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Point-of-Care Ultrasound Before and After Transfemoral Transcatheter Aortic Valve Implantation

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Abstract

Objective: Surgical aortic valve replacement requires a comprehensive transoesophageal echocardiography (TEE) assessment before and after the intervention by cardiac anaesthesiologists. For patients undergoing transfemoral transcatheter aortic valve implantation (TF-TAVI), TEE is not routinely used. We started using transthoracic echocardiography (TTE) as a diagnostic and monitoring modality during TF-TAVI procedures. The aim of this study is to examine the usefulness of TTE before and after TF-TAVI. We hypothesised that TTE can serve as a screening tool in TF-TAVI patients and help rule out significant paravalvular leaks (PVLs), and serve as a monitoring tool.

Methods: A retrospective, observational study of 24 patients who underwent TF-TAVI with perioperative TTE over a 3-month period was conducted. Intraoperatively, two TTE examinations were performed. The first was a baseline pre-procedural TTE examination after anaesthetic induction, and the second was performed after TAVI valve implantation. Both pre- and post-procedural examinations included five focused TTE views. PVLs were graded as none, non-significant (trace or mild) or significant (moderate or severe).

Results: The average age and median body mass index of the patients were 82 years and 28.5 kg m^{-2}, respectively. The average time recorded for the pre- and post-TAVI TTE examinations were approximately 4 and 5.5 min, respectively. Non-significant PVL was detected in 6 (25%) patients, and no leak was detected in 18 (75%) patients.

Conclusion: A focused TTE examination was found to be a useful adjunct during TF-TAVI for a cardiac anaesthesiologist in the absence of TEE, and useful in ruling out significant PVLs.

Keywords: Point-of-care ultrasound, transcatheter aortic valve implantation, transthoracic echocardiography

Introduction

Cardiac surgery is rapidly evolving from a traditional, open surgical approach to transcatheter (structural heart) interventions, such as aortic valve implantation, mitral clips and watchman procedures. Transfemoral transcatheter aortic valve implantation (TF-TAVI) is a procedure wherein a prosthetic aortic valve is implanted by groin cannulation. In many institutes including ours, experienced cardiac anaesthesiologists who are transoesophageal echocardiography (TEE)-certified provide care for these patients. However, anaesthesia for TF-TAVI has evolved from general anaesthesia (GA) to monitored anaesthesia care (MAC) sedation (1), thereby limiting the routine use of TEE for diagnostic and monitoring purposes. In addition, TEE procedure is invasive and may cause injuries (2, 3). This is true particularly when an echocardiogram is needed during an urgent situation during MAC sedation. Under these conditions, it is hypothesised that a transthoracic echocardiography (TTE) examination can serve as a useful modality for a cardiac anaesthesiologist and can be used as an alternative to TEE in ruling out paravalvular leaks (PVLs). It can provide critical information about a newly implanted aortic valve, status of other valves, myocardium and pericardium post procedure. Thus, cardiac anaesthesiologists may need to hone their TTE skills. With prior knowledge of sonoanatomy due to TEE imaging acquisition and interpretation skills, a fellowship-trained cardiac anaesthesiologist may have an advantage in learning and interpreting TTE images.

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At our institute, we have started to use focused TTE perioperatively, especially during TF-TAVI. A retrospective, observational study was conducted to explore the usefulness of TTE during a TF-TAVI to rule out significant PVLs.

Methods

This retrospective study was approved by the departmental and institutional review board. A written and verbal consent was obtained from the patients for administering anaesthesia and performing TTE examination. Twenty-four patients with severe aortic stenosis who underwent an elective TF-TAVI were studied. An Edwards Sapien valve (Edwards Lifesciences, Irvine, CA, USA) or a Medtronic Core valve (Medtronic Inc., Minneapolis, MN, USA) was used in all these patients. TAVI procedure was performed under GA using a supraglottic airway device or an endotracheal tube (ETT). This study was conducted over a 3-month period (September to November 2018). Patients who underwent a TAVI procedure via alternative (transapical or subclavian) access were excluded. An American Board of Anaesthesiology–certified, cardiac fellowship- and TEE-trained anaesthesiologist with TTE experience performed all the examinations. For this retrospective study, these TTE examinations were later reviewed by a critical care–trained anaesthesiologist with competence in critical care echo. Procedural and anaesthesia data were collected from the hospital records. The average time spent by the anaesthesiologist for both pre- and post-TAVI TTE examinations was noted from the TTE reports.

Pre-procedural screening prior to the TAVI procedure was performed by a multi-disciplinary meeting involving the structural heart team. Patients' medical history, severity of aortic stenosis, previous cardiac imaging, procedural difficulties and anaesthesia concerns were discussed. Sizing the stenosed aortic valve annulus was performed using a computerised tomography scan. The size of the prosthetic aortic valve was determined by the cardiology team.

Preoperative assessment

Each patient was observed at the preoperative anaesthesia clinic; however, the anaesthesia plan was chosen by the anaesthesiologist involved on the day of the procedure. The choice of anaesthesia was determined based on patient factors and the anaesthesiologist preference. The factors considered include the patients' body mass index (BMI), co-morbidities, ability to lie supine, back pain, and airway assessment. All patients were consented pre-operatively for anaesthesia. Vivid E95 (GE Healthcare, CA, USA) ultrasound machine was used for the pre- and post-intervention TTE examinations.

Main Points:

- The usefulness of TTE before and after TF-TAVI is examined via a retrospective observational study.
- TTE can be used to detect major prosthetic PVLs of haemodynamic significance during TF-TAVI.
- TTE can supplement TEE as a visual monitoring tool by anaesthesiologists during TF-TAVI.

Operating room

Upon arrival of the patient, a pre-anaesthesia checklist was conducted. At our institute, a surgical preparation of the chest is not routinely performed for a TF-TAVI. A five-lead electrocardiogram, non-invasive blood pressure, pulse oximetry and temperature monitoring were used in all the patients. Defibrillator pads were also applied in the right infraclavicular area and left infraaxillary area so that the TTE could be performed. After preoxygenation and induction, either an I-Gel (a second-generation supraglottic airway device from Intersurgical Inc., Syracuse, NY, USA) or an ETT was used. Some of the considerations for endotracheal intubation were obesity (BMI >35 kg m^{-2}), severe obstructive sleep apnoea (OSA), large and distended abdomen, predicted difficult airway, and diffuse atherosclerotic disease requiring a cut down of groin vessels. GA was maintained by using an inhalational agent, opioid, and a neuromuscular blockade agent.

A focused TTE examination was performed post-induction using a portable ultrasound machine equipped with a phased array TTE probe (3.6 MHz). Five standard TTE views were attempted for all patients. These included the parasternal long-axis (PLAX), parasternal short-axis (PSAX), subcostal four-chamber (SC4C), subcostal inferior vena cava (SC-IVC) and apical four-chamber (A4C) views. Three views were utilised after TAVI (namely, PLAX, PSAX and SC4C); A4C was not used after TAVI.

Pre-TAVI focused TTE examination and its sequence

Initially, SC4C two-dimensional (2D) and colour flow Doppler (CFD) views were obtained followed by SC-IVC view. Subsequently, an A4C view was obtained. The TTE probe was then placed at the second or third intercostal space to obtain a PLAX 2D and CFD views. After recording an optimal view, the ultrasound probe marker was rotated to the left shoulder to obtain a PSAX view. The structures examined in various views are provided in Table 1.

Post-TAVI TTE

After a prosthetic aortic valve implantation and restoration of normal blood pressure, a focused TTE was performed, and S4C, PLAX and PSAX views were obtained. The structures examined post-TAVI are displayed in Table 1. The PVL was assessed in PLAX and PSAX views and graded as none, non-significant or significant. The focus of the post-TAVI examination was assessing the prosthetic aortic valve and its seating, and eyeballing the PVL, biventricular function and pericardial space. The SC4C and PSAX views were used for other potential indications shown in Supplementary Table 1.

Table 1. TTE examination sequence using five standard views during TF-TAVI procedure

Views	Structures examined
PLAX 2D and CFD views	RV and LV size, position of the interventricular septum, stenotic AV, MV, implanted AV, PVL, SAM
PSAX 2D and CFD views	Stenotic AV, AI, position of the interventricular septum, RV and LV size/function, pericardial effusion, implanted TAVI valve, PVL
SC4C 2D and CFD views	Pericardial effusion, RV and LV
SC-IVC view	Assesses volume status
A4C 2D view	LV and RV, TV, MV

2D: two dimensional; A4C: apical four-chamber; AV: aortic valve; AI: aortic insufficiency; CFD: colour flow Doppler; IVC: inferior vena cava; LV: left ventricle; MV: mitral valve; PLAX: parasternal long-axis; PSAX: parasternal short-axis; PVL: paravalvular leak; RV: right ventricle; SAM: systolic anterior motion; TAVI: transcatheter aortic valve implantation; TF-TAVI: transfemoral transcatheter aortic valve implantation; TV: tricuspid valve; TTE: transthoracic echocardiography

Table 2. Demographic data

Parameter	Mean, number of patients (range or %)
Age (years)*	84 (64–91)
BMI (kg m^{-2})*	28.5 (20.08–44.70)
Male/Female**	12/12 (50/50)
STS score*	4.9 (1.6–9.9)
Mean AV gradient (mm Hg)*	44.1 (23.4–87)
Ejection fraction (%)*	52.4 (25–65)
Aortic valve area (cm2)*	0.75 (0.3–0.9)
Parameter**	**Number/total (%)**
Coronary artery disease	7/24 (29.1)
Previous myocardial infarction	8/24 (33.3)
Diabetes mellitus	6/24 (25)
Hypertension	24/24 (100)
Chronic kidney disease	5/24 (20.8)
Previous CVA/stroke	7/24 (29.1)
COPD	7/24 (29.1)
Pulmonary hypertension	8/24 (33.3)
Mitral regurgitation (non-graded)	21/24 (87.5)
Tricuspid regurgitation (non-graded)	17/24 (70.8)

AV: aortic valve; BMI: body mass index; CVA: cerebrovascular attack; COPD: chronic obstructive pulmonary disease; STS: the Society of Thoracic Surgeons score (STS score serves as a validated risk-prediction model for open surgery based on data from the STS National Cardiac Surgery Database audit).

*Continuous data, **Dichotomous categorical data.

Bleeding and vascular injury were ruled out upon encountering a significant and persistent haemodynamic instability. TTE was then used as a screening modality for ruling out intrathoracic aetiology, pericardial effusion, acute ventricular dysfunction, valvular dysfunction and volume status; SC4C and PSSAX views were used. After ruling out pericardial effusion and the aforementioned causes, the IVC diameter was measured in a subcostal view. An M-mode was used to measure the respiratory variation of the IVC. These two parameters were used as a guide for administering intravenous fluids (Figure 1).

Image quality and acquisition

The image quality was graded as good, adequate, poor or unable to obtain. Good quality images were characterised by clearly displayed structures that were intended to be examined. Adequate images meant that the images had sufficient quality to view the cardiac structures. Poor image quality meant the operator could not identify the structures and the clinical question was unanswered. If the operator was not able to acquire the intended images despite the proper position and placement of the TTE probe, the image quality was graded unable to obtain.

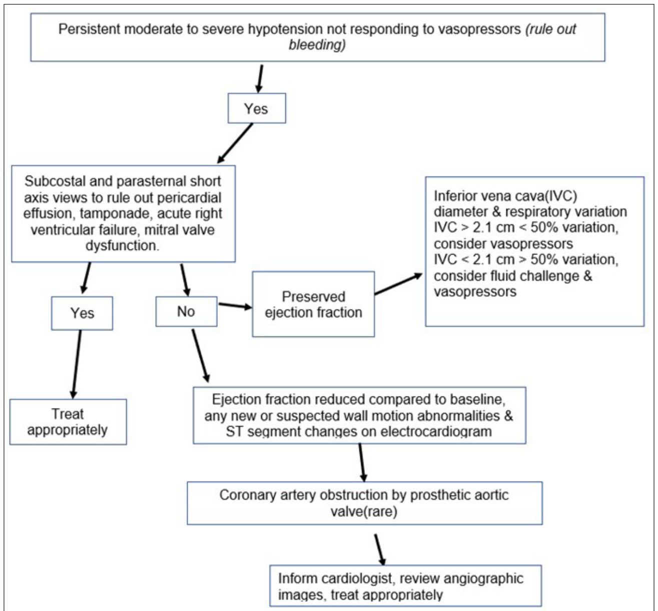

Figure 1. General intraoperative guide to use TTE during moderate-to-severe hypotension. After ruling out bleeding due to vascular injury, TTE was used to rule out procedure-specific complications. TTE cannot diagnose retroperitoneal and annular rupture.
EF: ejection fraction; IVC: inferior vena cava; PSAX: parasternal short-axis view; POCUS: point of care ultrasound; RWMA: regional wall motion abnormality; TTE: transthoracic echocardiography

The statistical analysis was performed by the statistician at our institute. The demographic data were classified as categorical and dichotomous continuous variables. The data were analysed using Minitab® 19 statistical software and reported using mean, median, range and percentages. The procedural data were reported using percentages. The Fisher's exact test was used to calculate the p-values for PVLs, as our sample size was small.

Results

A total of 24 patients were studied during TF-TAVI, with peri-procedural TTE examinations (pre- and post-TF-TAVI) performed for all the patients. Tables 2 and 3 provide the demographic and procedural data, respectively. Table 4 shows the TTE views that were successfully obtained. PLAX view was obtained in 23 (95.8%) patients, and PSAX view was obtained in 21 (87.5%) patients. A4C and SC4C views were obtained in 17 (70.8%) and 22 (91.6%) patients, respectively. SC-IVC view was obtained in 20 (83.3%) patients. It was found that 18 (75%) patients had no PVL and 6 (25%) patients had a non-significant PVL. None of the patients had a significant PVL or pericardial effusions after TF-TAVI. The Fisher's exact test statistic value was 0.021 for detecting PVLs by using TTE. The result is significant at $p<0.05$.

Table 3. Procedural data

Parameter**	Number/total (%)
Edwards Sapien valve	21/24 (87.5)
Medtronic Core valve	3/24 (12.5)
Procedure success	24/24 (100)
Pacemaker post–TF-TAVI	6/24 (25)
Procedure-related mortality	None
30-day mortality	None
Life-threatening bleeding	None
Transfusion needed	None
Parameter*	**Mean (range)**
Fluoroscopy duration (minutes)	7.302 (3–26.4)
Room time (minutes)	75.083 (50–131)
Hospital stay (days)	2.182 (1–11)

TF-TAVI: transfemoral transcatheter aortic valve implantation
*Continuous data, **Dichotomous categorical data

Table 4. Intraprocedural TTE views during TAVI

TTE views	Number/total (%)
Parasternal long-axis view	23/24 (95.8)
Parasternal short-axis view	21/24 (87.5)
Apical four-chamber view	17/24 (70.8)
Subcostal four-chamber view	22/24 (91.6)
Subcostal IVC view	20/24 (83.3)

IVC: inferior vena cava; TAVI: transcatheter aortic valve implantation; and TTE: transthoracic echocardiography

Discussion

The major finding of our study was that TTE can be used by anaesthesiologists to evaluate the degree of PVLs after a TF-TAVI. The secondary findings are that TTE can be used as an additional monitoring tool by anaesthesiologists providing care and to obtain all five standard TTE views. A recently published study by cardiologists (4) also mentioned the role of TTE as a monitoring tool not only to evaluate the degree of PVLs but also to monitor procedural complications.

Perioperative TTE has emerged as an important tool for anaesthesiologists (5, 6). Echocardiography is being used in many different perioperative patient care areas, including thoracic and orthopaedics (7). It serves as a visual monitoring tool for anaesthesiologists in both elective and urgent situations (7, 8). TTE has been described as the 21st century stethoscope (9); however, the feasibility and usefulness of TTE before and after a TF-TAVI by anaesthesiologists providing care for TAVI patients have not been studied previously or reported in the literature. In our study, we found that TTE can be used during the TF-TAVI procedure by anaesthesiologists to rule out PVLs of haemodynamic significance. TTE served as an additional monitoring tool.

At our institute, for a TF-TAVI procedure, the aortic valve sizing is currently performed based on CT images; therefore, the routine use of TEE for sizing and monitoring has decreased. In addition, MAC sedation became more common, creating an imaging void for anaesthesiologists due to lack of routine use of TEE during TF-TAVI (1). Thus, TTE was implemented to fill this gap, and we hypothesised that it can serve as both a monitoring and diagnostic tool during TAVI. TTE helped in evaluating the implanted aortic valve, and ruling out major PVLs and other causes of severe haemodynamic disturbance. Although arrhythmias are the most common cause of hypotension during TF-TAVI, TTE was immediately available for diagnosing any evolving intrathoracic pathology that can cause hypotension. We were able to inspect and evaluate for pericardial effusions, ventricular dysfunction and aggravated mitral regurgitation. This is particularly true in patients with a pre-existing low ejection fraction and/or pulmonary hypertension. In addition, TTE is also used in evaluating and optimizing right ventricular (RV) function before the induction of anaesthesia in patients with pre-existing RV dysfunction and/or pulmonary hypertension.

The American Society of Echocardiography provides guidelines for focused cardiac ultrasound (10). Focused TTE examinations mainly include a 2D modality, and limited TTE examinations may include additional pulse-wave/CFD and M-mode. We have developed our own institutional- and procedure-specific guidelines for limited TTE examinations. A pre-determined format was followed before and after TAVI. In our experience, SC4C and parasternal views were most useful and swiftly reproducible. Subcostal views using 2D and CFD modes provided us with views that allowed us to assess the RV and left ventricular (LV) size and function, position of the interventricular septum, mitral and/or tricuspid valve regurgitation and pericardial space. A PLAX displayed the position of the interventricular septum, stenotic aortic valve before procedure, prosthetic aortic valve position and PVLs. A PSAX view provided information about the LV and RV functions including PVLs.

A slight left lateral position is usually recommended for a good apical view, which was not appropriate during TAVI. Furthermore, we found that apical views were challenging in supine patients and in patients with chronic obstructive pulmonary disease, as described in other studies. Because of prior TEE experience, the interpretation of TTE images was easier for cardiac anaesthesiologists. When compared with TEE, one major disadvantage of TTE is that it is an intermittent monitor. The position of the patient during the TAVI procedure was a minor limiting factor. Subcostal images in obese patients may be challenging. In addition, reaching the subcostal area with the fluoroscopy equipment can be difficult.

TF-TAVI has emerged as a promising, minimally invasive alternative for high-risk patients with severe aortic stenosis (10, 11). We are a high-volume centre for TAVI procedures, and our interventional cardiologists rely on the anaesthesiologists for echocardiography during TAVI and other structural heart procedures.

The use of perioperative TTE by anaesthesiologists is rapidly increasing, both in the United States and other countries (6, 12). Ultrasound is an established technology for other purposes, such as central line placement, regional anaesthesia and TEE for cardiac procedures (6, 13, 14). A recent study on TTE performed for thoracic surgeries (15) demonstrated adequate image quality 98.1% of the time. Focused intraoperative TTE has also shown to influence clinical decision-making in multiple studies (15-17). With the implementation of TTE by cardiac anaesthesiologists, we may be opening a new discussion for TTE and certification for TEE-trained cardiac anaesthesiologists.

PVLs are one of the most commonly reported complications after a TAVI procedure (18, 19). However, with more experience, optimal annular sizing methods and evolution of the new generation of TAVI valves, the incidence of a major PVL has been declining (20, 21). Considering these factors, we used TTE to evaluate PVLs of haemodynamic significance. Fortunately, we did not find any significant PVLs. We observed mild PVLs in 25% of the patients. None of the patients in this study required interventions such as snaring, balloon dilatation and valve-in-valve implantation. Mild PVL was not associated with increased mortality (20). A five-point unifying approach and quantification scale is usually recommended as a multimodal approach to evaluate the PVL accurately (22). However, we wanted a simplified approach in this preliminary study. Furthermore, cardiologists now evaluate the severity of the PVL mainly by using angiographic and haemodynamic (pulse pressure difference and diastolic blood pressure) methods.

Finally, our study was not intended to promote or generalise the use of TTE without formal proper training and board certification in TTE. This study may apply to cardiac anaesthesiologists who are board certified in TEE, involved in the care of TF-TAVI patients and have experience in TTE. Although basic TTE image acquisition and interpretation skills can be easily attained with certified courses and limited training, advanced imaging and training may need local mentors who are TTE certified.

This study has several limitations including a small sample size. In addition, we used only 2D, CFD modalities to assess the implanted TAVI valve and did not obtain prosthetic aortic valve gradients using continuous wave Doppler. TAVI valve gradients were obtained by measuring LV and aortic pressures after valve implantation by the cardiologist performing the procedure. Future studies can possibly include a comprehensive TTE examination including all Doppler modalities.

Conclusion

In this study, we concluded that TTE can be used to detect major prosthetic PVLs of haemodynamic significance during TF-TAVI. All five standard TTE views can be successfully obtained during the procedure. Further, TTE can be used by anaesthesiologists to supplement TEE as a visual monitoring tool during the TF-TAVI procedure.

Ethics Committee Approval: Ethics committee approval was received for this study from the ethics committee of Albany Medical Center.

Informed Consent: Written informed consent was obtained from patients who participated in this study.

Peer-review: Externally peer-reviewed.

Author Contributions: Concept – S.R.M.; Design – S.R.M., M.F.; Supervision – S.R.M., D.C., N.B., M.F., A.D., C.S.; Materials – K.S., Data Collection and/or Processing – S.R.M., K.S.; Analysis and/or Interpretation – S.R.M., D.C.; Literature Search – S.R.M., K.S.,, İ.S.K., Y.B.Ü.; Writing Manuscript – S.R.M., D.C.; Critical Review – C.D.C., N.B., S.R.M., D.C.; Other – C.D.C.

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References

1. Pani S, Cagino J, Feustel P, Musuku S, Raja A, Bruno N, et al. Patient selection and outcomes of transfemoral transcatheter aortic valve replacement performed with monitored anesthesia care versus general anesthesia. J Cardiothorac Vasc Anesth 2017; 31: 2049-54. [CrossRef]
2. Cote G, Denault A. Transesophageal echocardiography- related complications Can J Anesth 2008; 255: 622-47. [CrossRef]
3. Piercy M, Mc Nicol L, Dinh DT, Story DA, Smith JA. Major complications related to the use of transesophageal echocardiography in cardiac surgery. J Cardiovasc Thorac Anesth 2009; 23: 62-5. [CrossRef]
4. Stella F, Melillo C, Capogrosso A, Fisicaro F, Ancona A, Latib M, et al. Intra-procedural monitoring protocol using routine transthoracic echocardiography with backup trans-esophageal probe in transcatheter aortic valve replacement: a single center experience. Eur Heart J Cardiovasc Imaging 2020; 21: 85-92. [CrossRef]
5. Haskins SC, Vaz MV, Garvin S. Perioperative point-of-care-ultrasound for anesthesiologist. J Anesth Perioper Med 2018; 5: 92-6. [CrossRef]
6. Botker MT, Vang ML, Grofte T, Sloth E, Frederiksen CA. Routine preoperative ultrasonography by anesthesiologists in urgent surgical procedures. Acta Anaesthesiol Scand 2014; 58: 807-14. [CrossRef]
7. Canty DJ, Royse CF, Kilpatrick D, Bowyer A, Royse AG. The impact on cardiac diagnosis and mortality of focused transthoracic echocardiography in hip fracture patients with increased risk of cardiac disease: a retrospective cohort study. Anaesthesia 2012; 67: 1202-9. [CrossRef]
8. Marchi L, Meineri M. POCUS in perioperative medicine. A North America perspective. Crit Ultrasound J 2017; 9: 19. [CrossRef]
9. Skubas N. Teaching whole body ultrasound. Anesthesiology 2015; 123: 499-500. [CrossRef]
10. Spencer KT, Kimura BJ, Korcarz CE, Pellikka PA, Rahko PS, Siegel RJ. Focussed cardiac ultrasound: Recommendations from the American Society of Echocardiography. J Am Soc Echocardiogr 2013; 26: 567-81. [CrossRef]
11. Onishi T, Sengoku K, Ichibori Y, Mizote K, Kuratani T, Sawa Y, et al. The role of echocardiography in transcatheter aortic valve implantation. Cardiovasc Diagn Ther 2018; 8: 3-17. [CrossRef]
12. Mok D, Schwartz SKW, Rondi K. Point-of-care ultrasonography in Canadian anesthesiology residency programs: a national survey of program directors. Can J Anaesth 2017; 64: 1023-36. [CrossRef]
13. Haskins, S, Tanaka C, Boublik J, Wu C, Sloth E. Focused cardiac ultrasound for the regional anesthesiologist and pain specialist. Reg Anesth and Pain Med 2017; 42: 632-44. [CrossRef]
14. Meineri M, Bryson G, Arellano R, Skubas N. Core point-of-care ultrasound curriculum: What does every anesthesiologist need to know? Can j Anesth 2018; 65: 417-26. [CrossRef]
15. Kratz T, Holz S, Steinfeldt T, Exner M, dell-Orto M, Kratz C, et al. Feasibility and impact of focused pre and post intervention transthoracic echocardiography on management in thoracic surgery patients: an observational study. J Cardiothorac Vasc Anesth 2018; 32: 848-52. [CrossRef]
16. Kolev N, Brase R, Swanevelder J, Oppizzi M, Riesgo MJ, Van der Maaten JM, et al. The influence of transoesophageal echocardiography on intra-operative decision making. A European multi- center study. European Perioperative TOE Research Group. Anaesthesia 1998; 53: 767-73. [CrossRef]
17. Kratz T, Campo Dell'Orto M, Exner M, Timmesfeld N, Zoremba M, Wulf H, et al. Focused intraoperative transthoracic echocardiography by anesthesiologists. a feasibility study. Minerv Anesthesiol 2015; 81: 490-6.
18. Généreux P, Head SJ, Hahn R, Denault B, Kodali S, Williams MR, et al. Paravalvular leak after transcatheter Aortic valve replacement the new Achilles' heel? A Comprehensive Review of the Literature. J Am Coll Cardiol 2013; 61: 1125-36. [CrossRef]
19. Athappan G, Patvardhan E, Tuzcu EM, Svensson LG, Lemos PA, Fraccaro C, et al. Incidence, predictors, and outcomes of aortic regurgitation after transcatheter aortic valve replacement, meta-analysis and systematic review of literature. J Am Coll Cardiol 2013; 61: 1585-95. [CrossRef]
20. Sorin VP, Vuyisile TN, Gurpreeet SS. Assessment of prosthetic valve function after TAVR. J Am Coll Cardiol Img 2016; 9: 193-206. [CrossRef]
21. Finkelstein A, Rozenbaum Z, Zhitomirsky S, Halkin A, Banai S, Bazan S, et al. Safety outcomes of new versus old generation transcatheter aortic valves. Catheter Cardiovasc Interv 2019; 94: 44-53. [CrossRef]
22. Piborat P, Hahn RT, Weissman NJ, Minaghan MJ. Assessment of paravalvular regurgitation following TAVR. a proposal of unifying grading scheme. J Am Coll Cardiol Img 2015; 8: 340-60. [CrossRef]

Supplementary Table 1. Other Indications for TTE

Views	Indications
PSAX, SC-IVC	Assess volume status
PSAX, SC4C	Moderate-to-severe hypotension (>15–20% decrease in mean blood pressure)
PSAX, SC4C	Hypotension post-protamine; to assess the RV and LV size and function
PSAX	Hypotension with associated ST-T wave changes, suspected coronary artery obstruction post-TAVI
PSAX, SC4C	Assess RV function in moderate-to-severe pulmonary hypertension

IVC: inferior vena cava; LV: left ventricle; PSAX: parasternal short-axis; RV: right ventricle; SC4C: subcostal four-chamber; SC-IVC: subcostal inferior vena cava; and TAVI: transcatheter aortic valve implantation