Utility of Point-of-Care Ultrasound in Differentiating Causes of Shock in Resource-Limited Setup

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Abstract

Background: Delivering early diagnosis of shock in resource-limited setting is challenging, especially with limited availability of point-of-care laboratory and radiological diagnostic facilities. There is growing urgency to provide point-of-care diagnosis and treatment for time-sensitive condition like shock. Aims: We tried to evaluate the application of point-of-care ultrasound (Rapid Ultrasound for Shock and Hypertension [RUSH] protocol) considering different disease cohort and practice realities in our setup. Settings and Design: This study was a single-center prospective diagnostic study to check the diagnostic accuracy of point-of-care ultrasound (RUSH protocol). This study was approved by the ethics committee. Materials and Methods: The study was conducted at the emergency medicine department of a tertiary care government hospital in Central Gujarat from November 16 to October 17. All adult patients with clinical features of shock with systolic blood pressure <90 mmHg and shock index >1 presenting to emergency department were included as participants. The results of point-of-care ultrasound (RUSH protocol) were compared with the diagnosis given by consultants of respective department as per standard departmental practices. Statistical Analysis and Results: A total of 130 patients were enrolled in this study. Mean time taken to examine by the point-of-care Ultrasound (RUSH protocol) was 12 min (range 11 – 14 min). Kappa index was 0.860. This protocol was able to correctly diagnose 100% of obstructive shock, 96.3% of cardiogenic shock, 94.4% of hypovolemic shock, 80.9% of mixed type of shock, and 75% of distributive type of shock. Conclusion: This study highlights the role of point-of-care ultrasound (RUSH protocol) for early diagnosis of the shock etiology in emergency medicine department. Diagnosis using point-of-care ultrasound (RUSH protocol) significantly agreed with medical diagnosis. It showed good efficacy of point-of-care ultrasound (RUSH protocol) to differentiate causes of shock with good accuracy except distributive shock.

Keywords: Emergency medicine, point-of-care ultrasound, Rapid Ultrasound for Shock and Hypertension protocol, shock

INTRODUCTION

Shock is a final common pathway associated with regularly encountered emergencies including myocardial infarction, microbial sepsis, pulmonary embolism, significant trauma, and anaphylaxis. Shock results in impaired tissue perfusion, cellular hypoxia, and metabolic derangements that cause cellular injury. Final outcome of the patient in shock is dependent on the severity and duration of inadequate organ perfusion and tissue oxygenation. It is important that emergency physicians, familiar with the broad differential diagnosis of shock, be prepared to rapidly recognize, resuscitate, and target appropriate therapies aimed at correcting the underlying process.

As per the current practice policy, etiological diagnosis of shock evolves from detailed history, clinical examination, and laboratory and radiological investigations. Clinical findings of different types of shock can easily overlap each other due to which etiological diagnosis remains uncertain.[1] Clinical examination and laboratory investigations often consume time, which is often not suitable for critically ill patients. Obtaining history from patients in shock may be difficult or impossible due to altered mental status.

Point-of-care ultrasound (Rapid Ultrasound in Shock [RUSH] protocol) is an emergency ultrasound protocol designed
to recognize distinctive shock etiologies integrating pulmonary, cardiac, abdominal, and venous examinations. It is evaluated in three-part assessment simplified as the pump (heart), the tanks (inferior vena cava [IVC], internal jugular vein [IJV], lungs, pleural cavity, and peritoneal cavity), and the pipes (aorta, femoral veins, and popliteal veins).\(^2\)\(^-\)\(^4\)

Delivering early diagnosis of shock in resource-limited setting is challenging, especially with limited availability of point-of-care laboratory diagnostic facilities. There is growing urgency to provide point-of-care diagnosis and organized treatment, especially for time-sensitive critical condition like shock.

While the core concepts of emergency medicine are internationally universal, we tried to evaluate the application of point-of-care ultrasound (RUSH protocol) considering different disease cohort and practice realities in one of the largest government tertiary care hospitals of Central Gujarat having an average of 250 patients per day.

The hypothesis of the study was to check whether the early diagnostic predictions guided by point-of-care ultrasound (RUSH protocol) would significantly agree with medical diagnoses.

This study was done to compare point-of-care ultrasound (RUSH protocol) diagnosis with medical diagnosis for the etiology of shock. This study also analyzed the causes of shock in different categories to analyze whether Indian disease cohort behaves in a similar manner as in Western countries.

### Materials and Methods

This study was a single-center prospective diagnostic study to check the diagnostic accuracy of point-of-care ultrasound (RUSH protocol). The study was conducted at the emergency medicine ward of a tertiary care government hospital in Central Gujarat from November 16 to October 17. With 92% prevalence of various type of shock, 5% risk, and 95% confidence interval, the sample size was calculated to be 114 and considering 10% data loss, the size was rounded off to 130. All adult patients with clinical features of shock with systolic blood pressure <90 mmHg and shock index >1 presenting to the emergency department (ED) were included as participants. Patients with severe obesity (body mass index >40), pregnant patients, and patients with known ascites and pleural effusion due to chronic diseases were excluded from the study. A semi-structured checklist [Table 1] was prepared for the collection of data. Data collection tool was having three parts; initial basic demographic details were collected followed by point-of-care ultrasound (RUSH protocol) checklist, and the last part of the pro forma details was collected by follow-up with medical diagnosis. The point-of-care ultrasound (RUSH protocol) was carried out parallel to critical standard resuscitation and management of the patients. Mylab 30 from Esaote ([Mylab 30 from Esaote (E. Melen, 77, 16152 Genova, Italy)]) with linear (7.5–10 MHz) and curvilinear probe (3–5 MHz) were used to perform point-of-care ultrasound (RUSH protocol).

Point-of-care ultrasound (RUSH protocol) in detail:\(^2\)\(^-\)\(^3\)

The patient was positioned supine. Curvilinear probe was used for adequate thoraco-abdominal inter costal

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**Table 1: Check list for Point Of Care Ultrasound (RUSH protocol)**

| PUMP | Pericardial effusion | Present/Absent |
|------|----------------------|----------------|
| Right ventricular diastolic collapse | Present/Absent |
| Cardiac chamber size (Visual) | Small/Normal/Dilated |
| Global left ventricular contractility (Visual) | Poor/Good/Vigorous |
| Right ventricular strain | Present/Absent |
| Paradoxical septal movement | Present/Absent |

| TANKS | Inferior vena cava/ | IVC size | <2.1 cm/≥2.1 cm |
|-------|---------------------|----------|-----------------|
| Internal jugular vein | IVC collapse with inspiration | ≥50%/<50% |
| Assessment | IJV collapse with inspiration | ≥50%/<50% |
| E-FAST Examination | Free fluid in peritoneal cavity | Present/Absent |
| Free fluid in pleural cavity | Present/Absent |

| Lung Ultrasound | Lung Sliding | Present/Absent |
|-----------------|--------------|----------------|
| Comet tail | Present/Absent |
| Lung rocket | Present/Absent |
| Seashore sign | Present/Absent |
| Barcode sign | Present/Absent |

| PIPES | Abdominal aortic diameter | >3 cm/≤3 cm |
|-------|---------------------------|-------------|
| Proximal aortic diameter | ≥3.8 cm/≤3.8 cm |
| Aortic intimal flap | Present/Absent |
| Femoral vein Assessment | Direct pressure collapse | Incomplete/Complete |
| Thrombus | Present/Absent |

| Popliteal vein Assessment | Direct pressure collapse | Incomplete/Complete |
| Thrombus | Present/Absent |
scanning. A linear probe was used for the lung and venous examination. To avoid subjective bias, all the participants were examined and assessed by the same emergency physician expert in emergency medicine ultrasound. The checklist of point-of-care ultrasound (RUSH protocol) to differentiate the causes of shock was structured from a
review article by Perera and Mailhot et al. [Table 1]. For pump examination, a curvilinear probe (3–5 MHz) was used for the study of heart through the subcostal, parasternal long- and short-axis, and apical four-chamber views. The apical four-chamber view was checked for pericardial effusion and right ventricular (RV) diastolic collapse and
signs of RV strain [Figures 1-3]. The parasternal long- and short-axis views were examined for visual estimation of qualitative left ventricular function and cardiac chamber size and paradoxical septal movement [Figures 4-7]. For tank examination, the curvilinear probe was used for IVC exam [Figures 8 and 9] and extended focused assessment sonography for trauma (eFAST) exam [Figures 10 and 11] and pulmonary edema exam [Figure 12]. Linear probe was used for IJV exam [Figure 13] and lung exam [Figures 14-16]. For pipe examination, the curvilinear probe was used for aortic dissection [Figure 17] and abdominal aortic aneurysm examination, and the linear probe was used for femoral and popliteal venous exam for deep venous thrombosis.

By using point-of-care ultrasound (RUSH protocol), the type of shock was predicted and marked as hypovolemic, cardiogenic, obstructive, distributive shock, which was compared with medical diagnosis (gold standard). Mixed type of shock was a name given when the features were combined of different types of the shock.

**Medical diagnosis**

After applying point-of-care ultrasound (RUSH protocol), the findings were revealed as emergency medicine ultrasound report. All the patients were transferred to medicine or surgery ward for further management as per hospital policy. The consultants of respective department made diagnosis of shock based on clinical history.
examination, and detailed laboratory and radiological investigations as per departmental practices. Most of these medical diagnoses were done within 48 h. Point-of-care ultrasound (RUSH protocol) diagnosis was compared with the diagnosis given by the consultants of medicine or surgery department to check the diagnostic accuracy of point-of-care ultrasound (RUSH protocol).

Diagnostic accuracy was measured by calculating agreement, accuracy, sensitivity, specificity, positive predictive value, and negative predictive value (NPV) of point-of-care ultrasound (RUSH protocol). Kappa statistic was used to calculate agreement for these two different diagnoses. Data entry was done in Microsoft Excel and statistical calculations were done with the help of Medcalc Software (Ostend, Belgium).

**RESULTS AND ANALYSIS**

A total of 130 patients were contacted for the study among which 16 patients died within the first ¾ hour of their admission in emergency medicine, 10 patients died before reaching the medical diagnosis, 3 patients refused to get admitted, and, in 4 patients, it was difficult to obtain views in point-of-care ultrasound (RUSH protocol) due to obesity. Analysis was done for a total of 97 patients. A total of 58 (59.8%) participants were male in the age group of 42–65 years, while 39 (40.2%) participants were female in the age group of 39–55 years. Kappa index was 0.860. Mean time taken to examine by the point-of-care ultrasound (RUSH protocol) was 12 min (range 11–14 min).

In this study, the most frequent type of shock observed by point-of-care ultrasound (RUSH protocol) was cardiogenic shock (29 patients) followed by hypovolemic shock (21 patients), mixed-type shock (18 patients), obstructive shock (16 patients), and distributive shock (13 patients) [Table 2].

In this study, 21 patients were diagnosed as hypovolemic shock by point-of-care ultrasound (RUSH protocol) [Table 2]. Out of the 21 patients, medically, 17 patients were diagnosed as hypovolemic shock, 2 patients were diagnosed as distributive shock, and 2 patients were diagnosed as mixed-type shock. The etiologies of 18 medically diagnosed hypovolemic patients were ten cases of trauma, three cases of diarrhea, two cases of burns, two cases of aortic dissection, and one case of dengue shock syndrome.

A total of 29 patients were diagnosed as cardiogenic shock by point-of-care ultrasound (RUSH protocol) [Table 2]. Out of the 29 patients, medically 26 patients were diagnosed as cardiogenic shock, 2 patients were diagnosed as distributive shock, and 1 patient was diagnosed as mixed-type shock by medical diagnosis. The etiologies of 27 medically diagnosed as cardiogenic shock were 7 cases of acute myocardial infarction, 10 cases of congestive cardiac failure, 8 cases of arrhythmia with rheumatic heart disease, and 2 cases of complete atrioventricular nodal block.

A total of 16 patients were diagnosed as obstructive shock by point-of-care ultrasound (RUSH protocol) [Table 2]. Out of the 16 patients, medically 15 patients were diagnosed as obstructive shock and 1 patient was diagnosed as mixed-type shock. The etiologies of 16 medically diagnosed obstructive shock patients were 8 cases of cardiac tamponade, 4 cases of acute pulmonary embolism, and 3 cases of tension pneumothorax.

A total of 13 patients were diagnosed as distributive shock by point-of-care ultrasound (RUSH protocol) [Table 2]. Out of the 13 patients, medically 12 patients were diagnosed as distributive shock and 1 patient was diagnosed as hypovolemic shock. The etiologies of 13 medically diagnosed distributive shock were 6 cases of pneumonia, 3 cases of peritonitis, 2 cases each of urosepsis, 2 cases of swine flu, 1 patient of burns, 1 patient of infective endocarditis, and 1 patient of intrauterine fetal death.

A total of 18 patients were diagnosed as mixed-type shock by point-of-care ultrasound (RUSH protocol) [Table 2]. Out of 18 patients, medically 17 patients were diagnosed as mixed-type shock and 1 patient was diagnosed as cardiogenic shock. The etiologies of the 21 medically diagnosed patients were 6 patients of acute peritonitis with hypovolemia, 4 patients of ischemic heart disease with sepsis, 2 patients of pneumonia with tension pneumothorax, 3 patients of burns, 3 patients of pneumonia with acute pulmonary embolism, 2 patients of swine flu, and 1 patient of acute pulmonary embolism with cardiac failure.

While analyzing the level of agreement between point-of-care ultrasound (RUSH protocol) and medical diagnosis, Kappa index was 0.860 [Table 2].

### Table 2: Classification of shock by both methods

| Probable type of shock by RUSH examination | Number of patients | Medical diagnosis of shock type | Total |
|------------------------------------------|--------------------|--------------------------------|-------|
|                                         |                    | Hypovolemic shock | Cardiogenic shock | Obstructive shock | Distributive shock | Mixed-type shock |       |
| Hypovolemic shock                        | 17                 | 0                 | 0                 | 2                 | 2                 | 21               |       |
| Cardiogenic shock                        | 0                  | 26                | 0                 | 2                 | 1                 | 29               |       |
| Obstructive shock                        | 0                  | 0                 | 15                | 0                 | 1                 | 16               |       |
| Distributive shock                       | 1                  | 0                 | 0                 | 12                | 0                 | 13               |       |
| Mixed-type shock                         | 0                  | 1                 | 0                 | 0                 | 17                | 18               |       |
| Total                                    | 18                 | 27                | 15                | 16                | 21                | 97               |       |

\( \kappa = 0.860, 95\% CI: 0.770–0.950 \). RUSH: Rapid Ultrasound in Shock, CI: Confidence interval
Diagnostic accuracy of point-of-care ultrasound (RUSH protocol) was checked with sensitivity, specificity, PPV, and NPV as mentioned in Table 2. Point-of-care ultrasound (RUSH protocol) could correctly diagnose 100% of obstructive shock patients, 96.3% of cardiogenic shock patients, 94.4% of hypovolemic shock patients, 80.9% of mixed type of shock patients, and 75% of distributive type of shock patients. Point-of-care ultrasound (RUSH protocol) was able to positively predict 94.4% of mixed shock, 93.7% of obstructive shock, 92.3% of distributive shock, 89.6% of cardiogenic shock, and 80.9% of hypovolemic shock [Table 3].

DISCUSSION

The present study was conducted at the department of emergency medicine to compare point-of-care ultrasound (RUSH protocol) diagnosis of shock etiology in critically ill patients with medical diagnosis. There are few studies of similar nature carried out and reported in the literature in developed countries until now.

In this study according to structured checklist, the mean time to perform point-of-care ultrasound (RUSH protocol) was 12 min (11–14 min.). The initial impression provided by performing point-of-care ultrasound (RUSH protocol) after admission was comparable with medical diagnosis reached after the course of hospitalization.

In our resource-limited setup, before application of point-of-care ultrasound, we followed institutional investigation protocol comprising of laboratory and radiological profile, which was very time consuming and not always possible to completely follow in every patient of shock. After application of point-of-care ultrasound (RUSH protocol), we were able to differentiate the causes of shock within 12 min (11–14 min) without interrupting ongoing resuscitation.

In this study, the most frequent type of shock was cardiogenic shock followed by hypovolemic shock, mixed-type shock, obstructive shock, and distributive shock. The study performed by Ghane et al.[1,5] also documented that the most frequent type of shock was cardiogenic shock.

Sensitivity to diagnose cardiogenic and obstructive shock was high (96.3% and 100%, respectively), while for distributive category, the sensitivity was low (75%). This could be due to the dynamic nature of distributive (septic) shock, which may have different types of complex findings in a point-of-care ultrasound (RUSH protocol).[2] Repeated point-of-care ultrasound (RUSH protocol) may be useful to reach the diagnosis of septic shock in such cases. When there is more than one underlying mechanism for shock (mixed type of shock), the point-of-care ultrasound (RUSH protocol) has again low sensitivity (80.9%).

It suggests that while labeling as distributive or mixed type of shock by point-of-care ultrasound (RUSH protocol), the consultant needs to be more careful.

This protocol was found to be extremely reliable to rule out cardiogenic, hypovolemic, or obstructive shock (NPV >98%) which proves that the components of point-of-care ultrasound (RUSH protocol) used to diagnose these three varieties were more specific as compared to distributive and mixed varieties of shock. These findings are comparable with studies done by Ghane et al.[2]

Point-of-care ultrasound (RUSH protocol) could be a good screening tool to evaluate the possible etiology of shock in the setting of emergency medicine, as there is 86% general agreement between diagnosis made by point-of-care ultrasound (RUSH protocol) and medical diagnosis. Kappa reflects acceptable general agreement between point-of-care Ultrasound (RUSH protocol) and medical diagnosis.

CONCLUSION

This study highlights the role of point-of-care ultrasound (RUSH protocol) for early diagnosis of the shock etiology in emergency medicine department. Diagnosis using point-of-care ultrasound (RUSH protocol) significantly agrees with medical diagnosis. It also shows good efficacy of point-of-care ultrasound (RUSH protocol) to detect different types of shock etiology with good accuracy to categorize various types of shock except distributive shock. This was an effort to integrate protocol-based point-of-care ultrasound-guided diagnostic evaluation of shock patients in the emergency medicine setup.

Limitation

The point-of-care ultrasound (RUSH protocol) is extensive and incorporates multiple ultrasound elements, and hence the skills and expertise of ultrasound performer are also crucial for maintaining sufficient level of diagnostic accuracy. The study could be done on larger scale with concept of blinding before extrapolating in emergency medicine department.

Table 3: Diagnostic accuracy of Rapid Ultrasound in Shock Protocol

| Parameters       | Hypovolemic shock | Cardiogenic shock | Obstructive shock | Distributive shock | Mixed-type shock |
|------------------|-------------------|-------------------|-------------------|-------------------|------------------|
| Sensitivity (%)  | 94.4              | 96.3              | 100               | 75.0              | 80.9             |
| Specificity (%)  | 94.9              | 95.7              | 98.8              | 98.8              | 98.7             |
| PPV (%)          | 80.9              | 89.6              | 93.7              | 92.3              | 94.4             |
| NPV (%)          | 98.7              | 98.5              | 100               | 95.2              | 94.9             |

PPV: Positive predictive value, NPV: Negative predictive value
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Conflicts of interest
There are no conflicts of interest.

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