

## Use of Rapid “Rescue” Perioperative Echocardiography to Improve Outcomes After Hemodynamic Instability in Noncardiac Surgical Patients

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**Objective:** To investigate if modified “rescue” echocardiography enhanced management during perioperative hemodynamic instability in patients undergoing noncardiac surgery.

**Design:** A retrospective analysis of the medical data.

**Setting:** Perioperative setting at a single academic medical center.

**Participants:** Thirty-one adult patients undergoing noncardiac surgery who experienced perioperative hemodynamic instability and were evaluated by either transthoracic echocardiography (TTE, n = 9) or transesophageal echocardiography (TEE, n = 22).

**Interventions:** None.

**Measurements and Main Results:** Rapid “rescue” echocardiography was performed on each patient looking for a specific cause for the patient’s perioperative compromise. Echocardiography results, medical management, surgical management, and patient outcomes were all reviewed from the medical record and the department database. All pa-

tients were found to have an explainable diagnosis for the hemodynamic instability on the echocardiographic examination. The most common diagnoses were left-heart dysfunction (n = 16), right-heart dysfunction (n = 9), hypovolemia (n = 5), pulmonary embolus (n = 5), and myocardial ischemia (n = 4). Based on findings at echocardiography, 4 patients (13%) underwent and survived an emergent secondary procedure. All 31 patients recovered during their surgical procedure, and 25 (81%) progressed to hospital discharge.

**Conclusions:** Both TTE and TEE can play a critical role in the diagnosis and management of perioperative hemodynamic instability.

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**KEY WORDS:** noncardiac surgery, transesophageal echocardiography, transthoracic echocardiography, resuscitation, monitoring echocardiography

OVER THE LAST DECADE, perioperative echocardiography has expanded to hemodynamically manage patients undergoing surgery. Many providers use transesophageal echocardiography (TEE) in cardiac and noncardiac operating rooms to monitor patients with a history of cardiopulmonary disease or in whom hemodynamic instability is suspected. Echocardiography is a unique imaging modality that allows providers to visualize the dynamic function of the heart, which, in turn, promotes ongoing adjustments of surgical and medical interventions. Both transthoracic echocardiography (TTE) and TEE are relatively noninvasive.<sup>1</sup> A recent study describing the use of TEE in an academic medical center suggests that TEE enhances the care of the vast majority of patients when appropriate criteria are used.<sup>2</sup> The use of echocardiography in elective procedures has led physicians to advocate its use in patients experiencing cardiovascular arrest during the perioperative period.<sup>3,4</sup>

Multidisciplinary guidelines published by the American Society of Anesthesiologists (ASA) and the Society of Cardio-

vascular Anesthesiologists (SCA) in 2010 recommend the use of TEE in patients who are undergoing noncardiac surgery and exhibit persistent hypotension or hypoxia despite intervention (category 2B and 3B evidence).<sup>5</sup> Nonetheless, there are still limited clinical data on the usefulness of TEE and TTE in patients during noncardiac surgery or in patients who are hemodynamically unstable.<sup>6</sup> Although some reports describe outcome data of echocardiography as an adjunct in resuscitation, a standard echocardiographic examination during times of cardiopulmonary instability has not been presented.<sup>3</sup>

A retrospective review of 31 patients who underwent perioperative echocardiograms (both TTE and TEE) performed by echo-trained physicians at an academic medical center during unexpected hemodynamic instability in noncardiac surgery are presented. The purpose of this study was to determine if modified “rescue” echocardiography enhanced management during hemodynamic instability. The authors reviewed echocardiography results, anesthesia records, operative reports, secondary procedures, and hospital discharge outcomes. Data were reviewed to determine if echocardiographic findings provided diagnoses useful in resuscitation and if management changes occurred based on those findings.

### METHODS

Institutional review board approval was obtained. Patients were identified from an internal departmental echocardiography database. Echocardiograms were performed between June 2006 and July 2010 by an anesthesiologist (97% of cases) or cardiologist (3%) with advanced training in TTE and TEE. Patients included for review underwent noncardiac surgery and had unexplained hemodynamic instability not

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**Table 1. "Rescue" Transesophageal and Transthoracic Echocardiographic Examination**

Perioperative "Rescue" Transesophageal Echocardiographic Examination				
Examination Order	Window	View	Omniplane Angle	Structures Evaluated
1	ME	AV SAX	40°	Aortic valve
2	ME	AV LAX	130°	Aortic valve, ascending aorta, left ventricular outflow tract
3	ME	Bicaval	110°	Superior vena cava, inferior vena cava, right atrium, intra-atrial septum
4	ME	RV Inflow/outflow	60°	Right atrium, right ventricle, tricuspid valve, pulmonic valve, pulmonary artery
5	ME	4 Chamber	0°	Atria, right and left ventricle, intra-atrial and intraventricular septum, tricuspid valve, mitral valve
6	ME	2 Chamber	90°	Left atrial appendage, mitral valve, left ventricle
7	ME	LV LAX	130°	Left ventricle, mitral valve, left ventricle outflow tract
8	UE to LE	Desc Ao SAX	0°	Aortic arch, descending thoracic aorta
9	TG	Mid SAX	0°	Left ventricle, right ventricle

  

Perioperative "Rescue" Transthoracic Echocardiographic Examination			
Examination Order	Window	View	Structures Evaluated
1	PS	AV LAX	Aortic valve, ascending aorta, left ventricular outflow tract
2	PS	AV SAX	Aortic valve
3	PS	RV Inflow/outflow	Right atrium, right ventricle, tricuspid valve, pulmonic valve, pulmonary artery
4	PS	LV SAX	Left ventricle, right ventricle
5	A	4 Chamber	Atria, right and left ventricle, intra-atrial and intraventricular septum, tricuspid valve, mitral valve
6	A	2 Chamber	Left atrial appendage, mitral valve, left ventricle
7	A	LV LAX	Left ventricle, mitral valve, left ventricle outflow tract
8	SC	4 Chamber	Right and left ventricle, intra-atrial and intraventricular septum, tricuspid valve, mitral valve

NOTE. Transesophageal echocardiographic examination is based on protocols developed by Miller et al.<sup>8</sup>

Abbreviations: A, apical; AV, aortic valve; Desc Ao, descending aorta; LAX, long axis; LE, lower esophageal; LV, left ventricle; ME, midesophageal; PS, parasternal; RV, right ventricle; SAX, short axis; SC, subcostal; TG, transgastric; UE, upper esophageal.

responsive to medical treatment. Patients were identified as needing TTE or TEE by the anesthesiologist or certified nurse anesthetist administering the anesthetic.

A retrospective analysis was performed of the perioperative events and findings of each echocardiography examination as recorded at the time of the event. Of the 33 patients initially identified, 31 were included in the final analysis. Two patients were excluded based on an incomplete medical record. Patient information from the electronic medical record, the anesthesia record, and the echocardiographic report form was stored in a separate database to allow further analysis.

In most cases (22/31, 71%), a certified nurse anesthetist or anesthesiologist not trained in echocardiography was caring for the patient and called for assistance from an echo-trained anesthesiologist or cardiologist. In 9 of 31 cases (29%), the anesthesia provider also completed the TTE or TEE. Echocardiograms were performed in the operating room ( $n = 30$ ) and recovery room ( $n = 1$ ). Five anesthesiologists and one cardiologist conducted the examinations. Studies were conducted using either Philips (Philips Healthcare, Andover, MA) or GE (GE Healthcare, Waukesha, WI) stand-alone echocardiography machines using a sector array transthoracic probe (1-5 megahertz [MHz]) or omniplane transesophageal probe (2-7 MHz).

With the exception of one case, echocardiographic examinations were performed as defined by the department's "rescue" echocardiography examination protocol for both TTE and TEE. Five anesthesiologists were trained in the departmental protocol for "rescue" echocardiography and were encouraged to use this standard approach for assessing patients. The examination protocol included 9 of the standard 20 echocardiography views as described by the ASE/SCA Comprehensive TEE Examination or a modified TTE examination that assessed

similar views.<sup>7</sup> For full details of the echocardiographic examination, please refer to Table 1. This examination is based on similar protocols published in 2001.<sup>8</sup>

Ventricular function was based on the reported values by the physician who performed the examination. The estimation of ejection fraction (EF) was performed using the visual estimation technique. Left ventricular (LV) systolic dysfunction was quantified by an EF <50%. LV function was defined as mild dysfunction if the EF was 40% to 50%, as moderate if the EF was 20% to 40%, and as severe if the EF was  $\leq 20\%$  (Table 2). Diastolic dysfunction was defined as abnormal LV filling as determined by mitral inflow and pulmonary vein flow patterns.<sup>9,10</sup> The subdivision of diastolic dysfunction was as follows: patients were diagnosed as having grade 1 diastolic dysfunction if indicated by impaired relaxation flow patterns through the mitral valve, grade 2 if pseudonormal flow patterns were seen on mitral inflow and supported by diastolic dominant pulmonary vein flow, and grade 3 if a restrictive pattern was reported on mitral inflow supported by diastolic dominant pulmonary vein flow.<sup>10,11</sup> Tissue Doppler imaging was not included in the definition of diastolic dysfunction because it was not used in every patient.

Right ventricular (RV) systolic dysfunction was diagnosed when depressed RV function with decreased LV filling was seen. Right-heart failure was described as the inability of the right heart to adequately fill the left ventricle and provide normal systemic perfusion. This included relative RV dilation compared with the left ventricle, tricuspid annular plane systolic excursion (TAPSE) <16 mm, and overall visual assessment of RV contractile dysfunction and dilation.<sup>12</sup> Qualitative analysis of RV function was categorized as mild, moderate, or severe by the physician at the time of the examination (Table 2).

**Table 2. Common Causes of Perioperative Hemodynamic Instability Diagnosed by Echocardiography and Classification of Ventricular Dysfunction Used**

Common causes of perioperative hemodynamic instability diagnosed by echocardiography			
Hypovolemia			
Ventricular failure			
Myocardial ischemia			
Acute pulmonary embolus			
Cardiac tamponade			
Valve abnormalities			
Systolic dysfunction classification			
Left ventricular dysfunction		EF estimate	
Mild		40%-50%	
Moderate		20%-40%	
Severe		<20%	
R ventricular dysfunction (mild, moderate, severe as by qualitative estimation)			
Tricuspid annular plane systolic excursion <16 mm			
Right ventricular contractile dysfunction			
Right ventricular dilation			
Diastolic dysfunction classification*			
Grade		E/A Ratio	Pulmonary vein flow pattern
1	Impaired relaxation	<0.8	S > D
2	Pseudonormal	0.8-2.0	S < D
3	Restrictive	≥2.0	S << D

\*Data from Otto.<sup>9</sup>

Hypovolemia was defined when low end-diastolic volumes were identified by visual estimation techniques and associated with decreased systemic blood pressure. LV segmental wall motion abnormalities (WMA) not previously reported were considered evidence of myocardial ischemia. The diagnosis of clinically relevant cardiac tamponade was based on the presence of pericardial effusion associated with early right atrium systolic collapse, RV diastolic collapse, and/or interventricular dependence. Pulmonary embolus was defined as the identification of a thromboembolism in the right atrium, right ventricle, or pulmonary artery on echocardiography associated with hemodynamic instability and/or RV dysfunction.

## RESULTS

Patient demographics and American Society of Anesthesiologists Physical Status (ASA-PS) are summarized in Table 3. Patients ranged in age from 26 to 87 years, with the average being 62 years. ASA-PS ranged from 2 to 5E, with most patients listed as either ASA-PS 3 (12/31, 39%) or ASA-PS 4 (9/31, 29%). Fifty-two percent were men (16/31), whereas 48% were women (15/31). The primary reasons listed in the medical record for requesting TTE or TEE were hypotension (n = 24), cardiac arrest (n = 4), and hypoxia (n = 3). Many patients had more than one reason listed (Table 4). Surgical services included abdominal, orthopedic, thoracic, transplant, urologic, vascular, obstetric, and otolaryngology and are summarized in Table 5.

The “rescue” echocardiograms consisted of 9 TTEs and 22 TEEs. There were no complications with TEE probe placement. Echocardiographic indications, findings, management,

and outcomes are summarized in Table 4. Some patients (n = 12) were found to have more than one diagnosis. Table 6 describes the perioperative “rescue” echocardiographic results in all 31 patients before any change in medical or surgical intervention.

Nineteen patients (61%) had preoperative echocardiograms that were completed from 0 to 857 days preoperatively as listed in Table 4. Most of these patients (16 of 19) had abnormal preoperative echocardiograms available to the anesthesia provider preoperatively. Thirty-six percent of the patients (7/19) were found to have worsening of the same abnormality on “rescue” echocardiography when compared with the preoperative echocardiogram.

All 31 patients in this review survived their operative procedure. Four patients (n = 4, 12%) died within 24 hours of their procedure; an additional patient died within the next 30 days. Hence, 30-day mortality was 16% (n = 5). One additional patient died in the hospital before discharge 4 months later after a prolonged hospital course, making the overall in-hospital mortality 19% (n = 6). The causes of death in these patients were pulmonary embolus (n = 2), sepsis (n = 2), end-stage liver failure (n = 1), and biventricular failure secondary to fat emboli from a femur fracture (n = 1). Twenty-five patients were discharged to an outpatient facility or to home; survival to discharge was 81%. Because of the lack of a control group, statistical analysis of outcome data and mortality benefit was not performed.

Sixteen of 31 (52%) patients had findings of LV dysfunction on “rescue” echocardiographic examination. Eight patients (8/31, 26%) had isolated systolic heart dysfunction; 2 patients (2/31, 6%) had isolated diastolic heart dysfunction, whereas 6 patients (6/31, 19%) had both systolic and diastolic heart dysfunction (Table 4). Four patients (4/31, 13%) had WMAs consistent with ischemia. Five patients (5/31, 16%) had findings of hypovolemia. Overall, 52% (16/31) of patients who underwent “rescue” echocardiography received inotropes because of findings on echocardiographic examination.

Acute right-heart failure (ARHF) was documented on “rescue” echocardiographic examination in a total of 29% of patients (9/31). Three had isolated RV dysfunction, 3 had RV and LV dysfunction, and the remaining 3 had intracardiac thromboembolus and RV failure. Two of the 9 patients with findings

**Table 3. Patient Demographic Data**

Variable	Patients (N = 31)		
	Mean	Standard Deviation	Range
Age (y)	62	17	26-87
	Count	Percent	
Sex			
Male	16	52	
Female	15	48	
ASA physical status			
2	3	10	
3	12	39	
4	9	29	
4E	5	16	
5E	2	6	

Abbreviation: ASA, American Society of Anesthesiologists.

**Table 4. Preoperative Patient Echocardiogram and “Rescue” Echocardiographic Results, Management Changes, and Patient Outcomes**

Patient	Age (y)	Procedure	Preoperative Study/ Interval Days Between Preoperative and “Rescue” Echocardiograms	Preoperative Echocardiographic Results	Event Prompting “Rescue” Echocardiography	“Rescue” Study Type/ Location	“Rescue” Echocardiographic Findings	Management Changes/Additions as Result of “Rescue” Echocardiography	Survived to Hospital Discharge
1	68	Orthopedic	TTE/161	Normal LV function	Hypotension followed by cardiac arrest	TEE/OR	Thromboembolism, moderate RV dysfunction	Inotrope support	No
2	74	Abdominal	DSE/71	Negative DSE, mild LV diastolic dysfunction	Hypoxia, bradycardia	TTE/OR	Mild LV diastolic dysfunction	Postoperative mechanical ventilation for pulmonary edema	Yes
3	86	Orthopedic	TTE/0	Moderate LV systolic dysfunction, mild LV diastolic dysfunction	Hypotension	TEE/OR	Moderate RV dysfunction	Inotrope support	Yes
4	87	Orthopedic	TTE/*	LVH, normal LV function, PASP 85-100 mmHg	Hypotension, ST depression	TEE/OR	Moderate LV systolic dysfunction, severe LV diastolic dysfunction	Inotrope support, ACLS	Yes
5	51	Vascular	TTE/181	Mild LV systolic dysfunction, mild LV diastolic dysfunction, PASP 60 mmHg	Cardiac arrest in PACU	TTE/PACU	Severe LV systolic dysfunction, severe LV diastolic dysfunction	Inotrope support	Yes
6	67	Orthopedic	TTE/56	Moderate LV systolic dysfunction, moderate RV dysfunction, PASP 66 mmHg	Hypoxia, decreased ETCO <sub>2</sub>	TEE/OR	Thromboembolism, moderate RV dysfunction	Postoperative mechanical ventilation	Yes
7	48	Thoracic	None	NA	Hypotension	TTE/OR	Hypovolemia	Fluid resuscitation	Yes
8	71	Abdominal	None	NA	Hypotension, decreased ETCO <sub>2</sub> , tachycardia	TEE/OR	Thromboembolism, severe LV systolic dysfunction, severe RV dysfunction	Inotrope support, emergency thrombectomy	Yes
9	83	Orthopedic	None	NA	Hypotension, bradycardia	TEE/OR	Segmental WMA	Inotrope support, ACLS	Yes
10	37	Abdominal	None	NA	Hypotension, ST elevation	TEE/OR	Aortic injury, severe LV systolic dysfunction, moderate RV dysfunction	Inotrope support, repair of aortic injury	Yes
11	62	Orthopedic	None	NA	Hypotension, mental status changes	TEE/OR	Moderate LV systolic dysfunction, severe RV dysfunction	Inotrope support, fluid resuscitation	<b>No</b>

**Table 4. Preoperative Patient Echocardiogram and “Rescue” Echocardiographic Results, Management Changes, and Patient Outcomes (Cont’d)**

Patient	Age (y)	Procedure	Preoperative Study/ Interval Days Between Preoperative and “Rescue” Echocardiograms	Preoperative Echocardiographic Results	Event Prompting “Rescue” Echocardiography	“Rescue” Study Type/ Location	“Rescue” Echocardiographic Findings	Management Changes/Additions as Result of “Rescue” Echocardiography	Survived to Hospital Discharge
12	74	Transplant	TTE/188	Moderate LV diastolic dysfunction, RV dilation	Hypotension, bradycardia	TEE/OR	Moderate LV diastolic dysfunction	Inotrope support, atropine	Yes
13	34	Abdominal	DSE/243	Basal inferoseptal segment hypokinesis	Cardiac arrest	TEE/OR	Thromboembolism, moderate LV systolic dysfunction	Inotrope support	Yes
14	52	Abdominal	None	NA	Hypotension	TEE/OR	Hypovolemia	Fluid resuscitation	Yes
15	75	Abdominal	TTE*	Segmental WMA, mild LV diastolic dysfunction	Hypotension	TEE/OR	Severe LV systolic dysfunction, mild LV diastolic dysfunction, moderate RV dysfunction	Inotrope support, fluid resuscitation, ACLS	<b>No</b>
16	55	Transplant	TTE*	Normal LV function	Hypotension	TEE/OR	Severe RV dysfunction	Inotrope support, procedure canceled	<b>No</b>
17	85	Orthopedic	TTE/827	LV systolic dysfunction, PASP 62 mmHg	Hypotension	TTE/OR	Severe LV systolic dysfunction	Inotrope support	Yes
18	66	Abdominal	TTE/7	Normal LV function	Hypoxia, ST elevation	TTE/PACU	Segmental WMA	Reintubation, cardiology consult	Yes
19	86	Orthopedic	None	NA	Hypotension, atrial fibrillation	TEE/OR	Thromboembolism	Heparinization	<b>No</b>
20	26	Abdominal	TTE/67	Preserved LV function, PASP 49 mmHg	Hypotension	TEE/OR	Severe LV systolic dysfunction, severe LV diastolic dysfunction	Inotrope support, fluid resuscitation	Yes
21	67	Urology	None	NA	Hypotension, ST depression	TEE/OR	Segmental WMA	Inotrope support	Yes
22	55	Abdominal	None	NA	Cardiac arrest	TEE/OR	Severe LV systolic dysfunction, severe LV diastolic dysfunction	Inotrope support, emergency RCA stent placement	Yes
23	59	Abdominal	None	NA	Cardiac arrest	TEE/OR	Hypovolemia	Transfusion, fluid resuscitation	Yes
24	28	Obstetric	None	NA	Hypotension	TTE/OR	Hypovolemia	Transfusion, fluid resuscitation	Yes

**Table 4. Preoperative Patient Echocardiogram and “Rescue” Echocardiographic Results, Management Changes, and Patient Outcomes (Cont’d)**

Patient	Age (y)	Procedure	Preoperative Study/ Interval Days Between Preoperative and “Rescue” Echocardiograms	Preoperative Echocardiographic Results	Event Prompting “Rescue” Echocardiography	“Rescue” Study Type/ Location	“Rescue” Echocardiographic Findings	Management Changes/Additions as Result of “Rescue” Echocardiography	Survived to Hospital Discharge
25	76	Abdominal	TTE/503	Moderate LV systolic dysfunction, mild LV diastolic dysfunction	Hypotension	TEE/OR	Severe LV systolic dysfunction	Switched to narcotic TIVA	Yes
26	73	Thoracic	TTE/70	Mild LV diastolic dysfunction	Hypotension	TEE/OR	Segmental WMA	Inotrope support	Yes
27	40	Abdominal	None	NA	Hypotension, hypoxia	TTE/OR	Moderate LV systolic dysfunction	Inotrope support, procedure canceled	Yes
28	54	Otolaryngology	TTE/0	Mild LV diastolic dysfunction, severe RV dysfunction, PASP 80 mmHg	Hypotension, hypoxia	TTE/OR	Moderate RV dysfunction	Fluid resuscitation	Yes
29	47	Abdominal	TTE/2	Hyperdynamic, preserved LV and RV function	Hypotension	TTE/OR	Hypovolemia, severe LV systolic dysfunction	Inotrope support, fluid resuscitation	No
30	62	Thoracic	TTE/5	Mild to moderate pericardial effusion, no tamponade	Hypotension	TEE/OR	Cardiac tamponade	Inotrope support, pericardial window, ACLS, ECMO	Yes
31	70	Orthopedic	TTE/857	Moderate LV systolic dysfunction, elevated PASP	Hypotension, ST elevation	TEE/OR	Severe LV systolic dysfunction	Inotrope support	Yes

Abbreviations: ACLS, advanced cardiac life support; DSE, dobutamine stress echocardiogram; ECMO, extracorporeal membrane oxygenation; ET<sub>CO</sub><sub>2</sub>, end-tidal carbon dioxide; NA, not applicable; PACU, post-anesthesia care unit; PASP, pulmonary artery systolic pressure; RCA, right coronary artery; TIVA, total intravenous anesthetic; WMA, wall motion abnormality.

\*Indicates where preoperative echocardiography was completed and the results dictated in the preoperative history and physical document, but no formal echocardiography report data were available in the institution’s medical record.

**Table 5. Procedure Classification of Patients Receiving Perioperative "Rescue" Echocardiography**

Surgical Procedure Classification	Count (N = 31)	Percent
Abdominal	13	41.90
Diaphragm	2	
Foregut	3	
Intestinal	4	
Colorectal	2	
Partial hepatectomy	1	
Inguinal herniorrhaphy	1	
Orthopedic	9	29
Hip arthroplasty	7	
Femur fracture	2	
Thoracic	3	9.70
Esophageal	1	
Pulmonary	2	
Transplant	2	6.50
Orthotopic liver transplant	1	
Heterotopic kidney transplant	1	
Urology	1	3.20
Transurethral resection of bladder tumor		
Vascular	1	3.20
Popliteal-distal bypass		
Obstetric	1	3.20
Cesarean section		
Otolaryngology	1	3.20
Sinus endoscopy		

of right-heart failure had known preoperative mild RV dysfunction that had worsened on the "rescue" echocardiogram.

Of the 9 patients diagnosed with ARHF, 4 received inotropic support and were treated with medical therapy alone. One patient had the procedure canceled, and another suffered an unanticipated aortic injury and massive hemorrhage requiring a secondary procedure. One patient with AHRF had massive pulmonary embolus and underwent emergent embolectomy.

Two of the 9 patients diagnosed with ARHF did not survive hospitalization.

The reasons the echocardiograms were performed in these patients (n = 5) were for cardiac arrest (n = 2), tachycardia with hypotension (n = 2), and hypoxia (n = 1). Along with thromboembolus, 3 of 5 patients also had ARHF. One patient underwent emergent embolectomy, 1 patient received systemic heparin, and the other 3 patients received supportive therapy, including inotropes, vasopressors, and postoperative mechanical ventilation.

Of the 31 patients, 4 (13%) underwent further surgical procedures based on the findings of emergent echocardiography. Patient 8 had RV failure and a saddle embolus. The patient underwent emergent embolectomy with cardiopulmonary bypass. Patient 10 had a vascular injury and aortic repair. TEE aided in the visualization of the unknown aortic injury as the patient was undergoing a laparoscopic surgery, and surgical visualization at the time was suboptimal. Patient 22 was found to have significant segmental WMAs and suffered cardiac arrest. The advanced cardiac life support algorithm was used, and the patient underwent emergent right coronary artery stenting. Patient 30 was known to have a small-to-moderate pericardial effusion without preoperative evidence of tamponade. The patient became profoundly hypotensive, and a pericardial window was performed secondary to findings consistent with pericardial tamponade on TEE. In all 4 cases, the patient survived the original surgery, the additional procedures, and was discharged (Table 4).

## DISCUSSION

Few studies exist to support the use of echocardiography in noncardiac surgical patients with hemodynamic instability. The present findings were similar to those of Memtsoudis et al,<sup>3</sup> who evaluated intraoperative TEE in 22 patients who suffered intraoperative arrest and found that TEE identified the primary diagnosis for the cardiovascular collapse in 19 patients. Al-

**Table 6. Perioperative "Rescue" Echocardiographic Results**

Rescue Echocardiographic Findings	Number of Patients (N = 31)	Percentage of Patients*
LV dysfunction	16	52
Systolic dysfunction	14	45
Mild dysfunction, EF 50%-41%	0	0
Moderate dysfunction, EF 40%-21%	4	13
Severe dysfunction, EF ≤20%	10	32
Diastolic dysfunction	7	23
Mild dysfunction (E < A, S > D)	2	6
Moderate dysfunction (E > A, S < D)	1	3
Severe dysfunction (E: A > 2)	4	13
RV dysfunction	9	29
Mild dysfunction, EF 50%-41%	1	3
Moderate dysfunction, EF 40%-21%	4	13
Severe dysfunction, EF ≤20%	4	13
Hypovolemia	5	16
Low LV end-diastolic volume		
Segmental WMAs	4	13
Regional hypokinesis, akinesis, or dyskinesis		
Cardiac tamponade	1	3
Effusion with restrictive chamber filling		
Pulmonary embolism	5	16
Visualization of thromboembolism		

Abbreviations: RHF, right-heart failure; WMAs, wall motion abnormalities.

\*Note some totals equal >100%; many patients were found to have multiple abnormalities on echocardiographic examination.

though the present authors intervened earlier, they found that TTE and TEE may offer benefit in the setting of hemodynamic instability. TTE can be used to better examine the left ventricular apex, and Doppler angles of interrogation across valves are occasionally more easily achieved with TTE. Thus, unlike the Memtsoudis study, the present authors often use either TTE or TEE in patients.

More than half ( $n = 21$ ) of the patients in this review received a change in pharmacotherapy that led to new inotropic support secondary to the echocardiographic findings, whereas the remainder received a change in fluid, drug, or ventilatory management. Although these patients were receiving vasopressor therapy, ongoing inotrope infusions were added after echocardiographic findings. It is likely these patients may have received inotropes without the “rescue” echocardiography; however, echocardiography may have allowed for specific pharmacotherapy management.

Other authors have shown TTE and TEE performed intraoperatively at times of hemodynamic instability demonstrated real-time information that led to improved patient care.<sup>6,13</sup> These studies, like the present one, lacked a control group. However, compelling echocardiographic findings may suggest a prospective controlled study would be unethical because of the availability of bedside echocardiography. Although this review was not strictly limited to cardiopulmonary arrest patients, 81% survived hospitalization. Survival may have been influenced by early changes in medical and surgical management because of “rescue” echocardiographic findings.

The present analysis found ventricular dysfunction to be a prevalent echocardiographic finding. Evidence of diastolic dysfunction was present in 22% of patients who underwent emergent echocardiography. Severe diastolic dysfunction (restrictive pathology) was the most common class of diastolic dysfunction found among the patients (4/31 patients, 13%). Recent literature suggests that the prevalence of diastolic heart failure among surgical patients is increasing.<sup>14-16</sup> A direct relationship between hemodynamic instability and diastolic dys-

function at the time of the “rescue” echocardiography is difficult to conclude. Further evaluation into the role of echocardiography as a means to measure diastolic function during times of arrest is warranted.

Echocardiography may not delineate the precipitating factor that led to the hemodynamic instability; for example, hypotension caused from hypovolemia may result in significant ventricular dysfunction. Although hypovolemia or vasodilation may lead to ventricular dysfunction, echocardiography can be used to measure ongoing efforts in volume resuscitation and drug therapy.<sup>17</sup>

The events surrounding the outcomes of patients 8, 10, 22, and 30 are of particular importance. In these cases, early echocardiographic identification of the etiology of hemodynamic instability may have offered a time advantage to secondary interventions. Without the diagnostic information provided by echocardiography, most surgeons would hesitate to proceed with intervention based on hemodynamic data alone.

#### LIMITATIONS

This study was a small, retrospective, single-institutional review without a definite propensity-matched control population and thus limited the ability to evaluate mortality benefit. The patient population was affected by the aggressive use of echocardiography in elective surgical patients for category 2B and 3B evidence in the authors’ institution.<sup>5</sup> Surgical cases in which intraoperative echocardiography was already used from the beginning of the surgical procedure were excluded. It is likely there were cases of hemodynamic instability that were not evaluated with echocardiography because of the small number of echocardiography-trained physicians at the authors’ institution. However, the number of cases of hemodynamic instability in which echocardiography was not used is unknown.

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