Contrast harmonic imaging improves the evaluation of left ventricular function in ventilated patients: comparison with transesophageal echocardiography

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Aims The study examined the value of contrast echocardiography (CE) in the assessment of left ventricular (LV) wall motion in ventilated patients in comparison with transesophageal (TOE) and standard fundamental transthoracic imaging (SE).

Methods Transthoracic echocardiograms were done in 40 ventilated patients. Wall motion was evaluated using the recommendations of the American Society of Echocardiography on SE, CE and TOE. A visualization score was assigned on a scale of 2–0 for each of 16 segments. The segment was assigned a value of 2 if the segment was seen in both systole and diastole, 1 if seen only in systole or diastole, and 0 if not seen at all. A confidence score was also given for each segment with each technique (unable to evaluate; not sure; sure). The ejection fraction (EF) was estimated visually for each technique, and a confidence score was also applied to the EF.

Results Visualization score 0 was present in 6.2 segments/patient on SE, 1.2 on CE (P<0.0001) and 1.1 on TOE (P<0.0001). An average of 6.5 segments were read with surety on SE, 11.5 on CE (P<0.0001) and 12.3 on TOE (P<0.0001). There was no significant dierence for CE vs TOE. EF was uninterpretable in 32% on SE, 0% on CE (P<0.0001) and 0% on TOE (P<0.0001). The EF was read with surety in 53% of patients on SE, 88% on CE (P<0.0001) and 93% with TOE (P<0.0001) with no dierence for CE vs TOE. Thus, wall motion was seen with more confidence on CE and TOE.

KEYWORDS contrast harmonic echocardiography; transesophageal echocardiography; intensive care unit; ventilated patients; left ventricular function.
Conclusions In the ventilated patients with suboptimal transthoracic echocardiograms for the evaluation of the LV function, CE provides image quality of regional and global LV function similar to that achieved with TOE echocardiography.

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Introduction

Patients in the intensive care unit (ICU) remain technically challenging to obtain adequate echocardiographic images. The frequent use of mechanical ventilation, presence of chest bandages, and difficulty in positioning the patient, poor lighting conditions are factors that impair image quality. Bedside echocardiography in the ICU is an important tool in managing such critically ill patients, often rendering invasive monitoring unnecessary. Transesophageal echocardiography (TOE) has proved to be a highly accurate diagnostic tool for the evaluation of wall motion and the left ventricular (LV) ejection fraction (EF) in these patients or in difficult to image patients. Its advantages of improved image quality and high diagnostic accuracy have to be weighed against disadvantages of semi-invasiveness and patient discomfort.

Many clinical trials with intravenous (IV) contrast agents for echocardiography have demonstrated that contrast agents can improve LV endocardial border delineation and provide generally excellent cavity opacification. The aim of our study was to evaluate the value of contrast harmonic echocardiography (CE) in the assessment of regional and global LV function among ventilated patients in comparison with TOE and with standard fundamental transthoracic imaging (SE).

Patients and methods

Patients

Bedside transthoracic echocardiograms were prospectively performed in 40 unselected patients supported with mechanical ventilation. The mean age of the patients studied was 61.2 ± 13.3 years. The study population comprised 29 men (73%) and 11 women. All these studies were performed for the evaluation of LV function. The patients were ventilated for various problems, including cardiogenic shock post-myocardial infarction (one patient), sepsis (22 patients), acute heart failure (five patients), post-sudden cardiac death (two patients) and other medical illnesses (12 patients). The research protocol was approved by the locally appointed ethics committee and the informed consent of the parents was obtained.

Methods

Experienced cardiologists performed bedside transthoracic echocardiograms in the ICU using a Toshiba Sonolayer Powervision 6000 (Toshiba Medical Systems, Tokyo, Japan) echocardiographic system. The cardiologists obtained the best possible fundamental imaging echocardiograms (standard echocardiography (SE)), followed by echocardiograms using second harmonic imaging after the IV injection of 0.5–1.0 cc of Optison (contrast imaging (CE)). This contrast agent opacified the cardiac blood pool. A multi-plane TOE with a multi-frequency 5–7 MHz probe was performed thereafter (Fig. 1). All hemodynamic parameters, heart rate, blood pressure and oxygen saturation were continuously monitored before, during and after each type of examination. The adjunction of a small dose of midazolam intravenously, if required, before the introduction of the TOE probe was also noted as the duration of the procedure.

All 40 studies were recorded digitally, and these were interpreted in a blinded fashion on a different day from the standard and transesophageal images.

LV wall motion was determined from standard, contrast imaging and TOE by the agreement of two experienced echocardiographers.

Analysis of echocardiograms

Sixteen LV segments were analyzed in four standard views—parasternal long axis, parasternal short axis, apical four chamber, and apical two chamber for transthoracic studies and in four different views for TOE—transesophageal four-chamber view, transesophageal two-chamber view, transesophageal long-axis view and transgastric left ventricular short-axis view, following the Guidelines from the Working Group for performing TOE.

For each segment, wall motion was graded as normal, hypokinetic (mildly, moderately or
severely), akinetic, or dyskinetic. Each of the 16 segments on standard echocardiography SE, CE and TOE was also graded using a visualization score on a scale of 2—0. The segment was assigned a value of 2 if the segment was seen in both systole and diastole, 1 if seen only in systole or diastole, and 0 if not seen at all. A confidence score to reflect the degree of confidence the echocardiographers had in their reading was assigned for each segment with the different techniques (unable to evaluate = C; not sure = B; sure = A).

Overall EF was then determined by visual estimation for each technique (standard, contrast and transesophageal) as increased (>70%), normal (50–70%), mildly reduced (40–49%), moderately reduced (30–39%), or severely reduced (<30%). An EF confidence score was then assigned for each patient (unable to evaluate = C; not sure = B; sure = A). No estimate of the EF could be made if the EF confidence score was C (uninterpretable).

Statistical analysis

Continuous variables were analyzed using Student’s t-test (paired, two-tailed), and discontinuous variables were analyzed using the chi-square test. A P value <0.05 was considered to be statistically significant.

Results

Feasibility

None of the patients needed additional injection of midazolam for CE. Midazolam additional dose required for TOE ranged from 2 to 7 mg.

In the majority of the patients, nasogastric tubes did not hinder insertion of the TOE probe. In case of difficult insertion, the nasogastric tube was mobilized and the TOE probe could be inserted afterward in all patients. Feeding tubes were systematically removed before TOE probe insertion. There were no major complications related to the different procedures.

SE and CE appeared to be well tolerated by the patients. TOE induced more blood pressure variations, heart rate increase and transient decrease of the oxygen saturation as summarized in Table 1.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Before</th>
<th>During CE</th>
<th>During TOE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Systole AP (mmHg)</td>
<td>120 ± 36</td>
<td>120 ± 36</td>
<td>152 ± 54*</td>
</tr>
<tr>
<td>HR (bpm)</td>
<td>100 ± 30</td>
<td>100 ± 30</td>
<td>128 ± 23*</td>
</tr>
<tr>
<td>Sat O₂ (%)</td>
<td>93 ± 8</td>
<td>93 ± 8</td>
<td>87 ± 10</td>
</tr>
</tbody>
</table>

*P <0.05 TOE vs CE and SE.
Visualization score

The improvement of the imaging quality was nearly the same for CE and TOE in comparison with SE in the ventilated patients. Visualization score 0 was noted in 6.2 segments/patient on SE, 1.2 on CE (P < 0.0001) and 1.1 on TOE (P < 0.0001). There was no significant difference for CE in comparison with TOE.

Confidence of wall motion interpretation for the different modalities

The improvement of the image quality with CE and TOE increased the confidence for interpreting the wall motion. An average of 6.5 segments were read with confidence on SE, 11.5 on CE (P < 0.0001) and 12.3 on TOE (P < 0.0001). There was no significant difference for CE in comparison with TOE.

Ejection fraction evaluation

CE and TOE improved evaluation of the EF and confidence for the evaluation of the EF in our patients. EF was uninterpretable in 32% on SE, 0% on CE (P < 0.001) and 0% on TOE (P < 0.001). The EF was read with confidence in 53% of patients on SE, 88% on CE (P < 0.0001) and 93% with TOE (P < 0.0001) with no difference for CE in comparison with TOE.

Interobserver agreement

A subset of 10 studies were randomly chosen to be re-read independently by two observers. The wall motion scores of 160 LV wall segments were assessed. On standard imaging there was agreement in 68% of wall segments evaluated. With CE there was agreement on 96% of the segments and with TOE on 95% of the segments. The wall motion confidence scores agreed in 60% of cases on SE, 92% on CE, and 91% on TOE.

Discussion

Transthoracic echocardiography has significantly improved the diagnostic capability of clinicians in the ICU. In ventilated patients, however, difficulty in obtaining an adequate transthoracic study can limit the accuracy of the technique. TOE offers a reliable alternative approach in this population when transthoracic findings are inconclusive or in situations where transthoracic approach is technically difficult. TOE has become a valuable tool in evaluating critically ill patients for multiple indications, most commonly for evaluation of LV function, wall motion, and structural heart disease.\(^4,10\)

Contrast imaging opacifies the cardiac blood pool, and thus allows better endocardial border detection. This effect is enhanced when used in conjunction with harmonic imaging.\(^11\) Previous studies have shown that this new modality of imaging improves the endocardial border definition compared to fundamental imaging and tissue harmonic imaging (without media contrast injection) in various settings.\(^12–20\) The superiority of CE by comparison with standard imaging and harmonic imaging without contrast injection, for LV function evaluation in mechanically ventilated patients in the ICU, has been shown by Kornbluth et al. The absence of alternative method used to assess the accuracy of wall motion assessment with the different imaging modalities was a limitation to the study.\(^21\) In another previous study, the CE has also been demonstrated to be safe and efficient for the evaluation of regional and global wall motion of the LV in ICU patients.\(^22\) The improvement in regional and global wall motion analysis that we have observed, as the higher diagnostic accuracy with CE, which compare well with TOE, are in agreement with the results recently reported in ICU patients.\(^23,24\) Despite TOE overcomes many of the limitations of transthoracic echocardiography in evaluating wall motion, it is more invasive, more expensive, uncomfortable, and has a small incidence of complications.\(^4\) It was of interest that oxygen saturation slightly decreased during TOE although these individuals were ventilated, probably due to insufficient sedation and to gag reflex during probe insertion. Our study has shown that CE gets an equivalent improvement of the image quality than TOE in comparison with SE in ventilated patients, the most challenging patients to image with ultrasound. This quality improvement leads to a better wall motion visualization, a better surety in the wall motion evaluation for regional and global function estimation and to a better interobserver agreement with less side effects.

Limitations of the study

Although the observers were blinded to the clinical information, they were not blinded to imaging modalities. This study was also limited by the relatively small number of patients. We did not analyze if clinical outcome or treatment was affected by the echocardiographic examination. Although second harmonic without contrast is pretty much standard today, we did not analyze the impact of harmonic imaging without contrast
injection on LV function in our ICU patients. The superiority of contrast harmonic on harmonic imaging without contrast has already been demonstrated in a previous study. 21

Conclusions

This study demonstrates that CE is equivalent to the TOE for the evaluation of global and regional LV function in mechanically ventilated ICU patients. The high quality of images obtained during CE, the non-invasive character of this modality, the smaller incidence of complications compared to TOE, makes this technique quite attractive for the clinical investigation of the regional and global LV function in ICU patients in whom conventional transthoracic echocardiography is not capable of producing adequate images.

References