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USG: Boon for Critically Ill Patients in Differentiating Shock and Early Management
Short Title: Usg in Shock

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ABSTRACT: The effects of shock on end-organs are reversible if appropriate therapy is administered before multi-organ failure (MOF) sets in. Shock is classified as1) hypovolemic, 2)distributive-as in septic, anaphylactic, toxic, neurogenic, or endocrine causes, 3)cardiogenic,4) obstructive. Clinical findings aren't sufficient for diagnosing the sort of shock.USG is noninvasive, with no radiation exposure. we've studied 100 patients in ICU. The Cohen kappa inter-rater coefficient of the agreement was a statistical test utilized in our study. According to USG diagnosis by RUSH protocol hypovolemic shock, cardiogenic, obstructive, and distributive shock had an almost perfect agreement with the ultimate diagnosis. The mixed shock had a substantial agreement and the undefined shock had a moderate agreement with the ultimate diagnosis. In our prospective observational study in hypovolemic shock, the hyperdynamic heart was present in 74.2%, 'A'-pattern within the lung was in 100%, IVC collapsibility was present in 100% of patients. In obstructive shock, RV strain was present in 71.4%, altogether 100% of patients' IVC wasn't collapsible. In cardiogenic shock, 100% cases had hypodynamic LV and 56.25% of cases had a 'B'-pattern within the lungs. In distributive shock, normal LV contractility in 100% of cases, 38.5% patients had A pattern in lungs, IVC collapsibility in 7.7% cases. In mixed shock, 18.75% have IVC collapsibility, 50% of cases had 'B'-pattern in lungs, 50% in 'C'-pattern, and 87.5% had hypodynamic LV. In undefined shock, IVC collapsibility in 50% of cases and LV contractility normal in 100% patients, 'A'-pattern within the lung, free fluid within the abdomen.

Key words: 'B' pattern, hypodynamic LV, IVC collapsibility, substantial agreement

I. INTRODUCTION

A severe mismatch between the supply and demand of oxygen is that the common feature of all kinds of shock.[1] Early recognition of the condition is significant if subsequent tissue injuries are to be avoided. Shock may be a clinical state of acute circulatory failure, [2] which will result from one, or a mixture, of many mechanisms. [3] The primary of those may be a decrease in venous return because of a loss of circulating volume (i.e. because of internal or external loss of fluids). The second may be a failure of the pump function of the heart that results from a loss of contractility (resulting from ischemia, infarction, myopathy, myocarditis) or arrhythmias like ventricular tachycardia. The third is an obstruction because of embolism, tension pneumothorax, or tamponade. The fourth is loss of vascular tone that leads to mal-distribution of blood flow (due to sepsis, anaphylaxis, or spinal injury). The features of every one of those four sorts of shock often overlap, and patients admitted with one sort of shock can develop other sorts of shock. Clinical examination is usually of limited value in tamponade during a patient with trauma or septic shock during a patient with chronic heart failure during which a diagnosis is harder. Early improvement in micro-vascular perfusion in response to goal-directed therapy was related to an improvement in organ function [4]. These data strongly suggest that microcirculatory alterations are related to the development of organ failure. Echocardiography allows rapid characterization of the sort of shock and is now proposed because the first-line evaluation modality,3opposed to more invasive technologies.[5]. So our study aims at early bedside USG consistent with RUSH protocol and diagnose different types of shocks. Ultrasound in Shock the protocol involves a 3-part bedside physiologic assessment of the heart first, followed by an ultrasound of the chest and abdomen and major blood vessels simply defined as "the pump," "the tank," and "the pipes"[6] and that we also studied their correlation with D-DIMER, PRO BNP, and PRO CAL and correlated with the ultimate diagnosis and began the treatment.

II. METHODS

After informed consent obtained from patients and approval of the ethics committee of the institutions this prospective observational study was carried out ,which is "USG: Boon for critically ill patients in differentiating shock and early management" in tertiary care centers between december2019-december2020. We have studied 100 patients with shock whose mean arterial pressure (MAP) was less than 65 mmHg in normo-tensive patients and in hypertensive patients MAP less than 75 mmHg , after initial fluid resuscitation in casualty and admitted to ICU for further management. We assessed bedside ultrasonography (USG) in all of the patients immediately after admitting to ICU. Simultaneously all blood investigations were sent like CBP, ABG RFT, LFT, Electrolytes, D-Dimer, PRO-BNP, PROCAL. Supplemental oxygen started, ECG was taken. We carried out our study using Philips ultrasound machine with phased array probe 3.5 to 5 MHZ, Linear probe(7.5 to 10 MHZ) We have differentiated all patients in hypovolemic , obstructive , distributive , mixed, and undifferentiated shock. Ultrasonographic diagnoses were compared with the respective final clinical diagnoses by employing the Cohen kappa inter-rater coefficient of agreement. We analysed data using R software Version 3.6.1. Based on kappa value ,interpretation of kappa value done as poor,slight,fair,moderate,substantial,and almost perfect. We studied parameters like 'A' pattern,' B' pattern,' C' pattern in lung USG and correlated clinically on chest auscultation for presence or absence of crepts. The presence of sliding sign , the presence of seashore sign, ' B' lines, and lung pulse excluded pneumothorax. The presence of a barcode sign on lung ultrasound suggested pneumothorax, and the shock was suspected as an obstructive shock. If pneumothorax suspected, intercostal drainage tube inserted in 4th to 5th intercostal space in midaxillary line. Presence of b/l B lines with good contractility of heart is correlated with ABG to see presence of ARDS and treated accordingly with NIV support and management of etiology of ARDS. In patients with b/l 'B' lines with poor contractility of heart treated with diuretics and NIV support. In 2DECHO, we have assessed contractility of the heart by eyeballing and measured ejection fraction of patients. The patients having poor contractility of heart with shock classified as cardiogenic shock and were started with ionotropic support. IVC collapsibility was assessed in spontaneously breathing patients and IVC distensibility in patients on mechanical ventilation. When IVC size lower than 2 cm and IVC collapsibility was greater than 50% and absence of 'B' lines on chest USG classified as hypovolemic shock and resuscitated with fluids. Diastolic dysfunction was assessed with an E/A ratio. The enlarged right ventricle and enlarged right atrium in a patient of shock suggested pulmonary embolism and obstructive shock. The patients having shock but no significant findings on USG were classified under undefined type of shock. In mixed shock, the patient had USG findings of two or more types of shock

III. RESULTS

According to USG diagnosis by RUSH protocol hypovolemic shock, obstructive shock, cardiogenic shock and distributive shock had almost perfect agreement with final diagnosis. Mixed shock had substantial agreement and undefined shock had moderate agreement with final diagnosis. In hypovolemic shock, hyperdynamic heart was in 74.2%, A-pattern in lung was 100%, IVC collapsibility was 100%.In obstructive shock RV strain was present in 71.4%,in all 100% patients IVC was not collapsible. In cardiogenic shock 100%cases had hypodynamic LV and 56.25% cases had B-pattern in lungs. In distributive shock, normal LV contractility in 100% of cases, 38.5% patients had A pattern in lungs, IVC collapsibility in 7.7% cases. In mixed shock,18.75% had IVC collapsibility, 50% cases had B-pattern in lungs, 50% in C-pattern and 87.5% had hypodynamic LV. In undefined shock IVC collapsibility was in 50% of cases and LV contractility normal in 100% patients, A-pattern in lung, free fluid in abdomen.

IV. DISCUSSION

Mohammad Reza Ghane etal,[7] in a study published in 2015 evaluated the prevalence of different types of shock based on the final diagnosis reached during hospitalization. The most frequent types of shock was cardiogenic shock (20 patients, 26% of the total). Eight cases (11%) died before they could clinically confirm the exact cause of shock state and were classified as "not defined". On the basis of the early RUSH exam

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findings for these patients, six were identified as mixed, and two as cardiogenic shock. The Kappa index for general agreement between shock types was defined using the RUSH protocol and which was shown to be 0.71 (P = 0.000) for all patients. This index was observed as 0.70 (P = 0.000) when the protocol was performed by the emergency physician and observed as 0.73 (P = 0.000) when performed by the radiologist, which reflects acceptable agreement for this protocol which is consistent with our study. In our study according to USG diagnosis by RUSH protocol 31 cases were hypovolemic shock but after final diagnosis 29 cases were hypovolemic shock, 1 case was distributive shock and 1 case was a mixed shock. According to USG diagnosis by RUSH protocol 7 cases were an obstructive shock in which 6 cases were finally diagnosed as obstructive shock and 1 case as a mixed shock. In cardiogenic shock, 16 cases were noted according to USG diagnosis by the RUSH protocol in that 15 cases were finally diagnosed as cardiogenic shock and 1 case was a mixed shock. According to USG diagnosis by RUSH protocol 26 cases were distributive shock in that 25 cases were finally diagnosed as distributive shock and 1 case as a mixed shock. Among 15 cases of mixed shock, 13 cases were finally diagnosed as mixed shock and 1 case as cardiogenic shock, 1 case as distributive shock, and 1 case as an undefined shock. In this study, according to USG diagnosis by RUSH protocol, there were 4 undefined shocks but in the final diagnosis 2 cases were distributive shock and 2 cases were an undefined shock.

In our study KAPPA agreement value in hypovolemic shock was 0.952, obstructive shock was 0.918, cardiogenic shock was 0.926, distributive shock was 0.875, mixed shock was 0.746, undefined shock was 0.556. According to USG diagnosis by RUSH protocol hypovolemic shock, obstructive shock, cardiogenic shock, and distributive shock had an almost perfect agreement with the final diagnosis. The mixed shock had a substantial agreement and undefined shock had a moderate agreement with the final diagnosis which is similar to the study conducted by Blanco, P. et.al.[8] in 2015 The overall agreement for type of shock estimated by the RUSH protocol and final diagnosis of the patient was perfect (kappa=0.84, p value= 0.0001 with 88 % sensitivity and 96 % specificity). They performed RUSH exam, blindly on the patient who were emergency medical staff and they were not part of the patient's care-giving team. The results of the RUSH exam were then compared to the final diagnosis of the patients and outcome seen for the 48-hours.

In our study we found out that sensitivity and negative predictive value of USG diagnosis by the RUSH protocol was 100 % in hypovolemic and obstructive shock. Sensitivity and positive predictive value were less in mixed and undefined shock. Specificity was 98.93% in obstructive shock, 98.8% in cardiogenic shock, 98.59% in distributive shock, 97.93% in undefined shock, 97.18% in hypovolemic shock, 96.38% in mixed shock. The negative predictive value was 98.80% in cardiogenic shock, 94.59% in distributive shock, 95.23% in mixed shock, 98.95% in undefined shock, which is similar to the study conducted by Mohammad Reza Ghane et al.[7] in which the sensitivity, specificity, PPV, NPV, and Kappa index of the protocol for determining each type of shock. Hypovolemic Shock had 100% sensitivity, and 100 % negative predictive value. Obstructive shock had 90.9% sensitivity and 98.3% negative predictive value. Cardiogenic shock had 97% negative predictive value. Distributive shock had 72.7% sensitivity and 95.1% negative predictive value. Mixed Etiology Shock had sensitivity of 63.6%. Tanvi et al,[13] studied the ultrasound findings in different types of shock. In their study in hypovolemic shock 71.8% patients had hyperdynamic heart, A profile in the lung was present in 90% patients, IVC collapsibility was present in 100% of the patients .In distributive shock, 71.8% had normal LV contractility, A profile present in 79.5% patients, IVC was collapsible in 79.5% patients. In cardiogenic shock, hypodynamic LV was present in 100% of cases and B profile in lung USG in 81.1% cases. In obstructive shock, 60% cases had RV strain and 40% cases had cardiac tamponade. This is consistent with our study in which in hypovolemic shock hyperdynamic heart was present in 74.2% patients, A-pattern in the lung was present in 100% patients, IVC collapsibility was present in 100%.In obstructive shock, RV strain was present in 71.4%, and in 100% patients, IVC was not collapsible. In cardiogenic shock, 100%cases had hypodynamic LV and 56.25% cases had B-pattern in the lungs. In distributive shock, normal LV contractility in 100% of cases, 38.5% of patients had A pattern in lungs, IVC collapsibility in 7.7% cases. In mixed shock, 18.75% have IVC collapsibility, 50% of cases had B-pattern in lungs, 50% in C-pattern and 87.5% had hypodynamic LV. In undefined shock, IVC collapsibility in50% of cases and LV contractility normal in 100% patients, A-pattern in the lung, free fluid in the abdomen.

In our study creptitations had a substantial agreement with decreased LV contractility in USG with kappa value = 0.747 this is consistent with the study conducted by R.Madhumathi et al,[12]in 2020 which shows new onset creptations during fluid therapy had a moderate agreement with decreased LV contractility(hypodynamic LV) in USG in the fluid intolerant state with kappa value of 0.559.R.Madhumathi et al,[12] in 2020 conducted a study that new-onset crepitations had a substantial agreement with pulmonary interstitial edema (B lines in USG) in the fluid intolerant state during fluid management with kappa value of 0.627 similar to our study which shows creptitations had a moderate agreement with B pattern in lung USG with kappa value of 0.495

In Jain, S. et al,[10] 2014 case report in their patient on bedside USG there was a grossly enlarged right atrium and right ventricle with D shaped left ventricle. McConnell's sign was present. The pulmonary artery was dilated with pulmonary artery systolic pressure 80 mm of hg. Left ventricular contractility was adequate. they have observed there was no evidence of pericardial effusion or any valvular dysfunction. Inferior vena cava was full, dilated and non collapsing with respiration. They have done screening for deep venous thrombosis, (femoral vein in the femoral canal, popliteal vein in popliteal fossa) and found to be normal. Screening of the aorta was also normal. With this information, diagnosis of pulmonary thrombo-embolism (PTE) causing obstructive shock was considered. They have concluded that by focusing on both the anatomy and the physiology, points of care ultrasound by intensivists may help in differentiating between various etiologies of hypotension in the unstable patient. The relatively poor sensitivity of ultrasound findings necessitates other investigations to rule out the diagnosis of pulmonary thrombo-embolism in critically ill patients.

In Bagheri-Hariri S, et al,[11] study twenty-five patients were enrolled in this study. The overall kappa correlation of the RUSH exam compared with the final diagnosis was 0.84 which is an almost perfect agreement. The overall sensitivity of the RUSH exam was 88 % and the specificity was 96 %. Although the mortality rate was 64 %, there was not a significant relationship between mortality and the protocol used for diagnosis. The RUSH exam could be used in emergency wards to detect types of shock. This was a single-center prospective study in which all patients with an unknown type of shock and no prior treatment were included.

V. CONCLUSION

We conclude that bedside USG by RUSH protocol is noninvasive, without any radiation exposure, easily repeated and immediate tool to diagnose different type of shock and decide on line of management with 100% sensitivity in hypovolemic and obstructive shock and high specificity in obstructive shock, cardiogenic shock, and distributive shock and undefined shock ,whereas less sensitive in undefined and mixed shock. We like to further add that hypovolemic shock, obstructive shock, cardiogenic shock and distributive shock had almost perfect agreement with final diagnosis. Mixed shock had substantial agreement and undefined shock had moderate agreement with final diagnosis.

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Tables and figures

Table no 1: Agreement of creptitations with hypodynamic left ventricle

Added sounds	Hyperdynamic heart	Hypodynamic LV	Total	Kappa
AEBE	23 (100%)	7 (23.4%)	30 (56.6%)	0.740
Crepts	0 (0%)	23 (76.6%)	23 (43.3%)	
Total	23 (100%)	30 (100%)	53 (100%)	

AEBE-air entry bilaterally equal,LV-left ventricle
Creptitations had substantial agreement with decreased LV contractility in USG with kappa value of 0.740

Table no 2: Agreement of creptitations with B pattern in lung USG

Added sounds	Normal lungs (non B pattern)	B pattern in lungs	Total	Kappa
AEBE	60(73.1%)	0(0%)	60(60%)	0.495
Crepts	22(26.8%)	18(100%)	39(39%)	
Total	82(100%)	18(100%)	100(100%)	

USG-ultrasonography
Creptitations had moderate agreement with B pattern in lung USG with kappa value of 0.495

Table no 3: Agreement of PRO-BNP with hypodynamic LV

Pro BNP	Hyperdynamic LV	Hypodynamic LV	Total	Kappa

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Normal	23 (100%)	0 (0%)	23 (43.4%)	1.000
Increased	0 (0%)	30 (100%)	30 (56.6%)	
Total	23(100%)	30 (100%)	54 (100%)	

PRO BNP had almost perfect agreement with hypodynamic LV in USG with kappa value of 1.000

Table no 4: Agreement of D DIMER with RV STRAIN

D-Dimer	RV strain present	RV strain absent	Total	Kappa
Normal	4 (80%)	95 (100%)	99 (99%)	-0.020
Increased	1 (20%)	0(0%)	1 (1%)	
Total	5 (100%)	95 (100%)	100 (100%)	

RV-right ventricle
D-Dimer had less chance agreement with RV strain in USG with kappa value of -0.020

Table no 5: Showing RUSH protocol and diagnostic accuracy

USG diagnosis by RUSH protocol	Shock by final diagnosis						
	Hypovolumic	Obstructive	Cardiogenic	Distributive	Mixed	Undefined	Total
Hypovolaemic	29			1	1		31
Obstructive		6			1		7
Cardiogenic			15		1		16
Distributive				25	1		26
Mixed			1	1	13	1	16
Undefined				2		2	4
	29	6	16	29	17	3	100

Among 100 cases included in the study according to USG diagnosis by RUSH protocol 31 cases are hypovolaemic shock but after final diagnosis 29 cases were hypovolaemic shock, 1 case was distributive shock and 1 case was mixed shock. According to USG diagnosis by RUSH protocol 7 cases were obstructive shock in which 6 cases were finally diagnosed as obstructive shock and 1 case as mixed shock. In cardiogenic shock 16 cases were noted according to USG diagnosis by RUSH protocol in that 15 cases were finally diagnosed as cardiogenic shock and 1 case was mixed shock. According to USG diagnosis by RUSH protocol 26 cases were distributive shock in that 25 cases are finally diagnosed as distributive shock and 1 case as mixed shock. Among 15 cases of mixed shock 13 cases were finally diagnosed as mixed shock and 1 case as cardiogenic shock, 1

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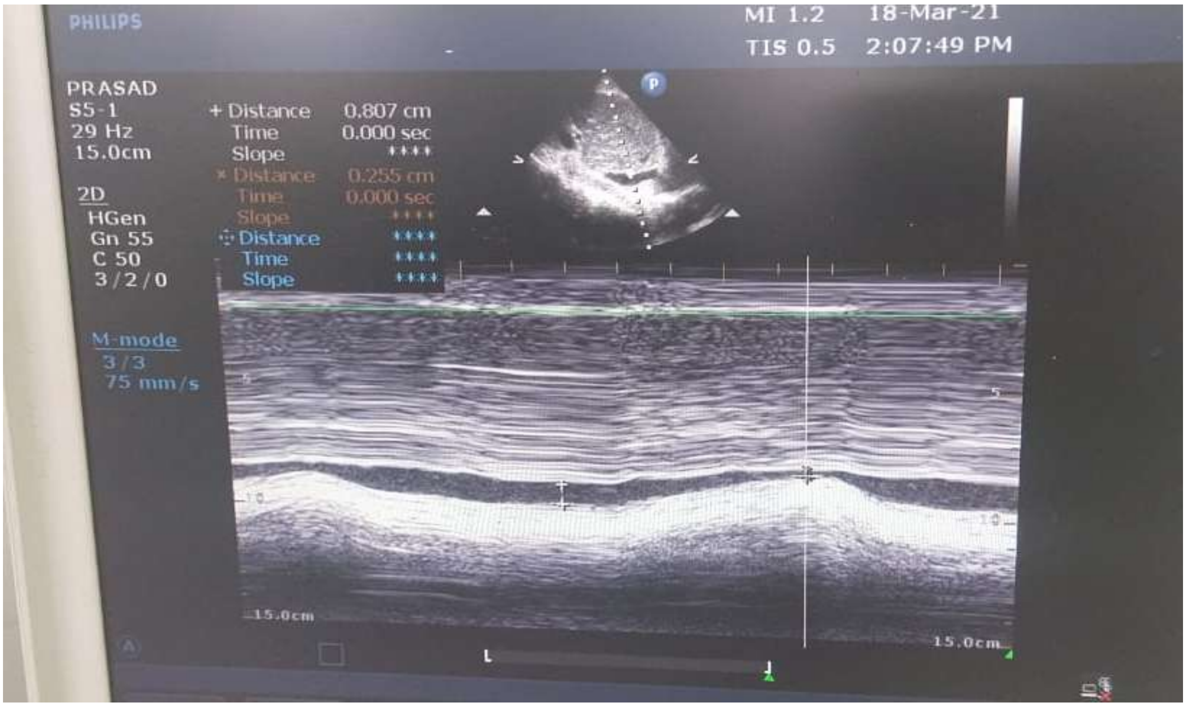
case as distributive shock and 1 case as undefined shock. In this study according to USG diagnosis by RUSH protocol there were 4 patients of undefined shock but in final diagnosis 2 cases were distributive shock and 2 cases were undefined shock.

Table 6: Statistical analysis of USG diagnosis and final diagnosis

Test	Shock					
	Hypovolaemic	Obstructive	Cardiogenic	Distributive	Mixed	Undefined
Sensitivity	100%	100%	93.75%	86.20%	76.47%	66.66%
Specificity	97.18%	98.93%	98.8%	98.59%	96.38%	97.93%
Positive predictive value	93.54%	85.71%	93.75%	96.15%	81.25%	50%
Negative predictive value	100%	100%	98.80%	94.59%	95.23%	98.95%
Kappa score	0.952	0.918	0.926	0.875	0.746	0.556

Sensitivity and negative predictive value of USG diagnosis by RUSH protocol was 100 % in hypovolemic and obstructive shock. Sensitivity and positive predictive value was less in mixed and undefined shock. Specificity was 98.93% in obstructive shock, 98.8% in cardiogenic shock, 98.59% in distributive shock, 97.93% in undefined shock, 97.18% in hypovolaemic shock, 96.38% in mixed shock. Negative predictive value was 98.80% in cardiogenic shock 94.59% in distributive shock, 95.23% in mixed shock, 98.95% in undefined shock. KAPPA agreement value in hypovolemic shock was 0.952, in obstructive shock was 0.918,in cardiogenic shock was 0.926, in distributive shock was 0.875, in mixed shock was 0.746, in undefined shock was 0.556.

Figure 1: USG showing IVC size and collapsibility



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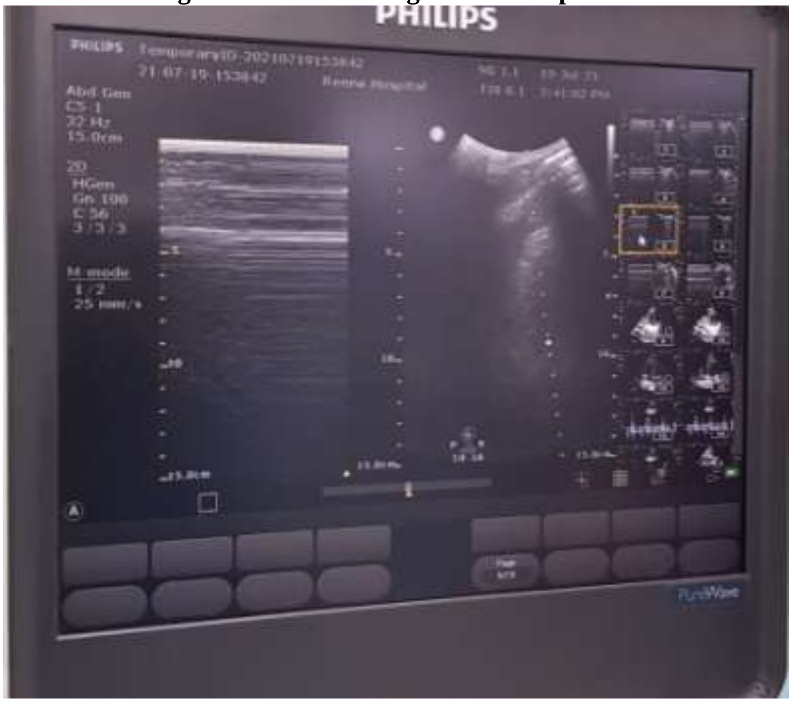
The above figure showing M mode in IVC and we can see IVC size and IVC collapsibility. We have confirmed IVC by pulse wave Doppler.Above USG finding of IVC collapsibility seen in hypovolemic shock.

Figure 2: USG showing M-mode in pleura



The above image showing sliding sign of pleura in USG chest and M-mode is applied on the pleura showing barcode sign suggestive of pneumothorax.

Figure 3: USG showing left ventricular contractility in short axis

The above figure shows the contractility of left ventricle in short axis view**.** We have assessed left ventricle contractility by eye balling and then measured in the ejection fraction and if left ventricle contractility is poor then the type of shock was diagnosed as cardiogenic shock and patient was started on Inj. dopamine and dobutamine support.