JACC: BASIC TO TRANSLATIONAL SCIENCE VOL. 9, NO. 12, 2024

Letters

RESEARCH LETTER: SHARK TANK

TriClover

Novel Transcatheter Technique to Repair the Tricuspid Valve With High Effectiveness and Wide Indications

Transcatheter repair of the tricuspid valve (TV) has entered clinical practice to address a large need that surgery alone could not satisfy for most patients with tricuspid regurgitation (TR).

The first-generation transcatheter edge-to-edge repair (TEER) technologies have paved the way: introduced a few years ago, derived from those developed and applied on the mitral valve (TriClip [Abbott] and Pascal [Edwards Lifesciences]), they are today the most effective transcatheter tricuspid valve repair (TTVr) devices in clinical use, and their adoption is wide spreading.

However, clip-based TEER are not as successful on TV as they are on mitral valves. Their therapeutic efficacy remains moderate when compared with the results obtained by open-surgery techniques developed specifically for the TV, such as the clover technique, and also to those obtained in the mitral valve, which are much closer to the outcomes of open surgery. Besides, first-generation TEER are not indicated for a vast population of patients, that is, those with large coaptation gaps, unfavorable jet locations, and highly irregular leaflets.

In addition to TTVr, transcatheter tricuspid valve replacement technologies (TTVR) have been recently introduced to clinical use. TTVR have been demonstrated to be effective in reducing TR in a selected population, but also have shown limitations in safety (eg, mortality, afterload mismatch, pacemaker) and indication (eg, large and dilated annuli, right atrial/right ventricular dimensions), implying high rates of patient screening failure and significant risk of adverse events.

TriClover (StarTric) is a novel, next-generation, triple edge-to-edge transcatheter repair technology with the potential to address the limitations of the transcatheter technologies of first-generation devices. It is conceived to restore coaptation in TR patients by systematically producing a clover configuration equivalent to that obtained through open surgery: devised specifically for the TV, the clover edge-to-edge open-surgery repair procedure has been used in complex types of TR, providing excellent and durable results.[1]

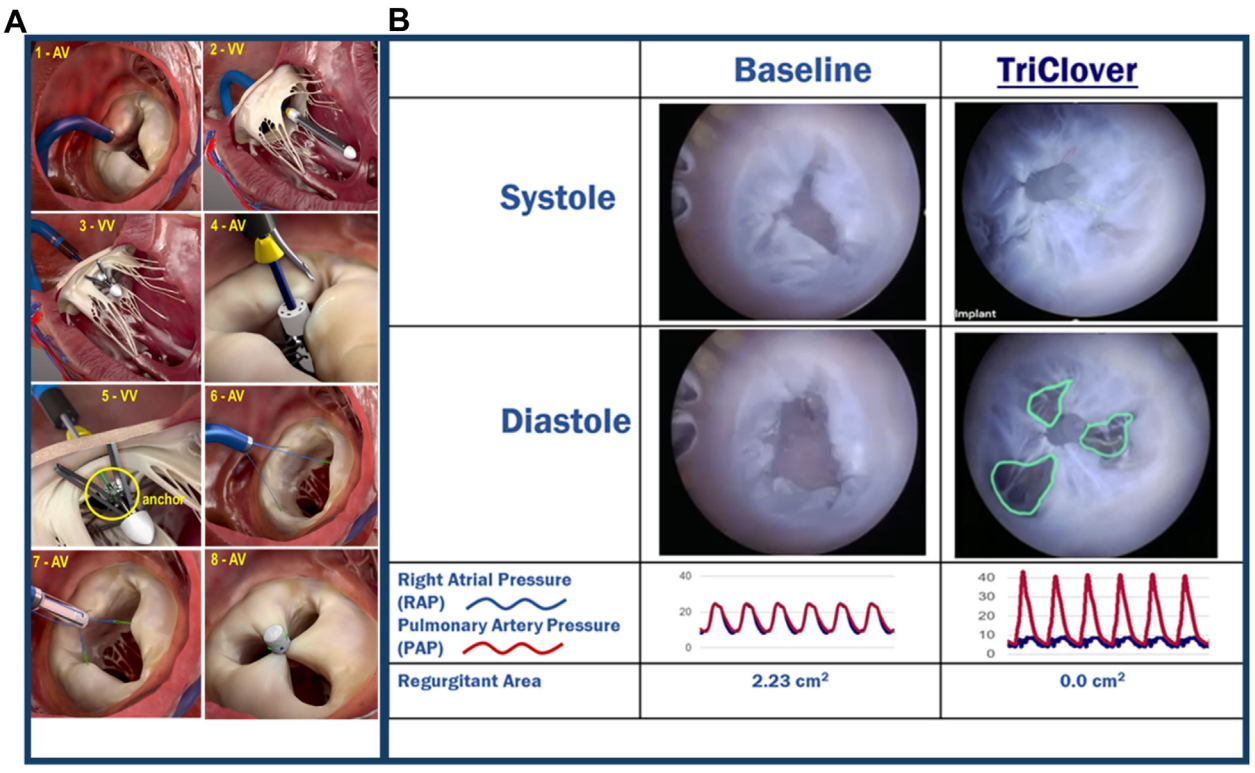
Unlike clip-based TEER devices, TriClover can adapt to most valve configurations, jet locations, and large coaptation gaps by simple adjustments during the implantation procedure, and was conceived to be easy to execute, standardized, and with predictable outcomes.

The procedure steps are as follows (**Figure 1A**): 1) access through femoral vein of a steerable catheter up to the right atrium; 2) introduction of a self-expanding leaflet stabilizer in the right ventricle (designed not to get entangled in the chordae); 3) stabilization of leaflets on the annular plane without interrupting blood flow; 4) puncturing of leaflets from the atrial side with 3 hollow needles that can be independently advanced, bent, and finely positioned by means of a sliding deflector so as to cross the leaflet in the optimal position independent of valve configuration and annular dilation; 5) release on the ventricular side of 3 self-expanding and tethered anchors; 6) removal of the stabilizer; 7) introduction into the atrium of a central locker along anchor tethering lines; and 8) pulling anchors against the locker so that the leaflets remain firmly grasped between the locker and anchors, releasing the double-loop tethers, removing the catheter, and eventually obtaining a clover configuration by means of a tiny edge-to-edge implant.

TriClover requires a single implant per procedure (rather than 2 or more clips), and the result is highly predictable and reproducible. TriClover's differentiating features are the ability to stabilize the leaflets for precise grasping without interrupting blood flow and to choose with accuracy the points where the leaflets are grasped and joined, so as to adapt the repair to each patient's valve configuration, including

ISSN 2452-302X https://doi.org/10.1016/j.jacbts.2024.10.003

FIGURE 1 TriClover Step-by-Step Implantation Procedure



TriClover step-by-step implantation procedure in atrial (AV) and ventricular (VV) views (A), and ex vivo repair result on a beating heart in a severely pathological swine model (B).

those that would not be treatable with first-generation transcatheter devices.

TriClover is conceived to prevent leaflet tearing, increase the forced coaptation surface, and potentially decrease the annular size to compensate for the lack of annuloplasty associated with TEER, an approach indirectly validated by the triple edge-to-edge surgical endoscopic technique recently introduced by Pitsis et al.[2]

The TriClover design has been prototyped and tested in several settings: mechanical bench test and ex vivo (porcine) pulsatile circuit for tissue resistance, safety, and clover-like functionality[3]; ex vivo (porcine) advanced pulsatile circuit for efficacy, robustness (margin of procedural error), procedure easiness, and repeatability; and in vivo porcine and ovine models, acute, subchronic, and chronic tests for functionality, implant stability, safety, and imaging properties.

The results of the ex vivo campaigns, performed on beating hearts, articulated in 45 sessions with more than 80 hearts tested, suggest that the TriClover technique can be applicable and effective in very different TV configurations, systematically produces a stable and effective result in extremely pathological TR cases, and is robust with respect to suboptimal implantation parameters. In the ex vivo pathological swine models, the TriClover implant has consistently restored leaflet coaptation along with overall valve functionality (**Figure 1B**).

The latest preclinical in vivo chronic results on ovine model (the most challenging from the anatomical and tissue resistance point of view) show that the tiny, edge-to-edge TriClover implant remains centered and stable in the annular plane, producing an effective clover configuration, with the animal showing at follow-up normal cardiac function, and no sign of stenosis. NB: Testing conforms with AAALAC

JACC: BASIC TO TRANSLATIONAL SCIENCE VOL. 9, NO. 12, 2024
DECEMBER 2024:1382–1384

International standards, European Convention for Protection of Vertebrate Animals Used for Experimental/Scientific Purposes, Council of Europe ETS 123.

On these bases, the TriClover investigational device is now being developed, with clinical trials to start in the near future.

*Michele De Bonis, MD[a]
Maurizio Taramasso, MD, PhD[b]
Marco Gard, MA[c]
Ottavio R. Alfieri, MD[a]

*Vita-Salute San Raffaele University
IRCCS San Raffaele Hospital
Via Olgettina 60
20132 Milan, Italy
E-mail: debonis.michele@hsr.it

From the [a]Vita-Salute San Raffaele University, IRCCS San Raffaele Hospital, Milan, Italy; [b]Herz- und Thorakale Gefässchirurgie FMH, Zürich, Switzerland; and [c]Gard Consulting, Borgomasino, Italy.

This work was presented at the 2024 TCT Shark Tank Session, October 27-30, Washington, DC, USA. To view the authors' full presentation at TCT Shark Tank, please visit https://www.jacc.org/journal/basic-translational/tct-2024-shark-tank.

Funding for this work was provided by the Italian Government, Ministero delle Imprese e del Made in Italy, Rome. Prof De Bonis is cofounder, shareholder, chief medical officer, and scientific advisory board director for StarTric srl, owner and developer of the TriClover technology. Prof Taramasso is a scientific advisory board member for StarTric srl. Mr Gard is chief technical officer and shareholder for StarTric srl. Prof Alfieri is cofounder, shareholder, and scientific advisory board president for StarTric srl.

The authors attest they are in compliance with human studies committees and animal welfare regulations of the authors' institutions and Food and Drug Administration guidelines, including patient consent where appropriate. For more information, visit the Author Center.

REFERENCES

1. De Bonis M, Lapenna E, Di Sanzo S, et al. Long-term results (up to 14 years) of the clover technique for the treatment of complex tricuspid valve regurgitation. *Eur J Cardiothorac Surg*. 2017;52(1):125-130.

2. Pitsis A, Marvaki A, Lolakos K, Andreas M. Totally endoscopic redo tricuspid repair with a modified clover triple edge-to-edge technique. *Innovations (Phila)*. 2024;19(3):242-243.

3. Salurso E, Perico F, Pappalardo F, et al. A novel transcatheter device for the edge-to-edge treatment of tricuspid regurgitation: a preliminary evaluation. *Ann Biomed Eng*. 2024;52(3):556-564.