Experts and Beginners Benefit from Three-Dimensional Echocardiography: A Multicenter Study on the Assessment of Mitral Valve Prolapse

Maximilian Dominik Hien, MD, Manuel Großgasteiger, Cand Med, Helmut Rauch, MD, Alexander Weymann, MD, Raffi Bekeredjian, Prof, MD, and Christian Rosendal, MD, *Heidelberg, Germany; Bern, Switzerland*

Background: Three-dimensional (3D) transesophageal echocardiography (TEE) has been claimed to provide more information than two-dimensional (2D) TEE in the localization of mitral valve prolapse (MVP). However, most studies have been performed by experts in echocardiography, without accounting for differences in training or expertise. This multicenter study was designed to assess the differences between experts and inexperienced echocardiographers in localizing MVP and ruptured chordae tendineae using 2D and real-time 3D TEE.

Methods: Thirty-six observers from 10 institutions in Germany and Switzerland interpreted 2D and 3D transesophageal echocardiographic images from six patients selected to represent a large spectrum of MVP diversity. Surgical findings served as a reference. Individual performance in the prediction of pathology was scored. Differences between 15 experts and 21 beginners in TEE were assessed, and the benefits conferred by 3D TEE were compared.

Results: Both study groups scored significantly higher when interpreting 3D transesophageal echocardiographic images ($P \leq .001$). The experts were superior in 2D MVP localization (14.8%; $P \leq .001$), a difference that diminished with 3D TEE (1.4%; $P = .41$). The benefit of access to 3D information for MVP localization was greater for inexperienced echocardiographers compared with experts ($P < .001$).

Conclusions: The reported diagnostic advantage of 3D TEE over 2D TEE in MVP assessment for expert echocardiographers can be transferred to inexperienced echocardiographers. Inexperienced echocardiographers benefit from the technology to a greater extent than their expert colleagues. (J Am Soc Echocardiogr 2013;26:828-34.)

Keywords: Experience, Training, Education, Mitral valve prolapse assessment, Three-dimensional transesophageal echocardiography

Since the introduction of real-time three-dimensional (3D) transesophageal echocardiography (TEE), several studies have aimed to explore its feasibility in evaluation of the mitral valve (MV) compared with conventional two-dimensional (2D) TEE. Consistently, it has been reported that 3D TEE provides additional information to 2D TEE in perioperative monitoring and MV evaluation.[1-9] Although recent studies involved study samples including >50 patients, the generalization of their results is limited because the conclusions were based on the interpretations of only one[2,5] or two[1,3,4,8-10] experts in the field of TEE. This selection of echocardiographers entails bias, calling into question the transferability of the results to the average physician performing TEE. The present multicenter study was designed to determine differences between experts and beginners in echocardiography when assessing MV prolapse (MVP) using 2D and 3D TEE.

METHODS

Ethical Approval

The study protocol conforms to the ethical guidelines of the 1975 Declaration of Helsinki as reflected in a priori approval by the regional research ethics committee. Written informed consent was obtained from all patients before surgery and TEE. No personal patient information was disclosed to the study participants.

Study Population

Thirty-six physicians were enrolled after giving their consent to take part in our study. Personal information was removed after data acquisition. None of the participants had previous access to the image

From Research Training Group 1126, German Research Foundation, Heidelberg, Germany (M.D.H., M.G.); the Departments of Pediatrics (M.D.H.), Cardiac Surgery (A.W.), Anaesthesiology (M.D.H., M.G., H.R.), and Internal Medicine (R.B.), University of Heidelberg, Heidelberg, Germany; and Hirslanden Clinics Berne, Klinik Beau-Site, Bern, Switzerland (C.R.).

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Reprint requests: Christian Rosendal, MD, Hirslanden Clinics Berne, Klinik Beau-Site, Schänzlihalde 11, 3000 Bern 25, Switzerland (E-mail: *christian.rosendal@me.com*).

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Abbreviations
ChR = Ruptured chordae tendineae
MV = Mitral valve
MVP = Mitral valve prolapse
TEE = Transesophageal echocardiography
3D = Three-dimensional
2D = Two-dimensional

material or the surgical results. The study population comprised two groups. One group consisted of 21 physicians from 10 institutions in Germany who were residents or fellows in cardiology or anesthesiology without previous experience in TEE. All were taking part in a four-day basic training course in TEE. The day before the study, they received a lecture on MV anatomy and pathology and how the scallops are displayed in standard and modified standard sections, as described by Lambert *et al.*[11] The other group consisted of seven cardiologists and eight anesthesiologists from four different institutions in Germany and Switzerland. All physicians in this group were certified echocardiographers at an expert level,[12] with ≥4 years of clinical experience in TEE.

Both groups received a general introduction to the study protocol, wherein prolapse was defined as either flailing free margin of a leaflet and/or leaflet tissue billowing >2 mm above the annular plane in the left ventricular long-axis view or >5 mm in any other view, respectively.[13] They were free to access handouts, including depictions of standard and modified standard 2D transesophageal echocardiographic sections displaying the MV.[11] Two-dimensional images composed a full set of B-mode standard sections, as recommended in the current guidelines (Figure 1).[11,14,15] The patients' personal information was removed from all cine loops, and 2D and 3D material was presented to each reader in random order.

Transesophageal Echocardiographic Acquisition and Case Selection

An iE33 ultrasound system, equipped with an X7-2t matrix-array transducer (Philips Medical Systems, Andover, MA), was used to record 2D and 3D cine loops. Six representative cases of MVP were selected from a large number of intraoperatively recorded transesophageal echocardiographic examinations. The examinations were performed by expert echocardiographers according to our standard clinical intraoperative protocol,[9] which is based on the American Society of Echocardiography guidelines[14] and additional literature.[13] A full set of 2D standard sections is displayed in Figure 1. After optimizing the probe position, 3D transesophageal echocardiographic images were acquired in a zoomed mode, displaying a pyramidal volume, which was adjusted to capture the MV with maximum resolution.

Images were reviewed offline (QLAB version 8.0; Philips Medical Systems). Three-dimensional image settings were adjusted to provide optimal gain and color coding, and the image was rotated to show an en face left atrial view onto the MV, with the aortic valve rotated to a 12 o'clock position according to the surgical intraoperative view (Video 1 [available at www.onlinejase.com] and Figure 2 vs Figure 3). Both 2D and 3D images were presented to the study participants in cine loops, played at normal speed and in slow motion.

The six cases were selected to cover a large spectrum of MVP diversity, as well as to limit the image load for the 36 interpreters to a reasonable number (60 cine loops had to be viewed by each). The selection was based on the following criteria: optimal image quality of both 2D and 3D images (determined by the display of the entire profile of the MV), a large spectrum of MVP diversity, and compliance with the more frequent involvement of scallop P2, according to the literature.[8-10,16,17] Table 1 shows the involvement of each scallop, single-scallop MVP, multiple-scallop single-leaflet and bileaflet MVP, and cases with and without ruptured chordae tendineae (ChR).

Surgical Evaluation

Intraoperatively, the left atrium was dissected and the MV was inspected by the operating surgeon from an en face left atrial view (Figure 3). A fine hook was used to test for prolapsing scallops and ChR. Surgical evaluation served as the reference standard.

Measurements

For each scallop, the readers determined whether it was prolapsing. By summing true-positives and true-negatives, a maximum of 36 points could be achieved across all six patients and in both methods of TEE for MVP. This score is directly proportional to the accuracy of detecting prolapsing scallops. Furthermore, the readers indicated whether no ChR, a single ChR, or multiple ChR were present. One point was given for a correct diagnosis of presence or absence of ChR, and one additional point could be obtained in three cases for the correct diagnosis of multiple ChR, leading to a maximum score of nine points for ChR.

Statistical Analysis

Statistical analysis was performed using SPSS version 19 (IBM, Armonk, NY). All tests were two-sided and P values $< .05$ were considered significant. The surgical intraoperative findings served as the gold standard. MVP localization was evaluated separately for experienced and inexperienced readers. Score results were tested for normal distribution using the Smirnov-Kolmogorov test. Differences between 2D and 3D evaluation within each group were analyzed using Student's t test for paired samples. Differences between experts and inexperienced readers within each method (2D or 3D) were analyzed using Student's t test for nonpaired samples.[18] Differences between the two groups of echocardiographers regarding the benefit of 3D TEE in the localization of MVP were evaluated using Student's t test for nonpaired samples. The benefit was calculated by subtracting the 2D from the 3D score of each reader. Asymptotic 95% confidence intervals were calculated for the difference in mean values between 3D versus 2D and between experts versus inexperienced readers. The ChR results were analyzed similarly.

RESULTS

The references for the evaluation of MVP and ChR were determined intraoperatively and are shown in Table 1. All 36 interpreters completed their evaluations; none was excluded from statistical analysis.

Expert Echocardiographers

The average score of the 15 expert echocardiographers was significantly higher using 3D compared with 2D data. The expert readers also found ChR more reliably with 3D than with 2D transesophageal echocardiographic images. Scores are shown in Table 2, and the benefit from 3D TEE is presented in Table 3.