Comparison of tricuspid and mitral annular plane systolic excursion in determination of acute blood loss in healthy volunteers

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Abstract

Ultrasound is used more and more in determining acute blood loss. This study is to compare tricuspid annular plane systolic excursion (TAPSE) and mitral annular plane systolic excursion (MAPSE) measurement to determine volume loss pre and post blood donation in healthy volunteers. The systolic, diastolic and mean arterial blood pressures and pulses of the donors were measured in the standing and supine position by the by the attending physician, then, inferior vena cava (IVC), TAPSE and MAPSE measurements were made pre and post blood donation. Statistically significant differences were found in systolic blood pressure and pulse rate values that obtained in the standing position, and in the systolic blood pressure, diastolic blood pressure, mean arterial pressure and pulse values that obtained in the supine position ($p<0.05$). The difference between IVC expiration (IVCexp) pre and post blood donation was 4.76 ± 2.94, and the difference in IVC inspiration (IVCins) was 2.73 ± 2.91. In addition, the MAPSE and TAPSE differences were 2.16 ± 1.4 and 2.98 ± 2.13, respectively. Statistically significant differences were found between IVCins-exp, TAPSE and MAPSE values. TAPSE and MAPSE can be used in the early diagnosis of acute blood loss.

Title Page

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Abstract

Ultrasound is used more and more in determining acute blood loss. This study is to compare tricuspid annular plane systolic excursion (TAPSE) and mitral annular plane systolic excursion (MAPSE) measurement to determine volume loss pre and post blood donation in healthy volunteers. The systolic, diastolic and mean arterial blood pressures and pulses of the donors were measured in the standing and supine position by the by the attending physician, then, inferior vena cava (IVC), TAPSE and MAPSE measurements were made pre and post blood donation. Statistically significant differences were found in systolic blood pressure and pulse rate values that obtained in the standing position, and in the systolic blood pressure, diastolic blood pressure, mean arterial pressure and pulse values that obtained in the supine position ($p<0.05$). The difference between IVC expiration (IVCexp) pre and post blood donation was 4.76 ± 2.94, and the difference in IVC inspiration (IVCins) was 2.73 ± 2.91. In addition, the MAPSE and TAPSE differences were 2.16 ± 1.4 and 2.98 ± 2.13, respectively. Statistically significant differences were found between IVCins-exp, TAPSE and MAPSE values. TAPSE and MAPSE can be used in the early diagnosis of acute blood loss.

Key Words : acute blood loss; early diagnosis; mitral annular plane systolic excursion; tricuspid annular plane systolic excursion

Introduction

Bleeding is a serious emergency condition that requires early detection and appropriate intervention. Bleeding is the leading cause of preventable death, especially in acute trauma patients . Bleeding secondary to trauma is one of the most common causes of death in Americans aged 1-46 years . Most patients can tolerate loss of up to 14% of blood volume without any change in physical or vital signs . Loss of up to 15% of blood volume is called Class I bleeding. The patient is usually asymptomatic and traditional vital signs (blood pressure, pulse pressure, pulse rate, and respiratory rate) are within normal limits . In the sudden onset of cardiovascular collapse, blood pressure drops without warning and it may be too late to start life-saving therapy. Therefore, early detection of acute bleeding is crucial to increase survival rates . We need rapid and non-invasive tools to detect bleeding at an early stage.

One of the most popular methods for assessing intravascular volume status is ultrasound of the inferior vena cava (IVCUS) . Both cardiology and emergency medicine societies especially recommend IVCUS to detect volume status (bleeding) . However, the value of IVCUS in detecting early bleeding is controversial in some studies . Therefore, there is a need for simple and reliable methods that can be easily evaluated for the early detection of bleeding patients. While the right ventricle (RV) is a neglected part of the heart, RV evaluation has recently become current. Tricuspid annular plane systolic excursion (TAPSE) is an echocardiographic parameter that provides reliable information about RV function . While LV ejection fraction is often used to predict left ventricular (LV) systolic function, another marker is mitral annular plane systolic excursion (MAPSE). Obtaining TAPSE and MAPSE measurements using echocardiography is simple and less dependent on image quality . These echocardiographic parameters may be useful in the early detection of acute blood loss. To the best of our knowledge, we could not find any literature evaluating TAPSE or MAPSE in volume depleted patients. The aim of this study is to compare TAPSE and MAPSE measurement to determine volume loss before and after blood donation in healthy volunteers.

Material and Methods:

Study design and settlement

This single-center, prospective and cross-sectional study was conducted at the Ege University Hospital blood center. The study was approved by the ethics committee.

Study Population

Donors who met the blood donation criteria and whose complete blood count data were found suitable for blood donation were included in the study. The patients included in the study were planned according to the availability of the personnel who will perform ultrasound procedure. Inclusion criteria were; volunteers aged 18-65 years, over 50 kg, with hemoglobin >13.5 g/dL (male) and >12.5 g/dL (female) who met the blood donation criteria. Exclusion criteria in this study were; subjects with chronic obstructive pulmonary disease, pulmonary hypertension, asthma, history of valve surgery, arrhythmia, heart failure, tricuspid and mitral insufficiency, right and left heart disease, volunteers with technical limitations in imaging inferior vena cava, TAPSE or MAPSE, and volunteers under the age of 18.

Study protocol and measurements

After obtaining written consent, the systolic, diastolic, mean arterial blood pressures and pulse rate of the donors were measured in sitting and supine positions before and after blood donation by the attending physician. After a rest period of at least 10 minutes, measurements were taken from the antebrachial region. The same physician measured the height and weight of each volunteer. Body mass index was calculated as weight [kilogram]/height^2 [meter]. Class 1 bleeding is defined as a volume loss of up to 15% [approximately 750 mL] of total blood volume. One unit of blood taken at the blood center was approximately 450 ml $\pm$ 10%.

Volunteers included in the study were randomly selected. After the basic measurements were made, IVC, TAPSE and MAPSE measurements were made with a color Doppler USG device (Philips Ultrasound system, Andover, USA) equipped with 3.5-5 and 5 MHz frequency curvilinear and phased array probes, respectively. Ultrasonographic IVC, MAPSE and TAPSE measurements were made by an emergency medicine specialist with a scientific background in ultrasonography, who have organized European- accredited ultrasonography courses previously. IVC measurements were taken from the subxiphoid region in the supine position. By looking at the neighborhood of the liver and heart through the subxiphoid window, it was seen that the inferior vena cava and the right atrium merged. Measurements were made from the image taken in M mode approximately 2 cm distal from this junction point. In the measurements, the diameters in expiration and inspiration were recorded. The maximum IVC measurement is the IVC measurement from the inner wall to the inner wall in the expiratory phase, while the minimum IVC measurement is the inner wall to inner wall measurement of the IVC in the inspiratory phase in the M-mode (Figure 1).

In order to evaluate tricuspid annular plane systolic motion, which gives important information about right ventricular functions, M-mode tracing was taken from the point where the tricuspid annulus meets the lateral free wall in the apical four-chamber window while the patient is in the supine position. Two movements towards the apex were observed in this tracing. The first forward movement was the systolic movement of the annulus, and the second positive wave was the low amplitude atrium systole. Taking the presystolic position as the basal level in these two movements, the distance between the basal and the peak gave the magnitude of the systolic movement for systolic function (Figure 2).

In order to evaluate the mitral annular plane systolic movement, which gives important information about left ventricular functions, an M-mode tracing was taken from the junction of the mitral annulus and the lateral free wall in the apical four-chamber window while the patient was in the supine position. Two movements towards the apex were observed in this tracing. The first forward movement was the systolic movement of the annulus, and the second positive wave was the low amplitude atrium systole. Taking the presystolic position as the basal level in these two movements, the distance between the basal and the peak gave the magnitude of the systolic movement for systolic function (Figure 3).

IVC, TAPSE and MAPSE measurements were repeated 3 times and the averages of all three measurements were calculated for analysis. IVC, TAPSE and MAPSE measurements took an average of 3 minutes for each patient. After the initial USG measurements were completed, the volunteers were allowed to proceed with the blood donation procedures. Blood donation procedures were completed in 10-15 minutes. After donating 450 mL of blood and resting for 10 minutes, IVC, TAPSE and MAPSE measurements were made without changing the position of the volunteer. Vital sign measurements were recorded similarly.

Sample size

In the sample size calculation for this study, Cohen's effect size coefficient which was used in the unknown situation was used because, there was no literature information that could provide prediction for the antecedent power analysis. The two main hypotheses were resolved with a paired t-test. For the dependent t-test, the

Cohen medium effect size (0.5), was minimum 45 people for the 95% power, and the 95% confidence interval. Since subgroup analyzes were also planned, 60 volunteers were planned to be included in the study.

Statistichal analysis

Categorical data were expressed as frequency and percentage, continuous variables were expressed as mean and deviation in parametric condition and median, minimum and maximum values in nonparametric condition for the presentation of descriptive data. Compliance with the normal distribution was checked with the Kolmogrov-Smirnov test.

In the baseline analytical evaluation, statistics of the difference between repeated measurements before and after blood donation were analyzed with the paired t-test in the parametric condition and the Wilcoxon test in the nonparametric condition. The difference between IVC diameter, TAPSE and MAPSE measurements measured before and after blood donation was considered as a distinguishing finding for hypovolemia. Analyzes were performed with SPSS version 26.0 software (IBM Corporation, Armonk, NY). In all statistical evaluations, the cutoff value of statistical significance was accepted as $p<0.05$ and 95% confidence interval was used for the mean values of all parameters.

Results

55 healthy blood donor volunteers who met the inclusion criteria were included in the study. In this study, 50 (90.9%) of the volunteers were male and 5 (9.1%) were female. The demographic characteristics of the volunteers in the study and the average distribution of the blood volume values obtained from the volunteers are given in Table-1.

Table 1

	Mean±SD	95% CI for Mean
Gender M/F (n, %) Age	50 / 5 36,09±9,74	90,9 / 9,1 33,46-38,72
Height (cm)	176,56±8,06	174,38-178,74
Weight (kg)	85,71±12,14	82,43-88,99
Body Mass Index	27,48±3,35	26,57-28,38
Hemoglobin	15,09±1,11	14,79-15,39
Blood volume Blood loss (%)	5,37±0,65 8,52±1,13	5,19-5,54 8,21-8,82

Table 1: Demographic characteristics, mean distribution of hemoglobin and blood volume values (M: Male, F: Female, cm: Centimeter, kg: Kilogram, SD: Standard deviation, CI: Confidence Interval).

When the vital signs that obtained before and after blood donation were examined, statistically significant differences were found in systolic blood pressure and pulse rate values that obtained in the standing position, and in the systolic blood pressure, diastolic blood pressure, mean arterial pressure and pulse values that obtained in the supine position ($p<0.05$). The difference between IVCexp before and after blood donation was 4.76±2.94, and the difference in IVCins was 2.73±2.91. In addition, the MAPSE and TAPSE differences were 2.16±1.4 and 2.98±2.13, respectively. Statistically significant differences were found between IVCins-exp, TAPSE and MAPSE values ($p<0.05$). Among other variables, there was no significant difference between the values obtained before and after blood donation (Table 2).

Table 2

	Mean±SD	95% CI for Mean	P
Delta SBP *(pre-post donation) (stand)*	11,22±11,09	8,22-14,22	0,000
Delta DBP *(pre-post donation) (stand)*	-2,04±8,87	-4,43-0,36	0,109
Delta MAP *(pre-post donation) (stand)*	2,38±8,61	0,05-4,71	0,053
Delta PR *(pre-post donation) (stand)*	-6,36±11,61	-9,5–3,22	0,000

	Mean±SD	95% CI for Mean	P
Delta SBP *(pre-post donation) (lying)*	10,62±11,06	7,63-13,61	0,000
Delta DBP *(pre-post donation) (lying)*	2,62±8,65	0,28-4,96	0,044
Delta MAP *(pre-post donation) (lying)*	5,33±8,73	2,97-7,69	0,000
Delta PR *(pre-post donation) (lying)*	2,24±7,67	0,16-4,31	0,008
Delta IVCexp. *(pre-post donation)*	4,76±2,94	3,97-5,56	0,000
Delta IVCins. *(pre-post donation)*	2,73±2,91	1,95-3,52	0,000
Delta MAPSE *(pre-post donation)*	2,16±1,4	1,78-2,54	0,000
Delta TAPSE *(pre-post donation)*	2,98±2,13	2,41-3,56	0,000

Table 2: Average distribution of values obtained before and after blood donation (SBP: Systolic blood pressure, DBP: Diastolic blood pressure, MAP: Mean arterial pressure, PR: Pulse rate, IVC: Vena Cava Inferior, TAPSE: Tricuspid Annular Plane Systolic Excursion, MAPSE: Mitral Annular Plane Systolic Excursion, SD: Standard Deviation, CI: Confidence Interval)

There was a positive and moderate correlation between (Delta VCI exp.) and (delta MAPSE), and a positive and weak correlation between (delta TAPSE) and standing systolic blood pressure and these correlations were statistically significant ($p<0.05$). There was no statistically significant correlation between the pre- and post-procedure changes of VCI, TAPSE and MAPSE variables and the pre- and post-procedure changes of other variables ($p>0.05$) (Table 3).

Table 3

	Delta IVC Exp	Delta IVC Exp	Delta IVC İns	Delta IVC İns	Delta MAPSE	Delta MAPS
	r	p	r	p	r	p
Delta MAPSE	0,435	0,001	0,048	0,728	1,000	
Delta TAPSE	-0,111	0,420	-0,097	0,483	-0,049	0,720
Delta SBP *(standing)*	0,210	0,124	0,127	0,354	0,088	0,521
Delta DBP *(standing)*	0,070	0,611	0,126	0,359	0,078	0,573
Delta MAP *(standing)*	0,138	0,314	0,141	0,304	0,091	0,508
Delta PR *(standing)*	0,077	0,578	0,066	0,631	0,128	0,353
Delta SBP *(supine)*	0,100	0,467	-0,085	0,540	-0,016	0,908
Delta DBP *(supine)*	-0,057	0,681	0,091	0,507	-0,101	0,463
Delta MAP *(supine)*	0,008	0,951	0,009	0,949	-0,039	0,775
Delta PR *(supine)*	0,257	0,058	0,094	0,496	0,258	0,057

Table 3: Correlation of differences between IVC, TAPSE and MAPSE values obtained before and after blood donation with differences between vital signs obtained in standing and supine position (SBP: Systolic blood pressure, DBP: Diastolic blood pressure, MAP: Mean arterial pressure, PR: Pulse rate, IVC: Vena Cava Inferior, TAPSE: Tricuspid Annular Plane Systolic Excursion. MAPSE: Mitral Annular Plane Systolic Excursion).

Discussion

In this study, we found that low VCI, TAPSE and MAPSE values were effective in determining blood loss after 450 ml blood donation. As a main conclusion, we revealed that the measurement of TAPSE and MAPSE can be useful in the early detection of acute blood loss. In addition, we found significant changes in systolic blood pressure and pulse rate values vital signs before and after blood donation obtained in standing position, and in systolic blood pressure, diastolic blood pressure, mean arterial pressure and pulse rate values obtained in supine position. To the best of our knowledge, this is the first study to compare the results of MAPSE and TAPSE measurements in determining blood loss.

In the staging of bleeding; blood pressure, pulse, pulse pressure, respiratory rate, state of consciousness and amount of urine output are used. However, these symptoms are poor indicators of acute blood loss and response to treatment . Various shock indices based on vital signs have been used in the triage of trauma patients and in determining the severity of shock, but it has been shown that the use of these indices based entirely on physiological parameters is limited in estimating the outcome in trauma patients . Tomo et al. used noninvasive volume assessment methods to predict acute blood loss in healthy volunteers donating blood. No change was detected in the pulse rate after blood loss, and the decrease in SBP, DBP and MAP values were found to be statistically significant . In the study of Güllüpınar et al., the diameter of the inferior vena cava and TAPSE measurement were compared to determine the volume loss in healthy volunteers donating blood. In this study, it was found that there was a decrease in SBP measured before and after blood donation, standing and lying down, and an increase in pulse rate, and the difference was statistically significant . Rouhezamin et al. evaluated the accuracy of the internal jugular vein waveform to detect the early stage of hemorrhagic shock in blood donor volunteers. In this study, it was found that there was a decrease in SBP and little increase in heart rate after blood loss, but the difference was not statistically significant and reliable .

In our study, after approximately 450 ml of blood loss, there was a decrease in SBP values and a slight increase in pulse rate values measured while standing, a decrease in SBP, DBP, MAP values and a slight increase in pulse rate measured in supine position. Although the difference was statistically significant, the obtained values were within normal limits.

It has been reported that various sonographic parameters decreased before the changes in traditional vital signs used to determine acute blood loss . The inferior vena cava (IVC) is a vessel that changes in size and shape with changes in intravascular volume. IVCUS is a non-invasive way of assessing volume status in acute situations. Johnson et al. performed ultrasound measurements of IVC diameter during simulated severe bleeding using low body negative pressure. They showed that IVC diameter measurement is important and the diameter decreases during blood loss . Lyon et al. aimed to provide a noninvasive measure of circulating blood volume by measuring the change in IVC diameter associated with blood loss. In healthy blood donors, IVC diameters were measured before and after blood donation during inspiration and expiration. On average, there was a decrease of approximately 5 mm in both IVCe and IVCi after 450 mL blood donation. They showed that IVC diameter measurement is a reliable indicator of blood loss even in small amounts (450 mL) . Resnick et al. evaluated the usefulness of ultrasound for detecting early signs of hemorrhagic shock in healthy volunteers, compared with changes in vital signs. In this study, changes in vital signs and IVC diameter after approximately 500 cc blood loss in healthy volunteers were found to be clinically insignificant . In a study by Olsen et al. investigating the relationship between changes in cardiac output (CO) caused by controlled bleeding and IVC diameter in healthy volunteers, it was found that IVC collapsibility index and IVCe were not correlated with the magnitude of hemodynamic response in early bleeding. The sensitivity of serial IVC diameter measurements has been reported to be approximately 80% for detecting early blood loss . In our study, the delta IVC expiratory diameter was 4.76 ± 2.94 and the inspiratory diameter was 2.73 ± 2.91 before the procedure, while the expiratory diameter was 3.97 ± 5.56 and the inspiratory diameter was 1.95 ± 3.52 after the procedure. . These findings of ours showed a significant decrease in the inspiratory and expiratory diameters of the IVC and was consistent with the literature. However, IVCUS may be associated with ventilator settings (high PEEP and/or low tidal volume), patient's inspiratory efforts (non-invasive ventilation/CPAP), lung hyperinflation (Asthma/COPD exacerbation), cardiac events that impede venous return (right ventricular infarction and It has been reported that it cannot accurately predict the fluid response in cases of cardiac tamponade) and increased abdominal pressure (intra-abdominal hypertension). Although IVC diameter measurement is useful on patients, it may not be applicable to a large number of intensive care or emergency room patients . The search for a potentially alternative parameter to IVC for assessing volume response continues.

The right ventricle (RV) received less attention than the left ventricle, and was considered a useless bystander for a long time due to its retrosternal location, very complex structure and shape . Tricuspid annular plane systolic excursion (TAPSE) measurement is one of the methods to evaluate RV systolic function and hence

RV ejection fraction. TAPSE is easy to measure, repeatable, and has unique properties derived from the forces that contribute to RV preload and afterload . Regarding TAPSE, there are many studies conducted on pulmonary hypertension, pulmonary embolism, heart failure, severe sepsis and septic shock, acute myocardial infarction and critically ill patients . MAPSE is an echocardiographic technique that is increasingly used to evaluate left ventricular (LV) function. The MAPSE measurement is simple, less sensitive to optimum image quality, and can be easily applied even by novice practitioners with little training in ECO . MAPSE has been used in critically ill patients in shock, acute pulmonary embolism, acute myocardial infarction, mechanically ventilated patients, and sepsis . Interestingly, MAPSE and TAPSE, which are used as markers of LV and RV systolic function, have not been used, although IVC studies have been performed to detect early signs of hemorrhagic shock. Recently, Güllüpınar et al. showed that TAPSE is a reliable bedside test and can be used in the early detection of acute blood loss in a prospective and cross-sectional study comparing IVC diameter and TAPSE measurement to determine blood loss in healthy volunteers donating blood . In this study, in healthy volunteers who were blood donors, the delta TAPSE value before donation was 2.98±2.13 and the delta MAPSE value was 2.16±1.4, the delta TAPSE value after donation was 2.41±3.56 and the delta MAPSE value was 1.78 ±2.54 and the changes were found to be statistically significant.

While our study provides a new perspective on the diagnosis of trauma patients, it has shown that MAPSE and TAPSE measurements are also useful in addition to IVC in detecting patients with early stage hemorrhagic shock. We think that measurement of both TAPSE and MAPSE may help the emergency physician to better diagnose and manage patients in hypovolemic shock patients. We also believe that serial measurement of changes in MAPSE and TAPSE in determining blood loss or ongoing blood loss can assist clinicians in the diagnosis and treatment of these patients.

The general limitations of our study are the limited number of subjects and the low male-female ratio. In addition, neurohormonal changes that occur as a result of accident or injury can affect both vital signs and TAPSE, MAPSE and IVC values. Therefore, the variables we measure should be tested on real patients. Future prospective studies should evaluate the advantages and weaknesses of TAPSE and MAPSE in trauma patients.

Conclusion

In conclusion, rapid and noninvasive echocardiographic parameters TAPSE and MAPSE can be used in the early diagnosis of acute blood loss.

Conflict of interest disclosure:

The authors and participating institutions have no conflicts of interest related to this article.

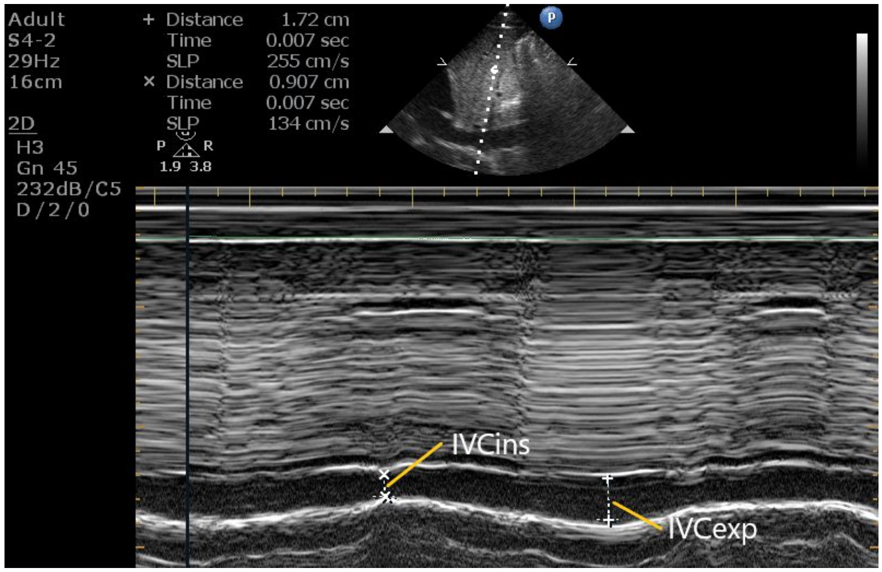
No funding was received to support data acquisition or preparation of this position paper. The research data is confidential and unsuitable.

Figure Lengeds:

Figure 1: The measurement of the inner wall diameter of the IVC in the inspiratory and expiratory phase view in M mode

Figure 2: Tricuspid annular plane systolic excursion view in M mode

Figure 3: Mitral annular plane systolic excursion view in M mode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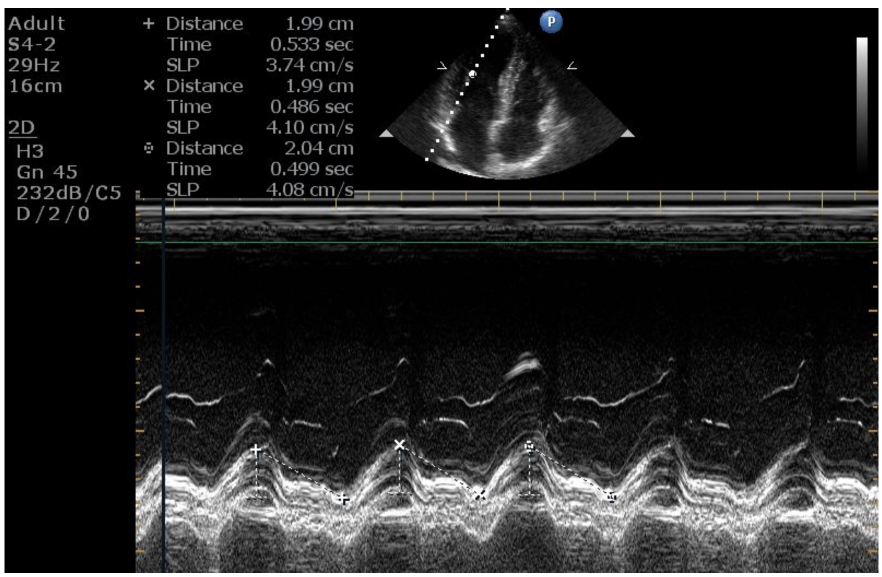
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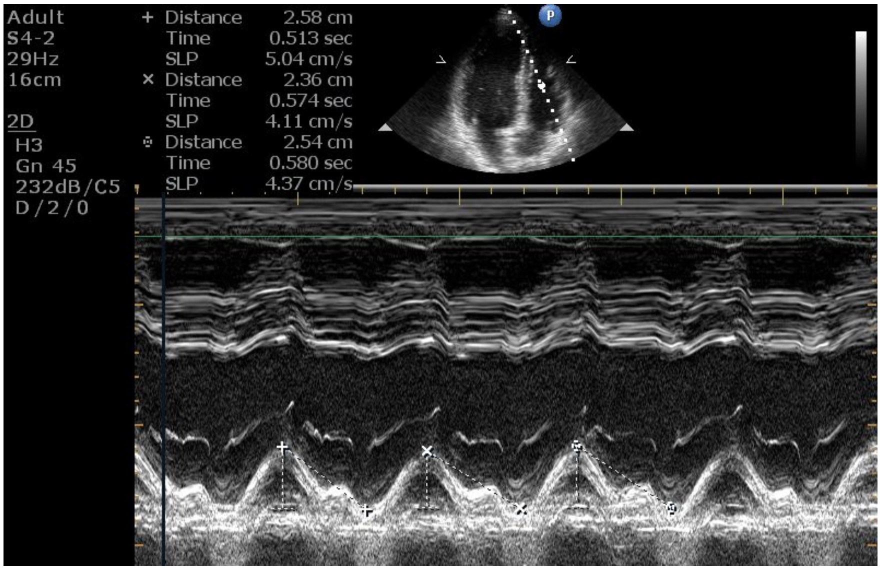

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