
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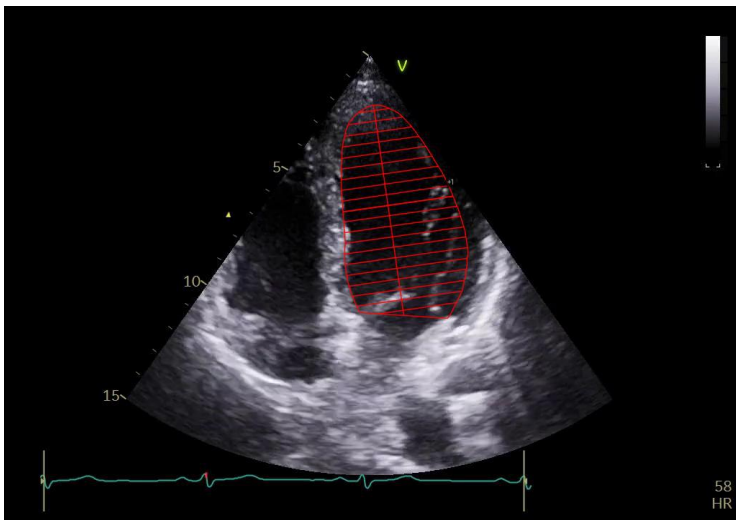
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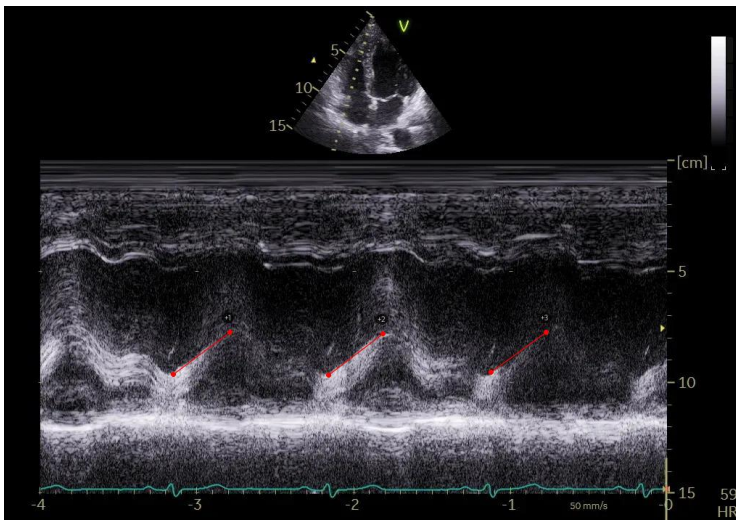
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[cm]
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50 mm/s
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Appendix S2 Example US.AI2 output for a patient undergoing echocardiography due to a murmur on auscultation before arteriovenous fistula formation.

First Name	-	Last Name	-
Visit Date	02/05/2025 12:59 PM	Gender	Male
Body Surface Area	1.5 m^2	Referral Reason: Murmur heard Prior to AV Fistula	
Age (on exam date)48		Date of Birth	

Conclusions

- The left ventricular (LV) systolic function is classified as moderately abnormal.
- The left ventricular (LV) diastolic function shows increased left atrial pressure (LAP) and grade II diastolic dysfunction.
- The left ventricular (LV) size is abnormal.
- The right ventricle (RV) size is normal.
- The left atrial (LA) cavity size is mildly abnormal.
- The right atrial (RA) cavity size is normal.

Main Findings

LV Systolic Function

The left ventricular (LV) systolic function is classified as moderately abnormal, with a calculated left ventricle ejection fraction (LVEF) of 38.3 % by modified biplane Simpson's method.

LV Diastolic Function

The left ventricular (LV) diastolic function shows increased left atrial pressure (LAP) and grade II diastolic dysfunction. The E/A ratio is 0.8. The mitral valve E velocity (MV-E) measures at 95.14 cm/s. The septal E' velocity is 2.5 cm/s. The lateral E' velocity is 3.6 cm/s. The average E/e' ratio, which represents the ratio of mitral inflow velocity (E) to average mitral annular early diastolic velocity (e'), at both septal and lateral regions is 31.2. The left atrial end-systolic volume indexed to body surface area (LAESVi) measures 38.4 ml/m^2 by modified biplane Simpson's method.

LV Size

The left ventricular (LV) size is abnormal. With a left ventricular internal diameter in diastole (LVIDd) measuring 48.9 mm, a left ventricular end-diastolic volume (LVEDV) of 165.1 ml and a left ventricular end-systolic volume (LVESV) of 101.8 ml, both by modified biplane Simpson's method. When indexed to body surface area, the LV end-diastolic volume index (LVEDVi) is 113.1 ml/m^2, and the LV end-systolic volume index (LVESVi) is 69.7 ml/m^2, both of which are beyond the expected range.

RV Size

The right ventricle (RV) size is normal, with right ventricular internal diameter in diastole (RVIDd) at the basal level measuring 28.1 mm.

LA Size

The left atrial (LA) cavity size is mildly abnormal, with an indexed LA volume of 38.4 ml/m^2.

RA Size

The right atrial (RA) cavity size is normal, with a right atrial area measuring 12.7 cm^2. RA end-systolic volume indexed to body surface area (RAESVi) in the A4C view measuring 21.9 ml/m^2.

Disease Guidelines

Aortic Stenosis

There is evidence of severe aortic stenosis. Aortic velocity 4.51 m/s. AVA by continuity equation is 0.81 cm^2. Indexed AVA is 0.55 cm^2/m^2. Velocity ratio by Vmax 0.20. Aortic Pmean 47.87 mmHg. Highest aortic velocity obtained from A3C + CW (AoV).

Measurements

Left Ventricle

Name	Value	Normal Ref. Range
LVEF MOD biplane	38.3 %	52.0 - 72.0
LVEF MOD A4C	39.5 %	55.2 - 73.3
LVEF MOD A2C	37.3 %	55.5 - 73.9
LVEDV MOD biplane	165.1 ml	62.0 - 150.0
LVEDVi MOD biplane	113.1 ml/m^2	34.0 - 74.0
LVEDV MOD A4C	165.5 ml	58.5 - 146.3
LVEDV MOD A2C	166.0 ml	54.0 - 142.3
LVESV MOD biplane	101.8 ml	21.0 - 61.0
LVESVi MOD biplane	69.7 ml/m^2	11.0 - 31.0
LVESV MOD A4C	100.1 ml	18.9 - 56.6
LVESV MOD A2C	104.0 ml	17.6 - 52.3
LVSV MOD biplane	63.7 ml	
LVSVi MOD biplane	43.6 ml/m^2	
LVCO MOD biplane	3.5 l/min	4.0 - 8.0
LVCI MOD biplane	2.4 $l/min/m^2$	2.5 - 4.0
IVSd	10.9 mm	6.0 - 10.0
LVIDd	48.9 mm	42.0 - 58.4
LVIDd index	33.5 mm/m^2	22.0 - 30.0
LVPWd	11.1 mm	6.0 - 10.0
LVIDs	44.2 mm	25.0 - 39.8
LVIDs index	30.3 mm/m^2	13.0 - 21.0
LV mass	200.3 g	88.0 - 224.0
LVMi	137.2 g/m^2	49.0 - 115.0
RWT	0.45	0.24 - 0.42

Left Ventricle - Doppler

Name	Value	Normal Ref. Range
MV-E	95.14 cm/s	46.0 - 112.0

MV-A	115.6 cm/s	35.0 - 98.0
E/A ratio	0.8	0.6 - 2.7
e' septal	2.5 cm/s	5.0 - 17.0
e' lateral	3.6 cm/s	6.0 - 22.0
E/e' mean	31.2	4.0 - 12.0
s' septal	2.8 cm/s	6.0 - 11.0
a' septal	5.1 cm/s	6.0 - 13.0
s' lateral	4.8 cm/s	5.0 - 14.1

Left Atrium

Name	Value	Normal Ref. Range
LAESVi MOD biplane	38.4 ml/m^2	16.0 - 34.0
LAESV MOD biplane	56.0 ml	29.5 - 70.3
LAESV MOD A4C	52.1 ml	25.2 - 70.0
LAESV MOD A2C	60.3 ml	27.6 - 75.0

Right Ventricle

Name	Value	Normal Ref. Range
RVIDd (basal)	28.1 mm	25.0 - 41.0
RV/LV ratio	0.57	< 1.0

Right Atrium

Name	Value	Normal Ref. Range
RA area A4C (s)	12.7 cm^2	13.2 - 19.0

Left Ventricle Outflow Tract

Name	Value	Normal Ref. Range
LVOT Vmax	0.89 m/s	
LVOT VTI	24.7 cm	
LVOT Pmax	3.14 mmHg	
LVOT Pmean	2.02 mmHg	
LVOT SV by VTI	87.19 ml	
LVOT SVi by VTI	59.72 ml/m^2	
LVOT CO by VTI	4.8 l/min	4.0 - 8.0
LVOT CI by VTI	3.28 l/min/m^2	2.5 - 4.0
LVOT	21.2 mm	

Aortic Valve

Name	Value	Normal Ref. Range
AoV Vmax	4.51 m/s	< 2.5
AoV VTI	108.17 cm	
AoV Pmax	81.37 mmHg	
AoV Pmean	47.87 mmHg	
AVA	0.81 cm^2	
AVAi	0.55 cm^2/m^2	
Velocity ratio by Vmax	0.2	

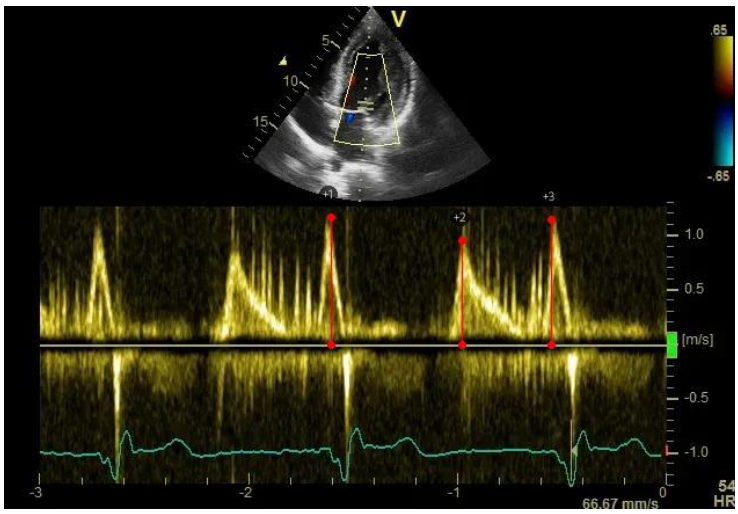
Tricuspid valve

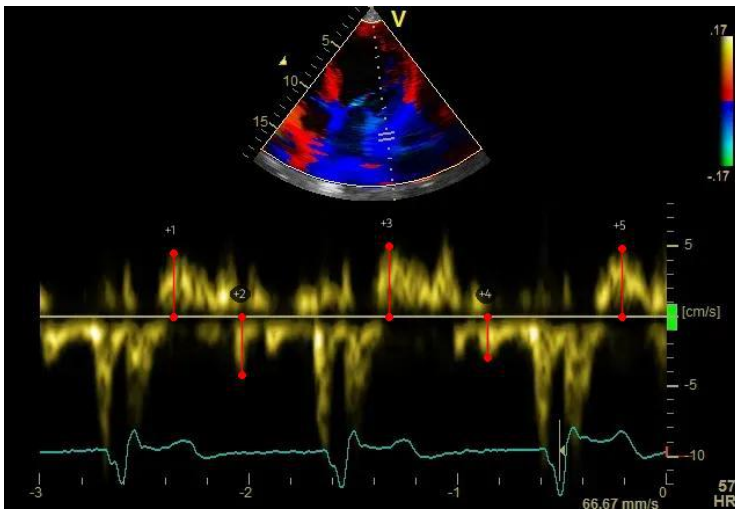
Name	Value	Normal Ref. Range
RAP	5.0 mmHg	

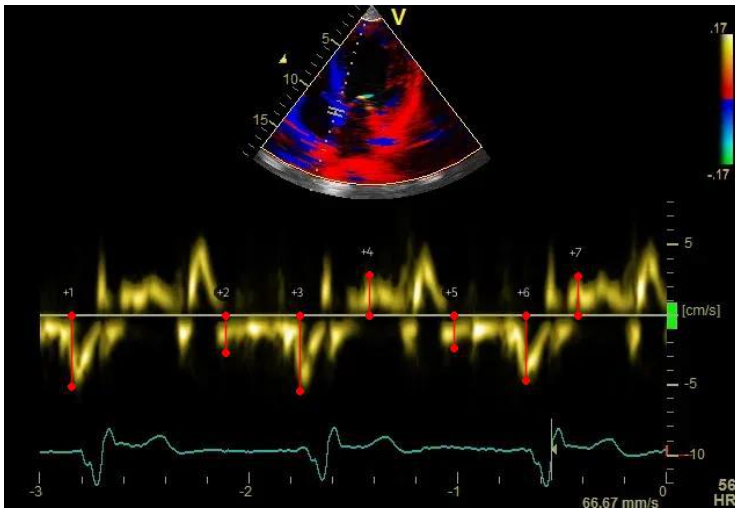
Other

Name	Value	Normal Ref. Range
IVC max	8.3 mm	< 21.0
IVC min	3.6 mm	
IVC collapsibility index	57.1 %	> 50.0

Images



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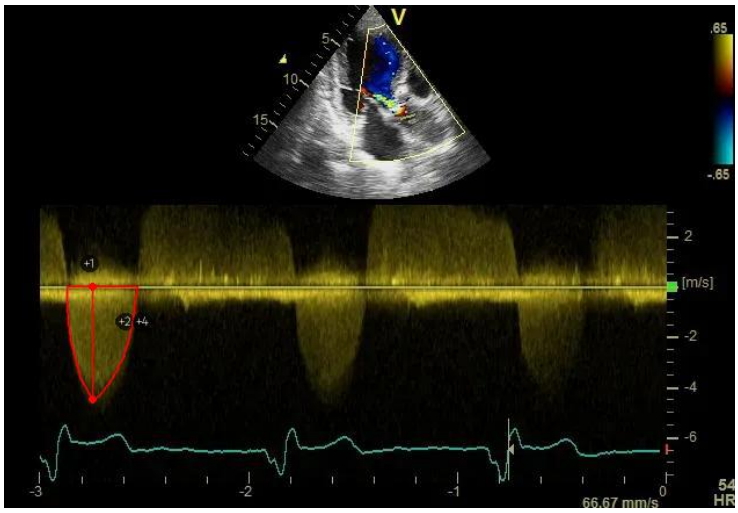
[cm/s]
66.67 mm/s
HR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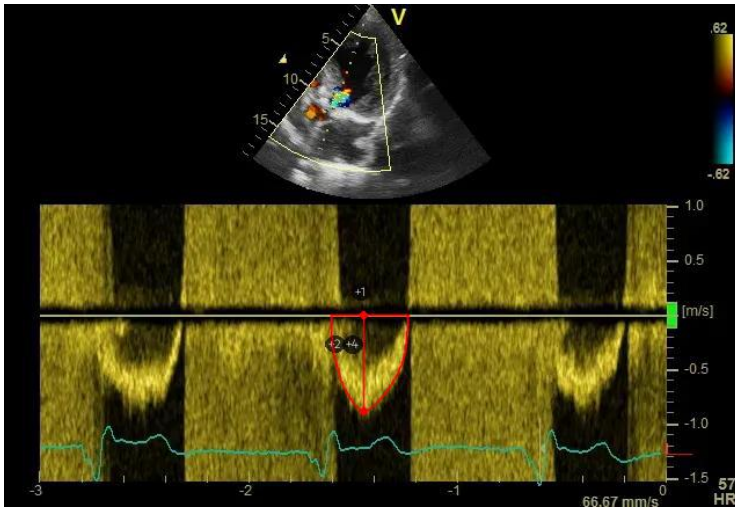
.65
-.65
[m/s]
66.67 mm/s
54
HR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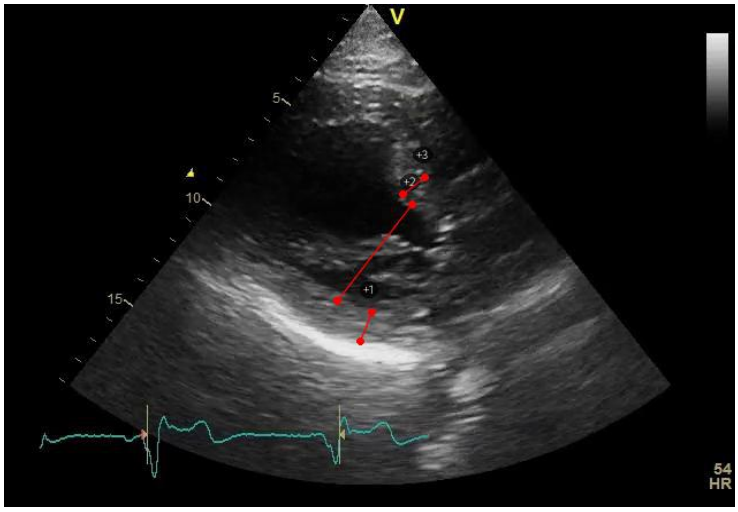
-.62
[m/s]
66.67 mm/s
57
HR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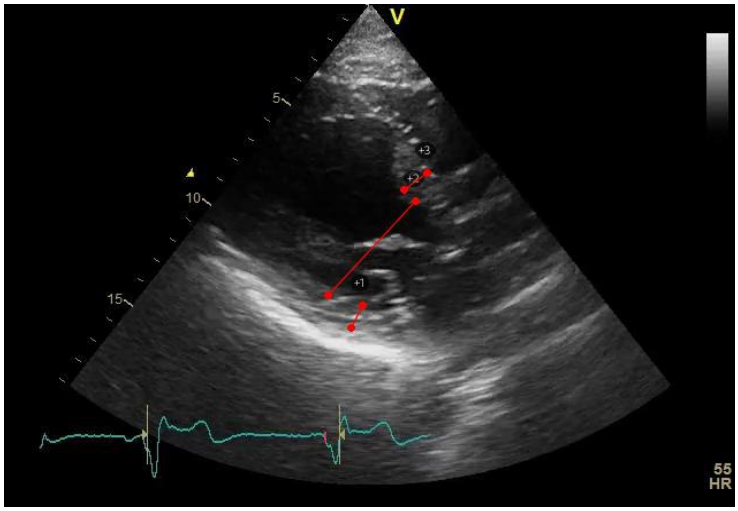
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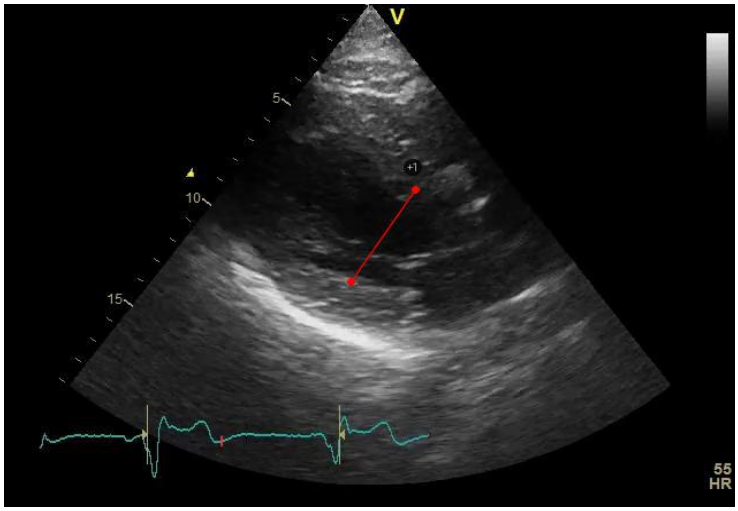
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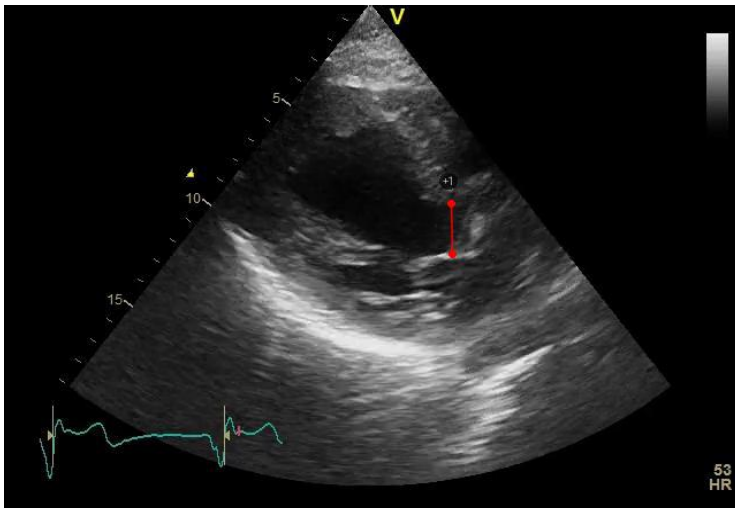
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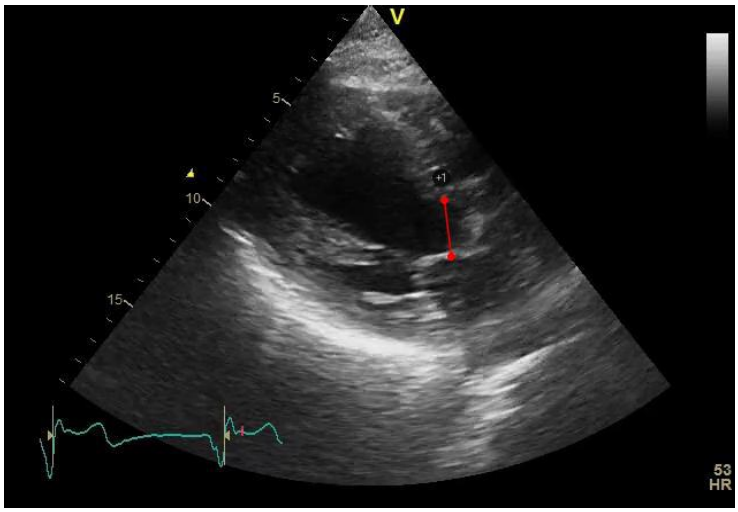
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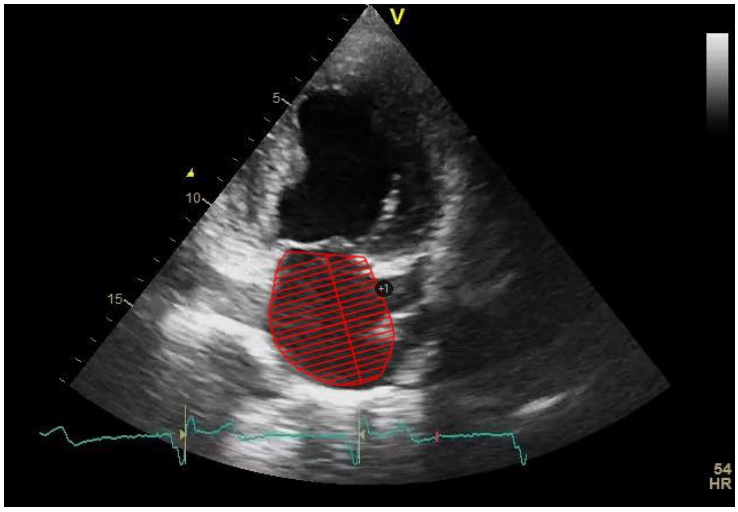
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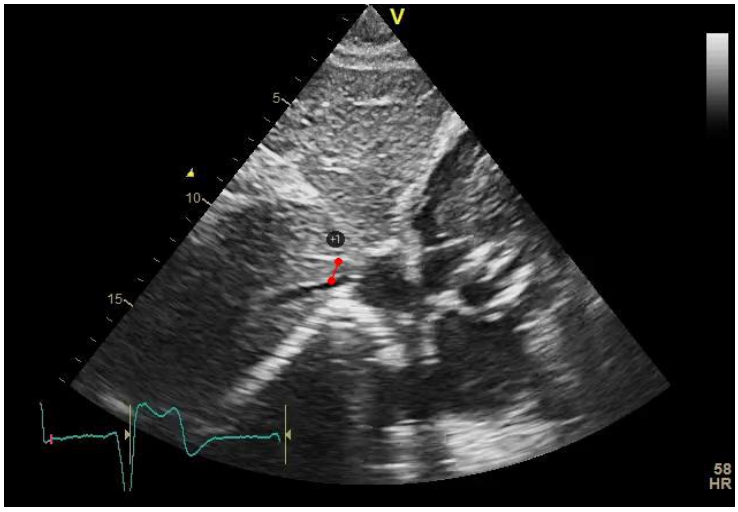
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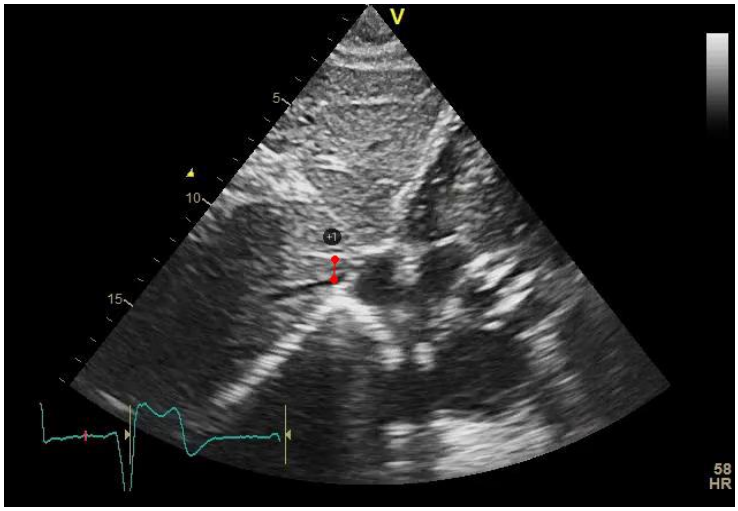
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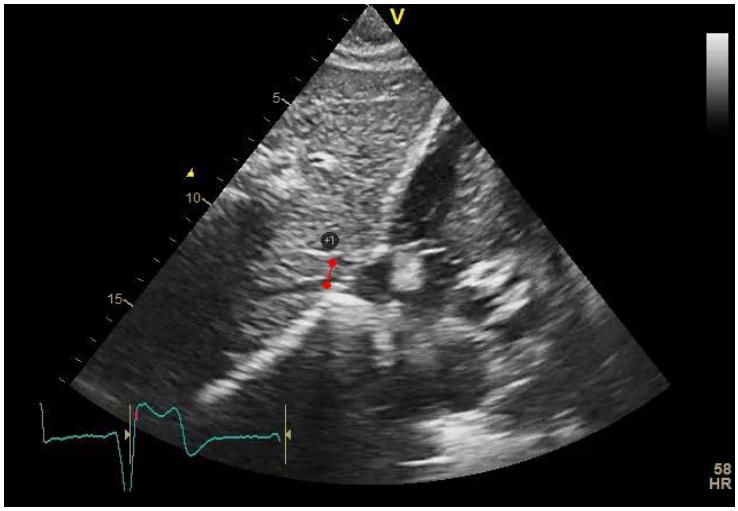
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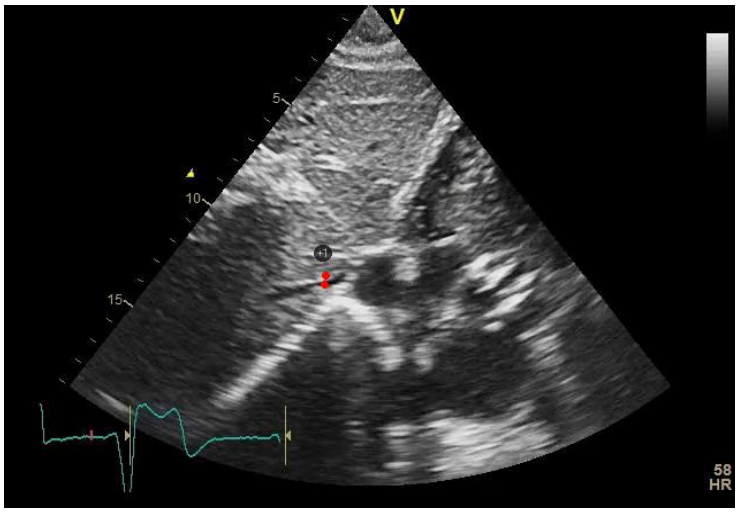
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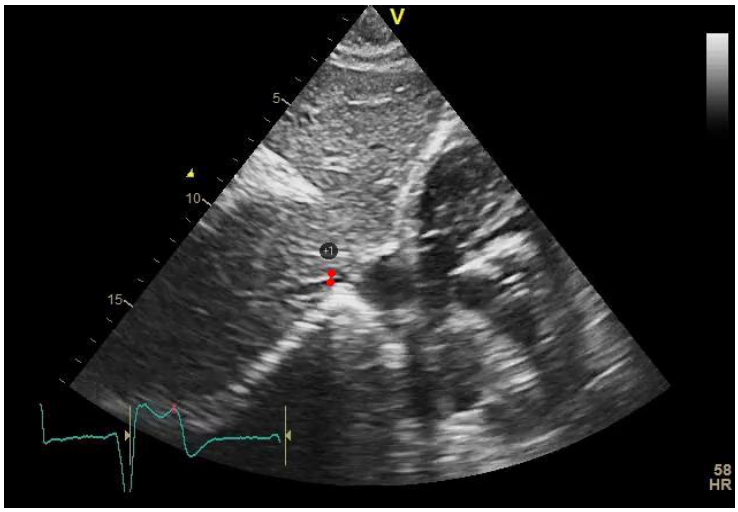
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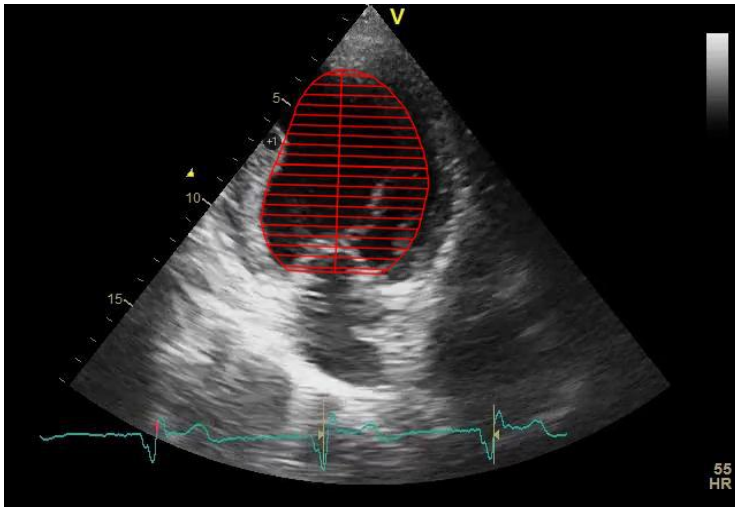
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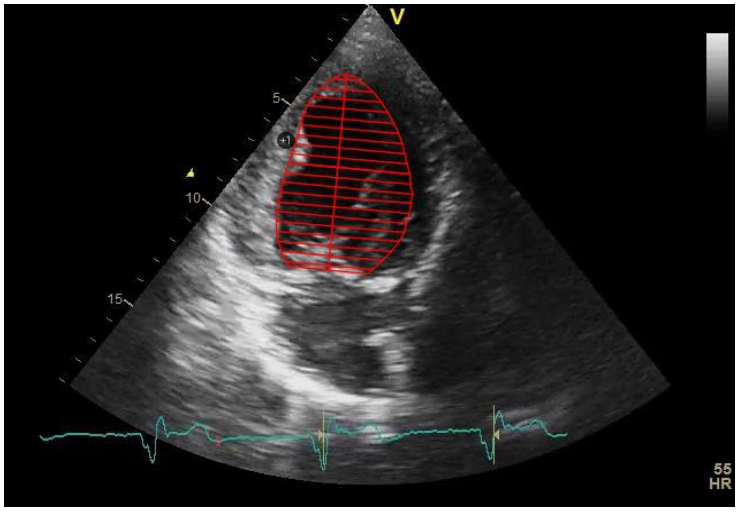
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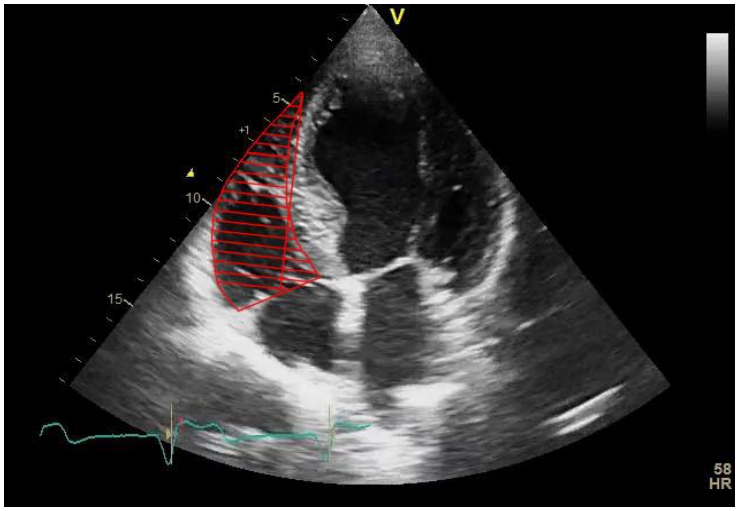
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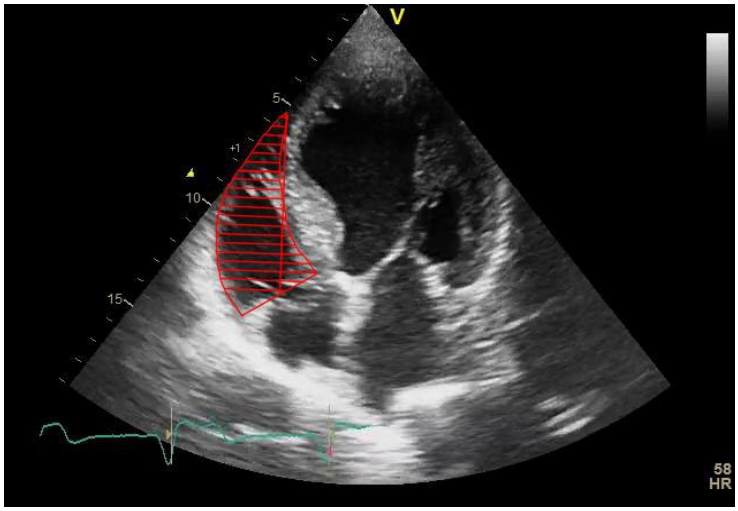
V
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+1
10
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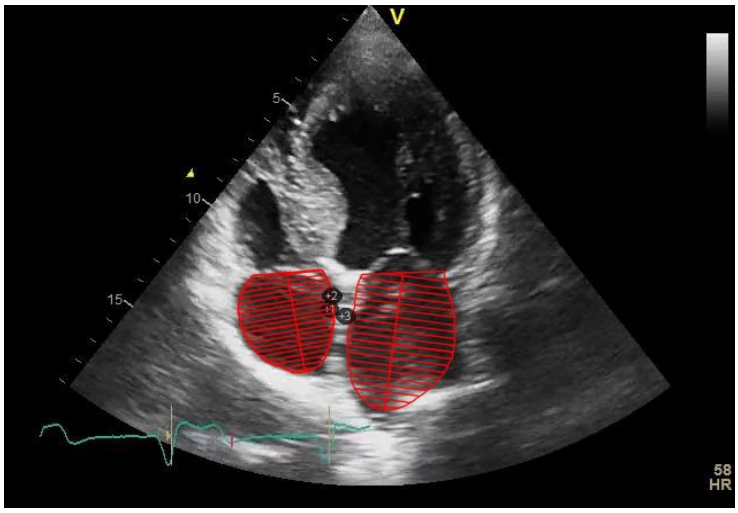
58
HR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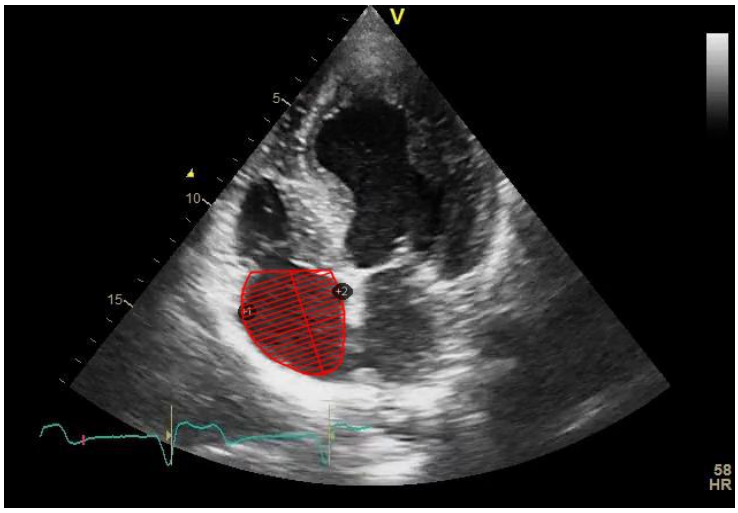
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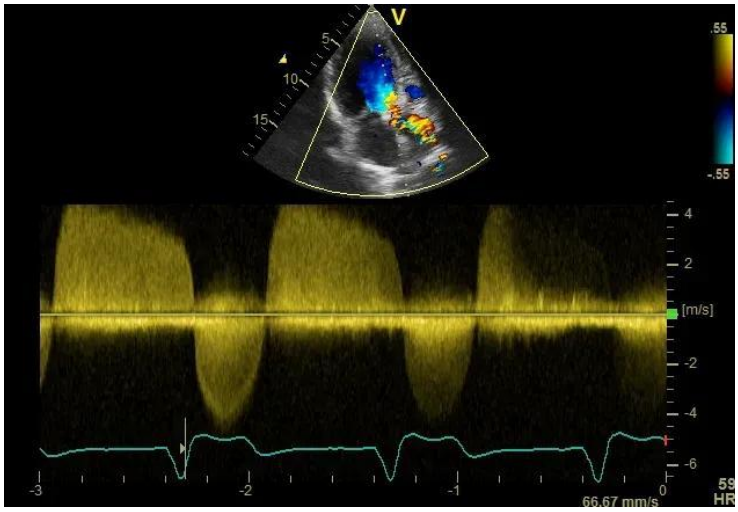
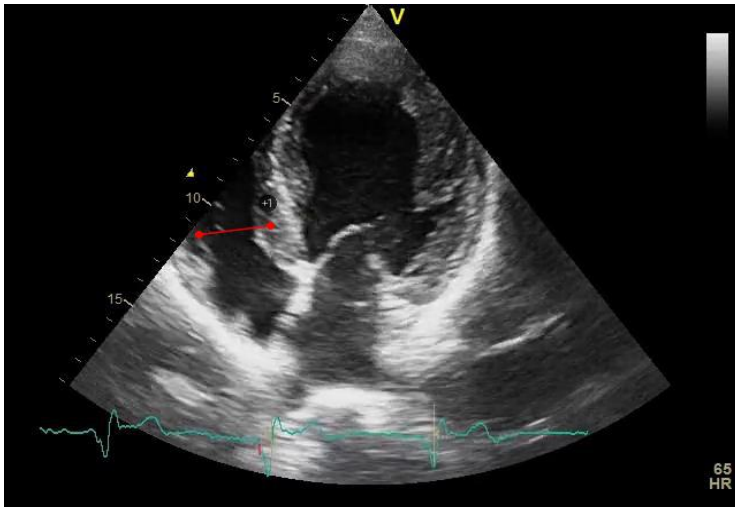
HR


V
.55
-.55
4
2
[m/s]
-2
-4
-6
-3
-2
-1
0
66.67 mm/s
59
HR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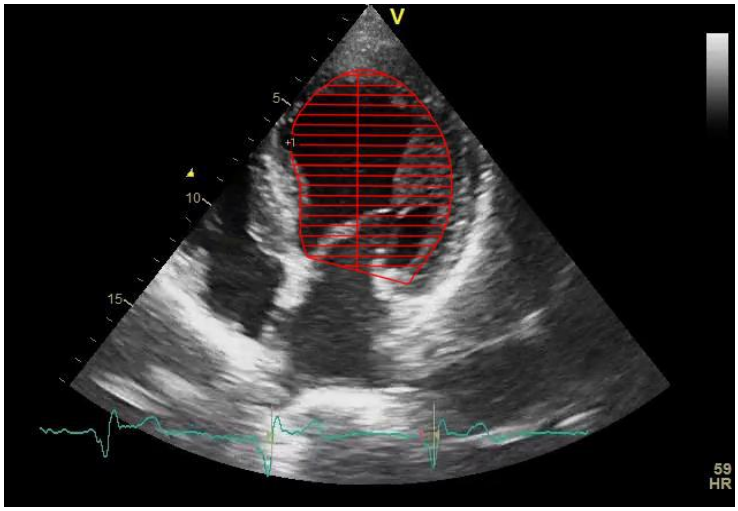
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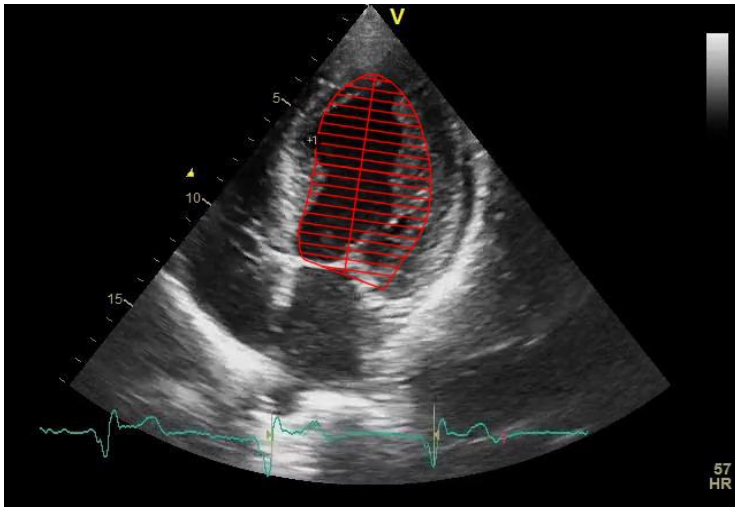
V
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