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The Effect of Perioperative Rescue Transesophageal Echocardiography on the Management of Trauma Patients

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Abstract

To evaluate the effect of rescue transesophageal echocardiography (TEE) on the management of trauma patients, we reviewed imaging and charts of unstable trauma patients at a level I trauma center. Critical rescue TEE findings included acute right ventricular failure, stress cardiomyopathy, type B aortic dissection, mediastinal air, and dynamic left ventricular outflow tract obstruction. Left ventricular filling was classified as low (underfilled) in 57% of all cases. Rescue TEE revealed a variety of new diagnoses and led to a change in resuscitation strategy about half of the time.

Rescue echocardiography is a point-of-care ultrasonography of the heart and great vessels in unstable patients, with the goal of identifying the hemodynamic problem. Diagnoses that have been made in a trauma setting by rescue echocardiography include hypovolemia, tamponade, impaired systolic function, and right heart failure.[1–3] Most of the medical literature on rescue echocardiography relates to cardiac surgery and septic shock.[2] The effects of rescue echocardiography on the management of trauma patients have been documented in case reports and small case series, mainly assessing the use of transthoracic echocardiography (TTE). These effects have primarily been related to expansion of the Focused Assessment with Sonography for Trauma examin
The literature also includes review articles and case reports on the clinical use of transesop
echocardiography (TEE) for evaluating trauma patients. One case series, limited to trauma p

in the surgical intensive care unit (ICU), demonstrated that TEE often leads to changes in management and that pulmonary artery (PA) catheter readings fail to identify hypovolemia compared with TEE assessments.[5]

Our perioperative echocardiography service mainly comprises intraoperative TEE examinations but also includes the ICU setting. We identified a case series of unstable trauma patients referred to our perioperative echocardiography service for rescue echocardiography using TEE, including both intraoperative and ICU settings, to better delineate the effect of TEE on the management of trauma patients with persistent shock, despite empiric resuscitation efforts. We describe the effect of rescue TEE on the clinical management of these patients and present the frequency of each echocardiographic diagnosis made in this trauma setting.

METHODS AND RESULTS DESCRIPTION

Methods

After obtaining approval from the University of Utah IRB, with permission for waiver of consent, we queried a database of 364 perioperative rescue echocardiography studies performed between February 2010 and June 2012 at a level I trauma hospital that is a tertiary referral center for trauma and burn care. We specified 3 inclusion criteria for this study: a primary diagnosis of trauma, an indication on echocardiography of shock, and an echocardiography study scheduled with emergency priority (i.e., to guide ongoing resuscitation). Images were obtained via a Philips iE33 with an X7-2t probe (Philips Healthcare, Andover, MA) or an Acuson Sequoia 256 or 512 with a TE-V5Ms probe (Siemens USA, Inc., Malvern, PA). Anesthesiology faculty with level 3 training in echocardiography performed the studies using a standard sequence of views.[3] Researchers reviewed the selected images, medical records, and echocardiography reports to score each component of the hemodynamic assessment (left ventricular [LV] function, right ventricular [RV] function, valve pathology, tamponade, volume status, and diastology).

Rescue echocardiography study results were discussed at the bedside with the attending trauma surgeon at the time of the examination. Medical records, echocardiography reports, and anesthesia records were reviewed to identify changes in clinical management that were based on the rescue echocardiography findings.

We define any of the following criteria to diagnose RV systolic dysfunction: dilated RV chamber size (as large as or larger than the LV chamber size), flattening of the inter-ventricular septum in short-axis, tricuspid annular plane systolic excursion <1.6 cm, and/or tricuspid lateral annular systolic tissue Doppler velocity <10 cm/s.

There is no standard definition of hypovolemia in echocardiography. The practice of our division is to use a depth setting of 12 cm on the initial transgastric short-axis LV clip and, by the use of this uniform perspective, judge whether the end-diastolic LV area appears to be definitely smaller than normal. Occasionally, our faculty also looks at inferior vena cava (IVC) or superior vena cava (SVC) size and collapsibility. The pattern recognition used to diagnose primary LV hypovolemia is to look for a small end-diastolic LV area along with the absence of prominent RV dilation.

Results

Thirty-seven patients (age range, 17–84 years) met the criteria for inclusion in the study. The mortality rate (death before discharge) for these patients was 22% (8/37). The patients' injuries were categorized as blunt (*n* = 31), penetrating (*n* = 5), and burn (*n* = 1), and the average Injury Severity Score was 25 (range, 1–75).[6] Twenty-two studies were performed intraoperatively, and 15 were performed in the surgical ICU.

LV systolic function was classified as hyperdynamic, normal, mildly decreased, moderately decreased, or severely decreased according to the LV ejection fraction norms defined by the American Society of Echocardiography (ASE) guidelines.[7] Eighty-six percent of the patients had normal (*n* = 19) or hyperdynamic (*n* = 13) function, 11% had mild (*n* = 2) or moderate (*n* = 2) dysfunction, and 3% had severely decreased LV systolic function (*n* = 1). Three patients had segmental LV systolic function abnormalities (i.e., regional wall motion abnormalities suggesting coronary artery disease), 3 had global hypokinesis, and the remaining 31 had normal segmental wall motion.

Diastolic LV function was determined on the basis of the pattern of transmitral flow, tissue Doppler imaging, and other standard factors described in consensus guidelines.[8] Given the emergent nature of the examinations, nearly half of the studies did not include clips providing this information and were, therefore, scored as indeterminate. Normal diastology was recorded for 35% of the patients, impaired relaxation was recorded for 14%, and a pseudonormal filling pattern was recorded for 5%. Restrictive diastology was not found in any of the patients. LV preload was classified as low (underfilled) for 62% of the patients, as normal for 22%, and as high for 5% and was not measured in 11%. The convention in our practice is to report high LV preload in case of elevated estimated filling pressure ($E/e' \geq 13$), low preload if the transgastric LV short-axis end-diastolic area is definitely small (based on visual estimation), and normal if neither finding is present.

RV dysfunction was rated as normal, mildly decreased, moderately decreased, or severely decreased in 78%, 8%, 11%, and 3% of cases, respectively, based on the ASE guidelines.[9] Moderate-to-severe valvular dysfunction was rare (4 cases). Other critical echocardiography findings included stress cardiomyopathy (*n* = 1), type B aortic dissection (diagnosed by echocardiography in the operating room, *n* = 1), pericardial effusion (*n* = 2), and mediastinal air (*n* = 1). One patient was diagnosed with dynamic left ventricular outflow tract obstruction.

Management changes based on rescue echocardiography findings were documented in 18 of the cases (49% of studies) (Table 1); the most common of these was fluid challenge (12 cases), followed by initiation of inotropic support (3 cases). In 2 cases, rescue echocardiography led to the use of an inhaled pulmonary vasodilator for acute, severe RV failure, and in 2 cases echocardiography findings triggered drainage of pericardial fluid. In the case in which dynamic left ventricular outflow tract obstruction was discovered by echocardiography, a fluid challenge was given and inotropic support was discontinued.

Table 1

Summary of Cases in Which a Change in Management Was Based on Rescue Transesophageal Echocardiography Findings

Case	Injury (age, years)	Surgery	Echocardiography diagnosis	Treatment based on echocardiography findings
1	Multiple stab wounds (24)	Ex lap	Hypovolemia	Fluid bolus
2	Splenic rupture from fall (29)	Ex lap	Hypovolemia	Fluid bolus
3	MCC (41)	Ex fix pelvis	Hypovolemia	Fluid bolus
4	GSW to chest (42)	Splenectomy and diaphragm repair	Hypovolemia	Fluid bolus
5	MVA (60)	Splenectomy	Right ventricular failure	Milrinone and epinephrine administered
6	MVA (50)	Ex lap, splenectomy	Hypovolemia	Fluid bolus
7	GSW to chest (47)	Trauma pneumonectomy	Right ventricular failure	Inhaled nitric oxide
8	Fall (84)	None (SICU)	Hypovolemia	Fluid bolus
9	Pedestrian hit by car (69)	Ex lap	Hypovolemia	Fluid bolus
10	ATV; flail chest (73)	Rib plating	Dynamic left ventricular outflow tract obstruction	Fluid bolus and inotrope discontinued
11	Fall; femur fracture (74)	None (SICU)	Right ventricular failure	Milrinone administered
12	Ski crash (30)	Chest exploration	Tamponade	Pericardial window
13	Stab in chest (42)	Repair of left ventricle	Hypovolemia	Fluid bolus
14	MVA (20)	Repair rupture of right atrium	Tamponade	Pericardial window
15	Fall (26)	Splenectomy	Hypovolemia	Fluid bolus
16	MVA (50)	ORIF femur	Hypovolemia	Fluid bolus
17	MVA (35)	Ex lap	Hypovolemia	Fluid bolus
18	Pedestrian hit by car (55)	None (SICU)	Right ventricular failure, pulmonary hypertension	Epoprostenol and dobutamine

ATV = all-terrain vehicle accident; ex fix = external fixation; ex lap = exploratory laparotomy; GSW= gunshot wound; MCC = motorcycle collision; MVA = motor vehicle accident; ORIF = open reduction and internal fixation; SICU = surgical intensive care unit.

Illustrative Case Summaries

A 20-year-old woman experienced a cardiac arrest with pulseless electrical activity in the computed tomography scanner after a motor vehicle accident and level I trauma activation. She was transferred rapidly to the operating room, where TEE was performed, which showed cardiac tamponade. The patient underwent drainage of the pericardial space and recovered cardiac output (Supplemental Digital Content, Supplemental Videos 1–4, http://links.lww.com/AACR/A59, http://links.lww.com/AACR/A60, http://links.lww.com/AACR/A61, http://links.lww.com/AACR/A62).

Severe hypovolemia was unexpectedly diagnosed in an 84-year-old woman who was in the ICU with a hip fracture. She had been treated with escalating doses of norepinephrine (up to 0.4 μg/kg/min). The TEE study revealed severe hypovolemia, manifested by small end-diastolic area (Supplemental Digital Content, Supplemental Video 5, http://links.lww.com/AACR/A63). After the diagnosis of severe hypovolemia by TEE, volume resuscitation resulted in improved stability and discontinuation of norepinephrine infusion.

In 2 cases, rescue echocardiography led to the diagnosis of acute pulmonary hypertension and specific management changes. A 47-year-old man with a gunshot wound to the chest underwent pneumonectomy and became hypotensive. Rescue echocardiography revealed severe tricuspid regurgitation and an estimated RV systolic pressure of 85 mm Hg; nitric oxide was started to treat acute right heart failure (Supplemental Digital Content, Supplemental Videos 6 and 7, http://links.lww.com/AACR/A64, http://links.lww.com/AACR/A65). A 50-year-old woman undergoing repair of a pelvic fracture after a motor vehicle collision became hypotensive, and the echocardiography study demonstrated moderate tricuspid regurgitation and RV failure. Fluid administration was decreased, resulting in improvement of hemodynamics.

DISCUSSION

We present a case series describing the clinical value of using rescue TEE to diagnose trauma patients with shock. We did not anticipate that all the trauma cases in our database of perioperative rescue studies would have undergone TEE rather than TTE. The perioperative echocardiography service of the Anesthesiology Department mainly provides intraoperative TEE examinations, but it also performs TTE in the preoperative clinic and preoperative suite, as well as in the postanesthesia care unit and surgical intensive care unit. We excluded cases in which TEE was requested to evaluate the aorta (based on findings from computed tomography suggesting aortic injury) because a consult to specifically image putative focal damage does not meet the criteria of rescue echocardiography.

TTE is the standard technique used for hemodynamic assessment in trauma patients, and the subcostal echocardiography window is included in the Focused Assessment with Sonography for Trauma examination. Patients who are intubated and immobile, however, may be more difficult to image by TTE than by TEE. One possible explanation for why perioperative echocardiography consultants selected TEE over TTE is that most of the patients were undergoing an operation, limiting the access for a transthoracic probe in the apical and subcostal windows. Another possibility is that the trauma surgeon requesting the echocardiography study may have asked for TEE for reasons not documented in the medical record (e.g., concern regarding cardiac contusion or pseudoaneurysm). Our series is similar to that reported by Burns et al.[5] in finding that the most common diagnosis made by TEE in unstable trauma patients is hypovolemia, despite vigorous resuscitation. Moreover, our series demonstrates the clinical effect of rescue TEE on intraoperative management and includes several diagnoses (such as right heart failure and tamponade) not included in the earlier case review.

There were no reports of esophageal bleeding or perforation in this series; however, the series was underpowered to determine the safety of TEE probe placement in this population. Future research is required to directly compare the feasibility, diagnostic yield, and therapeutic effect of rescue TEE with that of rescue TTE in unstable trauma patients.

The audit of our cases demonstrates that TEE is feasible in unstable trauma patients and often leads to a change in management (49% of studies in this series) or that it provides significant hemodynamic information. Despite aggressive efforts to resuscitate seriously injured patients before rescue echocardiography was performed, 62% of patients were found to have a low preload, leading to a fluid challenge in 40%.

The echocardiographic signs of volume and pressure overload of the LV are well described.[6] In contrast, hypovolemia or fluid responsiveness can be difficult to diagnose on the basis of static chamber dimensions or filling pressure. Dynamic indications of fluid responsiveness, such as an increase in stroke volume after a straight leg raise or significant stroke volume variation related to heart-lung interactions, are validated ultrasound methods of diagnosing fluid responsiveness.[10] Our rescue TEE examination for fluid responsiveness sometimes includes measurement of the degree of variability in stroke volume (by area under the curve of LV outflow tract pulse wave Doppler) as influenced by the respiratory cycle, the variability in mitral inflow peak velocity, or the degree of collapse of the venae cavae with respiratory phases—but not uniformly. Analysis of our rescue echocardiography cases raised the quality improvement question of whether a dynamic test of fluid responsiveness should be added to our standard rescue echocardiography imaging protocol.

The second most common management change resulting from the TEE examinations was initiation of inotropic support, which is traditionally started after a PA catheter is placed and low cardiac output is found. The advantages of using TEE over a PA catheter are that it is less invasive and that it provides more definitive information about the relative contribution of RV and LV dysfunction to a low-output state.[5]

A limitation of this study was that rescue echocardiography was ordered at the discretion of the trauma team, possibly introducing selection bias toward cases in which it was believed that imaging of the heart and great vessels would be helpful. Our trauma hospital has a perioperative echocardiography service available 24 hours per day, which is a resource not available to many hospitals. Another limitation of the study design was that only interventions documented in the medical record were detected, which may have caused us to underestimate how often rescue echocardiography findings led to changes in the resuscitation strategy. This realization led to a quality improvement effort to increase the documentation of communicating critical findings and initiating interventions based on the echocardiography findings. We looked for, but could not identify, a relationship between traumatic brain injury and diastolic dysfunction. This line of analysis was limited because almost half of the studies did not include measurements of diastology.

In conclusion, we found that TEE often was helpful in elucidating the cause of shock in our population of trauma patients and led to management changes in half of the cases. Further research is warranted to determine whether using rescue TEE changes the outcomes of seriously injured patients who remain unstable despite standard resuscitation efforts.

Supplementary Material

Supplemental Digital Video 1

Click here to view. (1.1M, mov)

Supplemental Digital Video 2

Click here to view. (1.0M, mov)

Supplemental Digital Video 3

Click here to view. (533K, mov)

Supplemental Digital Video 4

Click here to view. (1.2M, mov)

Supplemental Digital Video 5

Click here to view.(1.4M, mov)

Supplemental Digital Video 6

Click here to view.(3.1M, mov)

Supplemental Digital Video 7

Click here to view.(3.2M, mov)

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Footnotes

The authors declare no conflicts of interest.

Supplemental digital content is available for this article. Direct URL citations appear in the printed text and are provided in the HTML and PDF versions of this article on the journal's website www.cases-anesthesia-analgesia.org.

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