Impact of a One-Day Three-Dimensional Transesophageal Echocardiography Workshop on Clinical Practice at a Single Academic Centre

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ABSTRACT
Background: Transesophageal echocardiography (TEE) is a powerful diagnostic tool which has become an integral part in the management of cardiac surgery patients. We developed a one-day 3D TEE workshop specifically designed to meet the needs of perioperative cardiac anaesthesiologists. We hypothesized that participation in the workshop would increase the uptake of 3D TEE in routine perioperative practice.
Aims: To examine the impact of one-day 3D TEE workshop on 3D TEE image acquisition and incorporation into routine perioperative practice.
Setting: Tertiary care hospital.
Design: Prospective observational monocentric study.
Subjects and Methods: A convenience sample of 20 cardiac anesthesiologists (with an option to attend the one-day workshop midway through the study) from a single center consented to have their intraoperative TEE images collected during the course of the study reviewed for research purposes. Images acquired 6 months before, immediately after, and 6 months following the workshop and images were examined by a blinded, expert echocardiographer.
Results: Data collected for 16 participants (8 workshop attendees, 8 non-attendees) indicate that the TEE workshop increased the number of 3D TEE images, but not x images acquired immediately following the workshop (P=0.006). No difference was observed in number of 3D images at six months’ post workshop. Workshop participants obtained more 3D and multi-plane images after the workshop and more 3D images at 6 months compared to those who did not attend the workshop.
Conclusion: Our study suggests that a single day hands-on 3D TEE workshop may have had an impact on the implementation of intraoperative 3D TEE in experienced echocardiographers.

Keywords: Cardiac anesthesiology, cardiac surgery, education three-dimensional transesophageal echocardiography

INTRODUCTION
Intraoperative transesophageal echocardiography (TEE), first introduced in the 1970s,[1] has since become an integral part of the perioperative management of cardiac surgery patients[2-6] and contributes to improved patient outcomes.[7-9] Current practice guidelines mandate the use of TEE in all open cardiac surgery[10] and recommend...
it for intraoperative monitoring during coronary bypass surgery.\textsuperscript{2}

One of the challenges of TEE remains the conceptualization of the complex 3D cardiac anatomy from a series of two dimensional (2D) TEE slices.\textsuperscript{11} To fill this gap, real time three dimensional (3D) TEE became available in the early 2000's and 3D imaging is now incorporated into the comprehensive TEE examination in the latest American Society of Echocardiography (ASE)/Society of Cardiovascular Anesthesiologists (SCA) guidelines.\textsuperscript{12} Integrating 3D TEE into clinical practice however, requires further training to become familiar with the technology in order to obtain and manipulate 3D datasets.

3D TEE training has been incorporated into many residency/fellowship training programs and there are numerous training resources offered by national and international societies (e.g., European Association of Cardiovascular Imaging (EACVI) and the American Society of Anesthesiologists (ASA)/SCA).\textsuperscript{13,14}

Acquisition of 3D TEE conceptual knowledge may benefit from free on-line TEE teaching tools\textsuperscript{15} based on an interactive digital 3D heart model,\textsuperscript{16} which has already demonstrated efficacy for improving trainee knowledge and shortening the time required for trainees to develop probe manipulation skills for 2D TEE.\textsuperscript{17} Mannequin-based simulators used for echocardiography training\textsuperscript{11} may be advantageous over the web-based systems in that they offer a more realistic “hands-on” experience however 3D TEE is not fully integrated into all current platforms and their role in 3D TEE training has not been studied to date.\textsuperscript{11}

Training full time practicing clinicians on this complex new technology, presents many challenges including time constraints and motivation.\textsuperscript{18}

To fulfill these learning needs, and based upon current evidence of educational effectiveness,\textsuperscript{19} we developed a one day hands-on practical 3D TEE workshop for perioperative cardiac anesthesiologists with advanced 2D TEE skills.

The purpose of this retrospective observational study was to examine the impact of this one-day 3D TEE workshop on 3D TEE image acquisition and incorporation into routine perioperative practice for the course participants at a single academic center. Our hypothesis was that a single-day hands-on workshop would have increased the routine use of 3D and multi-plane TEE image acquisition among the course participants.

The primary outcome was the number of interpretable multi-plane and 3D images acquired as part of a comprehensive intraoperative TEE examination, immediately after the course compared to before.

Secondary outcomes were the number of interpretable multi-plane and 3D images acquired at six months after the course compared to immediately after, and before.

Additional outcomes were the total number of TEE images acquired; the time required to complete the TEE exam; the percentage of examinations including multi-plane and 3D images of the left ventricle (LV); the percentage of examinations that comprise multi-plane and 3D images of the aortic valve (AV) and mitral valve (MV) during AV and MV surgery respectively, and finally the number of interpretable multi-plane and 3D images in non-participants compared to participants at the same time-points.

**SUBJECTS AND METHODS**

Seven months after a hands-on 3D TEE workshop and institutional ethics board approval (approval number 370/17), a convenience sample of cardiac anesthesiologists at our Center was recruited. They included all workshop participants with TEE examinations available for review at all time points and an equal number of controls. All of the study subjects had at least one year of experience daily performing and reporting comprehensive 2D TEE examinations according to EACVI guidelines.\textsuperscript{20} Their comprehensive intraoperative TEE examinations before, immediately after and six months after the 3D TEE workshop were available to be reviewed. 3D TEE technology was available in all operating rooms for routine use for the entire period studied. None of the study subjects had any previous structured training in 3D TEE. Signed informed consent was obtained and all study subjects agreed to allow review of previous intraoperative TEE examinations. For each study participant, 10 consecutive intraoperative TEE examinations were reviewed at each of the following time points: Immediately before, immediately after, and at 6 months after the workshop. No written informed consent was required for the patients involved given the observational and retrospective nature of the study.

| Table 1: Workshop curriculum |
| --- |
| **Duration (h)** | **Workshop curriculum** |
| 1.0 | Image acquisition, Cropping and image optimization |
| 1.5 | Mitral valve evaluation by means of 3D Q |
| 1.5 | Aortic valve evaluation by means of 3D Q |
| 1.0 | Tricuspid valve evaluation by means of 3D Q |
| 1.0 | Evaluation of LV function by means of 3D Q and 3D QADV |
| 0.5 | Group discussion/case study |
3D TEE workshop

A one-day hands-on 3D TEE workshop was organized at the departmental level. It was designed by a cardiac anesthesiologist, board certified in perioperative TEE with experienced in 3D TEE who had no other involvement in the study. The workshop took place on Saturday, July 22nd, 2017 in the study Institution's lecture hall. Continuing Medical Education credits were provided. The workshop was advertised via e-mail to all department member and by a poster in the main Departments office. It was open to a maximum of 20 participants and was offered on a “first come-first served” base. The workshop [Table 1] consisted of one short lecture on image acquisition and small groups hands-on sessions for 3D image acquisition/manipulation using Q Lab 9, 3D Analysis Software on a stand-alone laptop (Philips, Andover, MA, USA) for a total of 6.5 hours.

TEE imaging

All operating rooms (ORs) were equipped with 3D CX 50 echocardiography systems and x7-2T probes (Philips, Andover, MA, USA). All intraoperative TEE examinations were performed with this platform following a standardized institutional 2D TEE image acquisition protocol based on 20 standard views. No specific 3D acquisition protocol was in place therefore multi-plane (more specifically X-plane on the CX 50 System) Philips, Andover, MA, USA) and 3D images were acquired at the echocardiographer’s discretion before as well as after the workshop. All Images were stored on a central DICOM server (Image Arena, TomTec, München, Germany). The completed examinations were retrospectively reviewed on a stand-alone computer connected to the institutional TEE database and evaluated by a blinded, board-certified echocardiographer who had no other involvement with the study.

Outcomes measures

The following outcomes were measured for all participants at all time-points (one month before, immediately after and six months after workshop participation):

1) Number of 3-D images acquired during one comprehensive study at each of the above mentioned time-points. All 3D TEE images deemed appropriate when examined using multi-planar reconstruction. Images were not included if the structure of interest was either not recognizable or not entirely included in the dataset.

2) Number of multi-plane images acquired. Images were not included if the structure of interest was either not recognizable or not entirely included in the two perpendicular planes.

3) The total number of images acquired for each examination including 2D, 3D, and multi-plane.

4) Percentage of examinations that comprise x plane and 3D images of the LV.

5) Percentage of examinations that comprise x plane and 3D images of the AV or MV, for AV and MV surgery respectively.

6) Time taken to complete a TEE examination measured as the difference between the time at which the last video-clip was saved and the time at which the first was saved.

Statistical analysis

Statistical analyses were performed using IBM SPSS version 20.0 software. Categorical variables are expressed using frequency and to test statistical significance of the differences between time-points, Chi-square or Fisher exact test, were used as appropriate. Continuous variables are presented by median and inter quartile range. To test the statistical significance of the differences in the median of variables between participants and non-participants, Mann Whitney U tests were used. P values <0.05 were deemed statistically significant.

RESULTS

Ten cardiac anesthesiologists participated in the 3D TEE workshop from which 8 had performed TEE examinations
available for review at all study time points. They were matched with 8 cardiac anesthesiologists with TEE examinations available for review at the same time points as controls. All study participants provided written informed consent. Participants’ characteristics are summarized in Table 2.

Among participants, we observed a significant increase in the number of 3D (3 (2-6) vs. 2 (0-4) ($P = 0.006$)) but not multi plane images acquired, before and immediately after the 3D TEE workshop [Table 3]. Six months after workshop participation, the number of 3D images had decreased to the pre-study baseline numbers. No difference was observed regarding the number of multi plane images acquired. The total number of images acquired and the time to complete the examinations were not significantly different at any time point [Table 3].

Immediately after and six months after the workshop no increase in 3D or multiplane image acquisition of LV was observed in workshop participants.

After the workshop, participants did acquire more 3D but not multi-plane images of the MV during MV surgery compared to pre-workshop. In AV Surgery they did not acquire more 3D AV images nor multi-plane images. At 6 months after the workshop, the acquisition of 3D and multi plane images was comparable to pre-workshop for both MV and AV surgery [Table 4].

Finally, the subjects who participated in the workshop, were already acquiring more multi-plane images compared to non-participants. After the workshop and still 6 months after, participants acquired additionally more 3D images, compared to those who did not attend the workshop. The total number of images obtained from participants was higher than from the non-participants but time needed to complete an examination did not differ between groups in all time-points [Table 5].

**DISCUSSION**

The current study suggests that the one-day hands-on 3D TEE workshop had some impact on the total number of 3D TEE images acquired immediately after the event.

To the best of our knowledge, no similar studies have examined the impact of a one-day hands-on 3D TEE workshop on routine clinical practices of intraoperative echocardiography. While the use of e-learning and simulators[16,17,22] have demonstrated a significant impact in the learning curve of 2D TEE their impact on implementing 3D TEE is not known. This may partially be due to the lack of integration of 3D into simulators at that time and the challenge to simulate different 3D TEE
platforms with very different user interfaces. In contrast to previous studies, our subjects were already proficient in intraoperative 2D TEE and did not need to acquire basic skills such as correlation of 2D view with 3D anatomy or hand-eye coordination. In our case, familiarization with image technique, the vendor-specific user interface, and 3D data manipulation on computers was enough to result in an increase in interpretable 3D acquired. The acquisition of and multi-plane images did not increase significantly probably because it was already quite high before the workshop (86.3% of LV, 43.8% of MV and 68.3% of AV). This may be justified by the fact that multiplane is quite self-explanatory to most experienced echocardiographers.

However, we observed minimal retention of newly acquired skills at 6 months after the workshop. This is an expected skill retention phenomenon that highlights the need for repetition and continuous use.[24] A change in the institutional image acquisition protocol to integrate 3D and Multi-plane TEE into standard protocol as well as one-to-one mentoring in the Operating room, may have prevented this set-back by prompting the use of this new technology on a daily basis.

The acquisition of 3D and multiplane LV images increased very marginally although the use of 3D and multiplane imaging for LV assessment is suggested by current guidelines.[24] and facilitates quantification of LV function using Simpson method and automated volume measurements. While multiplane acquisition was already commonly used before the workshop (86.3%), 3D images of the LV were rarely acquired (7.5% before and 12.5% after). This may be justified by the fact that the systems used in the study did not allow for EKG-gated acquisition if needed and 3D Volume reconstruction is time consuming. Furthermore the 3D LV acquisition and analysis might have required specific additional training.

This increase of 3D image acquisition was only significant for MV during MV surgery. Acquisition of 3D datasets form the MV is feasible in most cases and results in good quality datasets.[25] Furthermore, the ability to display the MV in the surgical orientation allows better communication with surgeons, and results into better identification of leaflets prolapse compared to 2D.[26]

In AV surgery, there was an increase in both multi-plane and 3D image acquisition after the workshop but none of them were significant. A possible explanation is that obtaining 3D TEE images of the AV is less commonly successfully done,[25] and less intuitive than that for the MV.

Our study also reported that integrating 3D and multi-plane TEE imaging acquisition into a standardized institutional image acquisition protocol does not result in a significantly prolonged time to complete the examination or significant increased number of images. These two findings support the use of 3D and multi-plane TEE in the operating room setting, even given the strict time constraints to complete an examination.

The positive effect of the 3D TEE workshop on clinical practice was only observed in those who attended the workshop and no “conditioning” effect was observed on those who did not attend.

This may be explained by the fact that integrating 3D and multi-plane TEE image acquisition into clinical practice requires specific training and a significant time commitment. Since participation to the course, although free of charge, was on a voluntary basis on a weekend day, the participants may have been a more self-motivated and committed to acquiring 3D TEE skills. This may also have been reflected by the fact that all workshop participants obtained TEE certification.

The current study has a number of limitations. First, it has the inherent limitations of a “before and after” trial.[27] Due to limited number of echocardiographic systems and computers the number of participants to the workshop was limited to 20 to allow maximum two participants per computer. Given the lack of previous similar trials upon which to base a sample size calculation, we could not properly power the current study but instead used a small convenience sample. The study is retrospective although in this case this study design may have avoided an inclusion bias therefore the workshop participants were unaware of being observed during the period studied. The workshop included only one system that was available at the Center during the study period. All of the above-mentioned limitations may have impacted the generalizability of these findings. Also, the participants were not randomized to group allocation, but rather volunteered for workshop participation outside of regular working hours, which raises the potential issue of sampling bias. Finally, this study did not examine the participants’ ability to interpret the images (i.e., clinical integration) and included no evaluation of competency which some could argue are among the most important aspects following such an educational initiative. Nevertheless, the current study did suggest that the one-day 3D TEE workshop increased the use of perioperative 3D TEE. This is significant since time constraints and multiple completing responsibilities can inhibit the adoption of 3D TEE[18] and these constraints may be intensified for cardiac anesthesiologists during the perioperative period.
CONCLUSION

Our study suggests that a single day hands-on 3D TEE workshop may have had an impact on the implementation of intraoperative 3D TEE in experienced echocardiographers. Follow-up and refresher courses, inclusion of 3D imaging in acquisition protocols and one-to-one mentoring may be needed to maintain this practice over time.

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Conflicts of interest

There are no conflicts of interest.

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