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The Potential Accuracy of the RUSH Exam

Harrison M. Friend

The Potential Accuracy of the RUSH Exam

Abstract

Background: Shock is a life-threatening state of circulatory system failure. Undifferentiated shock must be discerned among hypovolemic, cardiogenic, obstructive, distributive, and mixed classifications to allow for swift management of the acute patient. The rapid ultrasound in shock (RUSH) exam is a proposed tool to differentiate shock and therefore expedite the management these patients.

Methods: An exhaustive literature search of available medical literature using the following databases: MEDLINE-PubMed, Medline-OVID, Clinical Key, and Web of Science. Articles were excluded if published in a non-English language. Studies included indications of accuracy, specifically sensitivity, specificity, negative predictive value (NPV), positive predictive value (PPV), and kappa. Articles were assessed for quality using the Grading of Recommendations, Assessment, Development, and Evaluation (GRADE).

Results: The search revealed 151 possible articles, 3 of which fit inclusion criteria for this review. Each article demonstrated a small population and either one or an unknown number of emergency department providers that performed the ultrasonography.

Conclusion: The RUSH exam appears to be a viable tool to be used by trained and experienced providers. More studies must be performed to verify wide or absent confidence interval findings from these 3 small population studies. Since there was no gold standard to compare, the studies relied on the end diagnosis of the patient, therefore error cannot be excluded from this standpoint.

Keywords: RUSH exam, rapid ultrasound in shock examination, ultrasound, shock, emergency, diagnostic, and accuracy

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List of Abbreviations

CO	Cardiac Output
ED	Emergency Department
eFAST	Extended Focused Assessment with Sonography in Trauma
EMS	Emergency Medical Services
GI	Gastrointestinal
IVC	Inferior Vena Cava
IV	Intravenous
NPV	Negative Predictive Value
PE	Pulmonary Embolus
PPV	Positive Predictive Value
RUSH	Rapid Ultrasound in Shock
RV	Right Ventricle
SBP	Systolic Blood Pressure
SIRS	Systemic Inflammatory Response Syndrome
SVR	Systemic Vascular Resistance
US	Ultrasound

The Potential Accuracy of the RUSH Exam

Background

Shock is a state of collapse of the circulatory system resulting in hypoperfusion and inadequate oxygenation at a cellular level. Shock leads to hypotension, dyspnea, tachycardia, and ultimately multiorgan failure and death.[1] Shock may progress quickly, and patients experiencing shock are considered critically ill. In a 12-year population-based cohort study performed by Holler et al[2] approximately 80.6 per 100 000 emergency department (ED) patients were in a state of shock at arrival, and the 90 day mortality was 40%. While there are many diagnostic tools available in emergency departments, there are few that are rapid and effective in patients with shock. The rapid ultrasound in shock (RUSH) exam protocol has been suggested to quickly and effectively diagnose undifferentiated shock. Shock has multiple classifications that require different management due to their different causes, making it imperative for ED providers to rapidly differentiate between the various forms of shock. A patient in undifferentiated shock is at high risk.

The RUSH exam, first described by Perera et al,[3] is a 3-step ultrasound protocol designed to allow ED providers the ability to quickly classify a patient in undifferentiated shock into 1 of the 5 categories to permit swift management and better patient outcomes. The 5 categories of shock are: hypovolemic, cardiogenic, obstructive, distributive, and mixed. Hypovolemic shock may be either hemorrhagic (due to blood loss) or nonhemorrhagic (due to fluid loss other than blood, ie GI or skin loss etc.). Patients in hypovolemic shock are fluid depleted, therefore reducing cardiac output (CO). Cardiogenic shock is a failure of the heart to effectively fill and contract, thus reducing CO. Causes of cardiogenic shock are cardiac in origin and may be rhythmic, valvular, or cardiomyopathic.[4,5] Obstructive shock involves right ventricular (RV) dysfunction and causes include: decreased preload from increased thoracic or pericardial pressure from a tension pneumothorax, pericardial tamponade, etc., or increased pulmonary vascular pressure from pulmonary hypertension or pulmonary embolism (PE).[4] Distributive shock is due to systemic vasodilation leading to decreased systemic vascular resistance (SVR) and movement of intravascular fluid into interstitial space, reducing blood volume. Causes are diverse, including septic, anaphylactic, neurogenic, endocrine, and systemic inflammatory response syndrome (SIRS) related.[4] While mixed shock is not typically recognized as its own classification, mixed shock is exactly as its name states, mixed etiology. A patient in mixed shock, often referred to as combined shock, presents with multiple forms of shock. This can prove difficult to manage since multiple causes of shock may confound its management. For instance, a trauma patient with penetrating injury may have both hypovolemic shock from hemorrhage as well as distributive shock from SIRS due to the vast inflammatory response after their injury.[6]

The RUSH exam involves assessing the metaphorical pump, tank, and pipes of the circulatory system. Sebat et al[7] found that implementation of a rapid response system, or a rapid detection and treatment of shock leads to a relative reduction in mortality by 46.6%. Ultrasound is an emerging realm of possibility for quick diagnosis and management of acute conditions and the eFAST exam is now a common trauma exam.[8] This systematic review of literature aims to address the question: when implemented by ED providers, what is the potential accuracy of the RUSH exam in classifying critically ill adult patients presenting with undifferentiated shock?

Methods

An exhaustive search of available medical literature using the following databases: MEDLINE-PubMed, MEDLINE-OVID, Clinical Key, and Web of Science and using the search terms ((Rapid[All Fields] AND ("diagnostic imaging"[Subheading] OR ("diagnostic"[All Fields] AND "imaging"[All Fields]) OR "diagnostic imaging"[All Fields] OR "ultrasound"[All Fields] OR "ultrasonography"[MeSH Terms] OR "ultrasonography"[All Fields] OR "ultrasound"[All Fields] OR "ultrasonics"[MeSH Terms] OR "ultrasonics"[All Fields]) AND ("shock"[MeSH Terms] OR "shock"[All Fields])) OR (rush[All Fields] AND exam[All Fields]) AND (("diagnostic imaging"[Subheading] OR ("diagnostic"[All Fields] AND "imaging"[All Fields]) OR "diagnostic imaging"[All Fields] OR "ultrasound"[All Fields] OR "ultrasonography"[MeSH Terms] OR "ultrasonography"[All Fields] OR "ultrasound"[All Fields] OR "ultrasonics"[MeSH Terms] OR "ultrasonics"[All Fields]) AND ("ultrasonography"[MeSH Terms] OR "ultrasonography"[All Fields] OR "sonography"[All Fields]))) AND ("shock"[MeSH Terms] OR "shock"[All Fields]) AND English[lang]. Inclusion criteria required the study to evaluate the RUSH exam in the emergency department and its use in undifferentiated shock. Articles in languages other than English were excluded. Studies included indications of accuracy, specifically sensitivity, specificity, negative predictive value (NPV), positive predictive value (PPV), and kappa. Articles were assessed for quality using the Grading of Recommendations, Assessment, Development, and Evaluation (GRADE).[9]

Results

The search revealed 151 possible articles. Articles were evaluated and 2 were excluded for non-English language. There were 148 that were excluded for lack of implementation of the RUSH exam. Three studies were identified.[10-12] See Table I. The results pertaining to each measure of accuracy can be found in the Summary of Findings, Table II. Each study was performed at only 1 hospital and the number of patients were described. If given in each study, the confidence intervals are listed as well.

This systematic review was performed to investigate the accuracy of the RUSH exam in the ED. The 3 studies[10-12] all originated from Iran. No study had more than 77 participants. These studies are all prospective in nature and their methodology makes them closer to randomized, blinded studies than case control studies. Exam duration was not indicated in any of the studies and must be considered during review.

Bagheri-Hariri et al.

Bagheri-Hariri et al[10] provided the most in-depth data including confidence interval ranges. They examined 25 adult patients in shock, defined as a systolic blood pressure (SBP) of <90 mmHg or a shock index >1 with hypoperfusion symptoms. RUSH exams were performed by an unknown quantity of US credentialed board-certified emergency medicine attending physicians. There were 67 patients who excluded due to administration of IV fluid or vasoactive medication by EMS prior to arrival in the ED. Additionally, 42 patients were excluded due to a known type of shock (hemorrhagic shock due to external bleeding). Fourteen patients were excluded due to a known pleural effusion or ascites. Resulting in 14 male and 11 female patients with an mean age of 58.2 ± 5.4 years in undifferentiated shock being examined. No patients presented with obstructive shock. The majority of patients (n = 17) presented with hypovolemic shock, 3 were found with cardiogenic, 3 with distributive, and 2 with mixed shock. The end diagnosis of each patient was decided by an expert ICU panel and was used to assess the sensitivity, specificity, PPV, NPV, and kappa of the RUSH exam. In discerning hypovolemic shock, the RUSH exam was 100% sensitive (95% CI: 81.1 – 100), 72.7% specific (95% CI: 48.6 – 72.7), 82.4% PPV (95% CI: 66.7 – 82.4), 100% NPV (95% CI: 66.8 – 100), and kappa of 0.75. In cardiogenic shock, the RUSH exam was 60% sensitive (95% CI: 20.7 – 60), 100% specific (95% CI: 90.2 – 100), 100% PPV (95% CI: 34.4 – 100), 95.5% NPV (95% CI: 82 – 90.9), and kappa of 0.71. For distributive shock, the RUSH exam was 75% sensitive (95% CI: 26.5 – 75), 100% specific (95% CI: 90.8 – 100), 100% PPV (95% CI: 35.3 – 100), 100% NPV (95% CI: 86.6 – 100), and kappa of 0.83. In mixed shock, the RUSH exam was 100% sensitive (95% CI: 22.8 – 100), 100% specific (95% CI: 93.3 – 100), 100% PPV (95% CI: 22.8 – 100), 100% NPV (95% CI: 93.3 – 100), and kappa of 0.83.[10]

Ghane et al (Feb, 2015)

Ghane et al (Feb, 2015)[11] examined 77 patients in shock, defined as a SBP <100 mmHg or shock index >1. There were 38 men and 29 women with age range of 36 to 82 years and mean age of 61.5 years. Two examiners performed the exam in the ED, a board-certified emergency physician and board-certified radiologist, both who had vast ultrasound experience and familiarity with the RUSH protocol. RUSH exams were performed regardless of prior management by EMS. End diagnosis of patients was used to measure sensitivity, specificity, PPV, NPV, and kappa. End diagnoses were made by board-certified physicians in other medical units with "acceptable expertise in their fields." Confidence intervals for the various endpoints are not described. No exclusion criteria were indicated. Additional resuscitative and diagnostic tests were concurrently performed. The RUSH exam in hypovolemic shock (n=16) was 100% sensitive, 96.2% specific, 88.9% PPV, 100% NPV, and kappa of 0.92. The RUSH exam in cardiogenic shock (n=20) was 90% sensitive, 98% specific, 94.7% PPV, 97% NPV, and a kappa of 0.89. The RUSH exam in obstructive shock (n=11) was 90.9% sensitive, 98.2% specific, 90.9% PPV, 98.3% NPV, and a kappa of 0.89. The RUSH exam in distributive shock (n=11) was 72.7% sensitive, 100% specific, 100% PPV, 95.1% NPV, and a kappa of 0.81. The RUSH exam in mixed shock (n=11) was 63.6% sensitive, 98.2% specific, 87.5% PPV, 93.3% NPV, and a kappa of 0.70. Eight patients died before end diagnosis and were classified as "not defined."[11]

Ghane et al (Jan-Mar, 2015)

Ghane et al (Jan-Mar, 2015)[12] enrolled 52 patients in shock, defined as a SBP <100 mmHg or shock index >1. One ED board-certified ED physician performed all RUSH exams. There were 28 men and 24 women with mean age 51.6 and a range of 36 to 69 years old who were examined. Patients were excluded from this study if they required immediate lifesaving measures or had a distinct cause of shock such as GI or external bleeding. RUSH exams were performed regardless of prior management by EMS. Additional resuscitative and diagnostic tests were concurrently performed alongside the RUSH exam. End diagnosis of patients was used to measure sensitivity, specificity, PPV, NPV, and kappa. End diagnoses were made by a second board-certified physician with "acceptable expertise in their fields of interest." The second physicians were not blinded to information obtained from the RUSH exam. Confidence intervals for the various endpoints are not described. In hypovolemic shock (n=8) the RUSH exam was 100% sensitive, 94.6% specific, 80% PPV, 100% NPV, and kappa of 0.86. In cardiogenic shock (n=12) the RUSH exam was 91.7% sensitive, 97.0% sensitive, 91.7% PPV, 97.0 NPV, and a kappa of 0.89. In obstructive shock (n=7) the RUSH exam was 100% sensitive, 97% specific, 87.5% PPV, 100% NPV, and a kappa of 0.92. In distributive shock (n=8) the RUSH exam was 75% sensitive, 100% specific, 100% PPV, 94.9% NPV, and a kappa of 0.83. In mixed shock (n=10) the RUSH exam was 70% sensitive, 100% specific, 100% PPV, 92.1% NPV, and a kappa of 0.74.[12]

Discussion

In brief overview of the available literature regarding the RUSH exam,[10-12] the RUSH exam may be considered highly sensitive and specific, with high PPV, NPV and kappa for differentiating between hypovolemic, cardiogenic, obstructive, distributive, and mixed shock. Its potential usefulness as a tool makes it valuable on arrival in the ED to direct patient care. There is no other gold standard with which to compare the RUSH exam, making it extremely beneficial to identify its accuracy, and also equally to devise a study that is unbiased and fully blinded without causing potential harm to the patient.

The current literature has severe limitations. Small sample sizes, few examiners, and a potentially biased end diagnosis decision could cloud the results. Bagheri-Hariri et al,[10] Ghane et al (Feb, 2015),[11] and Ghane et al (Jan-Mar, 2015)[12] had only 25, 77, and 52 patients respectively, making a total population pool of only 154 total patients examined. While Ghane et al (Feb, 2015)[11] and Ghane et al (Jan-Mar, 2015)[12] only used 2 and 1 providers respectively to perform the RUSH exam, it is unknown how many examiners participated in the Bagheri-Hariri et al[10] study. An increased number of examiners would increase the likelihood of reproducibility of findings. It is also unknown if both or multiple examiners performed the RUSH protocol on the same patient or if only one examiner observed each individual patient. It is also unknown if the examiners had any background information on the patient prior to administration of the exam. This information could indicate bias of the examiner toward a particular type of shock (ie recent diagnosis of pneumonia and suspected distributive shock due to sepsis). Likewise, the physicians on other medical units being used as the method of identifying accuracy were not blinded to the results of the RUSH exam in any of the studies. The end diagnosis was made by a single board trained physician in both Ghane et al (Feb, 2015) [11] and Ghane et al (Jan-Mar, 2015)[12] studies. A single physician may limit the reliability of the results in each of these studies. Bagheri-Hariri et al[10] had a physician ICU panel to identify end diagnosis and may be more reliable from this standpoint.

All 3 studies[10-12] must be downgraded for serious imprecision. Bagheri-Hariri et al,[10] displayed very wide confidence intervals yet declared an overall result that is in satisfactory value of sensitivity, specificity, PPV, NPV, and kappa. Since it is unknown how many examiners were used in this study, it could be due to the variability in skill of the various examiners. Ghane et al studies[11-12] did not display any confidence intervals whatsoever. Absence of confidence intervals puts all data in question as to its reliability and precision.

Ultrasound use is well known to be a diagnostic tool that requires skill and additional training to perform well. In each of the studies the examiners were said to have undergone a training course on ultrasound use and were familiar with the RUSH protocol. This aspect was not fully discussed in each of the studies and could play a large role in the RUSH exam's usefulness in the emergency department setting. Although the purpose of the RUSH exam is to rapidly differentiate shock, no study identified the amount of time required to perform the RUSH exam. Some forms of shock may be easier to identify but there was no indication of the cause of each of the types of shock as to which causes were more easily identifiable.

Moving forward, a large sample size must be obtained. These patients should have no EMS interventions to cloud the information obtained from the RUSH exam. Those performing the RUSH exam should be independent ED providers who have no information patient history other than undifferentiated shock, so they have no potential for bias. Since there is no current gold standard for differentiating shock, there is no risk of harm to the patient by withholding results from their attending ED provider. Comorbid conditions, age, and gender should be tracked by study administrators to identify if there is a trend in accuracy based on other these variables. A panel of physicians should be used to ensure the end diagnosis is not left to a single physician and they should also be blinded to the results of the RUSH exam to remove potential bias.

Conclusion

As described during its conception, the RUSH exam may be an effective tool to be used by ED physicians on patients presenting in undifferentiated shock. The current literature available indicates that the RUSH exam must remain only as a tool and does not appear to have quality studies available to recommend protocol implementation into institutions. Additionally, when pertaining to an exam requiring a great deal of technique and technological experience such as ultrasonography, individual experience and training may be crucial in the decision to implement such a protocol.

There is no current gold standard to compare the RUSH exam. Only one study contained a consistent panel of experts to determine an end diagnosis. Until this can be performed, even small population size studies must be approached with caution due to potential inconsistency. An important piece that was missed in the studies was the duration of the exam. Even a tool, if time consuming, may be detrimental to patient care. To proceed with future studies, studies should be conducted with larger sample sizes in multiple institutions and duration of exam, a consistent panel of experts, and specific confidence intervals must be described.

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Table I. Characteristics of Reviewed Studies

Outcome	Number of studies	Study Designs	Downgrade Criteria					Upgrade Criteria	Quality
			Limitations	Indirectness	Inconsistency	Imprecision	Publication bias		
Sensitivity	3	Case Control	Serious[a]	Not Serious	Not Serious	Serious[bc]	Unlikely		Very Low
Specificity	3	Case Control	Serious[a]	Not Serious	Not Serious	Serious[bc]	Unlikely		Very Low
PPV	3	Case Control	Serious[a]	Not Serious	Not Serious	Serious[bc]	Unlikely		Very Low
NPV	3	Case Control	Serious[a]	Not Serious	Not Serious	Serious[bc]	Unlikely		Very Low
Kappa	3	Case Control	Serious[a]	Not Serious	Not Serious	Serious[bc]	Unlikely		Very Low

[a] Lack of blinding of data collectors, there is no gold standard for comparison
[b] Results not given with 95% confidence interval
[c] Wide 95% confidence interval

Table II. Summary of Findings

Type of Shock	Study #	n	Sensitivity	Specificity	PPV	NPV	kappa	p value
	1	17	100 (81.1 – 100)	72 (48.6 - 72.7)	82.4 (66.7 - 82.4)	100 (66.8 – 100)	0.75	<0.0001
Hypovolemic	2	16	100	96.2	88.9	100	0.92	<0.001
	3	8	100	94.6	80	100	0.86	<0.001
	1	3	60 (20.7 – 60)	100 (90.2 – 100)	100 (34.4 – 100)	90.9 (82 - 90.9)	0.71	0.004
Cardiogenic	2	20	90	98	94.7	97	0.89	<0.001
	3	12	91.7	97	91.7	97	0.89	<0.001
	1	3	75 (26.5 – 75)	100 (90.8 – 100)	100 (35.3 – 100)	95.5 (86.6 – 100)	0.83	0.002
Distributive	2	11	72.7	100	100	95.1	0.81	<0.001
	3	8	75	100	100	94.9	0.83	<0.001
	1	0	n/a	n/a	n/a	n/a	n/a	n/a
Obstructive	2	11	90.9	98.2	90.9	98.3	0.89	<0001
	3	7	100	97	87.5	100	0.92	<0.001
	1	2	100 (22.8 – 100)	100 (9.3 – 100)	100 (22.8 – 100)	100 (93.3 – 100)	1	0.003
Mixed	2	11	63.6	98.2	87.5	93.3	0.7	<0.001
	3	10	70	100	100	92.1	0.74	<0.001

Study #1 = Bagheri-Hariri et al[10]
Study #2 = Ghane et al Feb 2015[11]
Study #3 = Ghane et al Jan-Mar 2015[12]