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Echocardiographic Imaging of Procedural Complications During Balloon-Expandable Transcatheter Aortic Valve Replacement

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ABSTRACT

Transcatheter aortic valve replacement (TAVR) using a balloon-expandable valve is an accepted alternative to surgical replacement for severe, symptomatic aortic stenosis in high risk or inoperable patients. Intraprocedural transesophageal echocardiography (TEE) offers real-time imaging guidance throughout the procedure and allows for rapid and accurate assessment of complications and procedural results. The value of intraprocedural TEE for TAVR will likely increase in the future as this procedure is performed in lower surgical risk patients, who also have lower risk for general anesthesia, but a greater expectation of optimal results with lower morbidity and mortality. This imaging compendium from the PARTNER (Placement of Aortic Transcatheter Valves) trials is intended to be a comprehensive compilation of intraprocedural complications imaged by intraprocedural TEE and diagnostic tools to anticipate and/or prevent their occurrence.
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Transcatheter aortic valve replacement (TAVR) using a balloon-expandable valve is an accepted alternative to surgical replacement for severe, symptomatic aortic stenosis in high-risk or inoperable patients (1,2). Although echocardiography is important in the pre-procedural evaluation of patients undergoing TAVR (particularly to characterize and quantitate the severity of aortic stenosis [3,4] and assist in valve sizing [5,6]), other imaging modalities (e.g., computed tomography) are also useful for assessing the aortic valvular complex before transcatheter heart valve (THV) implantation (7–18). However, intraprocedural transesophageal echocardiography (TEE) offers the significant advantage of accurate real-time imaging and is incomparable in its ability to anticipate procedural complications and verify procedural results (19–21). Moreover, intraoperative TEE provides rapid and accurate information for detection of potentially lethal complications. Prompt diagnosis and subsequent treatment improve outcomes (21). Although some centers choose not to use this imaging tool during TAVR (22), other sites have advocated using TEE as the primary imaging tool (23), reporting a significant reduction in contrast media use with no reduction in safety.

The value of intraprocedural TEE is unlikely to diminish in the future. Current guidelines continue to advocate the use of TEE as a critically important component of the intraprocedural and immediate post-procedural success of TAVR (19,24,25). Recent studies suggesting that intraprocedural TEE may not be necessary for TAVR (22,26–29) fail to appreciate that the safety bar will be even higher in moderate

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risk patients who are subjected to TAVR. Sites using the "minimalist approach" are highly experienced, and recommending this approach to implant operators with lower procedural volumes may be ill advised. In fact, in a study of an intermediate risk population using the minimalist approach (26) the 30 day mortality rate is in fact higher than that reported in a higher risk patient population of the PARTNER (Placement of Aortic Transcatheter Valves) trial (30).

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Because TAVR is a relatively new procedure, it is important for both experienced and novice operators to be aware of the echocardiographic appearance of major complications and for the interventionalists to react to those findings. There have been multiple reports of complications of the procedure, including access issues (31-33), aortic root trauma (34-36), malpositioning of the THV (37-39), coronary obstruction (40,41), paravalvular regurgitation (PAR) (42-49), ventricular septal or mitral leaflet perforation (35), and cardiogenic shock (50,51). This imaging compendium from the PARTNER trials is intended to be a comprehensive compilation of intraprocedural complications imaged by using intraprocedural TEE and diagnostic tools to anticipate and/or prevent their occurrence. The compendium uses both standard and structure-specific imaging planes outlined in the recent American Society of Echocardiography (ASE) guidelines (25) as well as the guidelines for 3-dimensional (3D) echocardiographic imaging acquisition and display (52). Imaging planes and transducer angles are well described in the guidelines and will not be included in this paper.

The intended audience for this report includes experienced and beginning "procedural" echocardiographers, as well as interventionalists and surgeons performing TAVR. It is intended to serve both as a teaching guide providing "tips and tricks" to assist in daily practice and as a reference work containing unusual or exceptional findings. Because the PARTNER trials represent the initial experience with TAVR in the United States, many of the findings indicate steps on the learning curve for the field as well as for each of the participating research sites, almost none of whom had experience with this procedure. Documenting these early missteps is highly informative even though some of these findings may rarely occur for current, more experienced teams.

A total of 527 patients in the PARTNER 1 trial underwent TAVR with the first generation balloon-expandable THV (Edwards SAPIEN, Edwards Lifesciences, Irvine, California). The list of complications in **Table 1** was compiled by reviewing the adverse event log from the PARTNER I trial and the core laboratory records for complications noted on transthoracic echocardiographic follow-up. Complications that could be imaged by intraprocedural echocardiography were determined and sites polled for the availability of the original TEE images. Images were collected and reviewed. Of note, all the complications on the list had associated images, which are presented here. Important imaging considerations are summarized in **Table 2**.

ABBREVIATIONS AND ACRONYMS

AV = aortic valve

CMR = cardiac magnetic resonance

LCA = left coronary artery

LV = left ventricular

PAR = paravalvular aortic regurgitation

TAVR = transcatheter aortic valve replacement

TEE = transesophageal echocardiography

THV = transcatheter heart valve

COMPLICATIONS

STIFF WIRE LOCATION. Complications can occur during extra-stiff wire positioning. The most common complication is entanglement in the mitral apparatus. This is frequently recognized by paying strict attention to any change in mitral valve morphology or severity of regurgitation (**Figure 1A**, Online Video 1). 3D imaging may help confirm the site of entanglement (**Figure 1B**). When recognized, repositioning the wire may avoid other complications, such as rupture of mitral chordal attachments with subsequent flail leaflet (**Figures 1C and 1D**). The wire may also perforate the septum during transapical procedures, causing a ventricular septal defect.

Balloon aortic valvuloplasty complications. For the balloon-expandable valve, most operators use a balloon aortic valvuloplasty (BAV) to increase valve opening and improve precise positioning of the THV. Some investigators use the stability of the balloon catheter during BAV as a possible predictor of operator-independent motion of the THV and subsequent malpositioning. BAV is also used as adjunctive imaging for THV sizing (53-55) and to predict the final position of the native cusps after TAVR. Although complications with BAV are rare, they vary in appearance and many can be imaged during the procedure (e.g., severe aortic regurgitation, pericardial effusion) by using intraprocedural TEE (56).

Immediately after BAV, it is important to assure the interventionalists that the valve remains intact and that the aortic regurgitation is not significantly increased. In the first case (**Figures 2A and 2B**, Online Video 2), the etiology of the regurgitation is an avulsed aortic valve (AV). In the second case (**Figures 2C and 2D**, Online Video 3), the etiology is a displaced and fixed left coronary cusp. The latter complication may resolve spontaneously if the cusps