Use of Electrosurgery in Interventional Cardiology

Jaffar M. Khan, BM BCh, PhD\textsuperscript{a}, Toby Rogers, BM BCh, PhD\textsuperscript{a,b}, Adam B. Greenbaum, MD\textsuperscript{c}, Vasilis C. Babaliaros, MD\textsuperscript{c}, Christopher G. Bruce, MB ChB\textsuperscript{a}, Robert J. Lederman, MD\textsuperscript{a,*}

\textsuperscript{a}Cardiovascular Branch, Division of Intramural Research, National Heart Lung and Blood Institute, National Institutes of Health, Building 10, Room 2c713, MSC 1538, Bethesda, MD 20892-1538, USA

\textsuperscript{b}Medstar Washington Hospital Center, 110 Irving Street, Northwest, Washington, DC 20010, USA

\textsuperscript{c}Structural Heart and Valve Center, Emory University Hospital, 550 Peachtree Street Northeast, Medical Office Tower, Fl 6, Atlanta, GA 30308, USA

Keywords
Basilica; Lampoon; TAVR; TMVR

BACKGROUND

Transcatheter electrosurgery is a versatile tool that can be used to cut cardiac tissue without the need for a sternotomy, cardiopulmonary bypass, and cardioplegia. In fact, a controlled laceration can be performed using off-the-shelf equipment through 2 vascular sheaths and under local anesthesia. With adequate imaging and suitable anatomy, any cardiac tissue can be cut. Thus, transcatheter electrosurgery can provide bespoke therapies for complex patients who often have no other good treatment options.

In this review, we will discuss the common applications for electrosurgical tissue traversal and laceration, summarizing the evidence and the key technical steps for each.

PRINCIPLES OF TRANSCATHETER ELECTROSURGERY

Alternating current at radiofrequencies is transmitted through a guidewire to the target tissue, whereby it concentrates and generates heat. The water inside cells boils when it

\textsuperscript{*}Corresponding author. Cardiovascular Branch, Division of Intramural Research, National Heart Lung and Blood Institute, National Institutes of Health, Building 10, Room 2c713, MSC 1538, Bethesda, MD 20892-1538. lederman@nih.gov, Twitter: @TheBethesdaLabs (R.J.L.)

DISCLOSURE

(J.M.Khan), (T.Rogers), and (R.J.Lederman) are co-inventors on patents, assigned to NIH, on catheter devices to lacerate valve leaflets.(A.B.Greenbaum) is a proctor for Edwards Lifesciences, Medtronic, and Abbott Vascular. He has equity in Transmural Systems. (V.C.Babaliaros) is a consultant for Edwards Lifesciences, Abbott Vascular and Transmural Systems, and his employer has research contracts for clinical investigation of transcatheter aortic and mitral devices from Edwards Lifesciences, Abbott Vascular, Medtronic, St Jude Medical, and Boston Scientific. (T.Rogers) is a consultant/proctor for Edwards Lifesciences and Medtronic. He has equity in Transmural Systems. (R.J.Lederman) is the principal investigator on a Cooperative Research and Development Agreement between NIH and Edwards Lifesciences on transcatheter modification of the mitral valve. No other author has a financial conflict of interest related to this research.
reaches 100 °C and the cells vaporize. This, in essence, is tissue “cutting.” The effects on tissue of different heating thresholds are shown in Table 1.

From a practical standpoint, effective insulation is necessary to ensure sufficient charge concentration at the target tissue to effect cutting, and prevent unwanted dispersal in adjacent tissues including blood, which may coagulate and cause guidewire charring. Insulation is achieved by careful positioning of insulating microcatheters and guiding catheters, selectively denuding the guidewire polytetrafluoroethylene (PTFE) coating at the electrical contact points, and dispersing blood with nonionic 5% dextrose solution.

EQUIPMENT

Dedicated equipment for “traversal-only” transcatheter electrosurgery applications that are currently marketed include the VersaCross wire and the NRG needle for transseptal access, and the PowerWire RF guidewire and Nykanen RF wire for peripheral intervention (Baylis Medical, Austin, TX).

Coronary guidewires may be used off-label, with minor benchtop modifications, for both electrosurgical tissue traversal as well as laceration. Guidewires that perform best have a high tip load, a core-to-tip design, and a wire tip without a polymer jacket. We typically use the Astato XS 20 300cm guidewire (Asahi Intecc, Japan) for most of our transcatheter electrosurgery procedures. The distal PTFE coating is stripped with a scalpel at the point whereby the guidewire is connected to an electrosurgery pencil and generator with hemostatic forceps.

For traversal, the entire length of the guidewire inside the body is insulated in a microcatheter, typically a locking Piggyback Wire Converter (Teleflex, NC), with only the guidewire tip exposed. Once the tip is in contact with the target tissue, the guidewire is advanced through the microcatheter and perforates through the tissue during brief electrification at 30 to 50W continuous duty cycle “pure cut” mode.

For laceration, the microcatheter is withdrawn to the proximal half of the guidewire. The midshaft of the guidewire, adjacent to the Piggyback tip, is selectively denuded along 4mm of the guidewire length and across a 90° arc with the blade of a scalpel. The blunt end of the scalpel acts as a pivot to kink the denuded segment in the middle. The result is selective inner curvature denudation that will direct the current onto the target tissue and is called the flying V. The flying V is positioned across the target tissue between 2 guiding catheters which direct the laceration. 5% dextrose is infused during laceration to displace blood during current application. This serves 2 purposes. First, it displaces blood, preventing coagulation and thromboembolism, and char formation on the guidewire. Second, it is nonionic and so acts as an extra-insulator, concentrating charge dispersal at the target tissue.

ELECTROSURGERY TO RECANALIZE OCCLUSIVE LESIONS

The first reported use of transcatheter electrosurgery was to restore right ventricular to pulmonary artery flow in patients with atretic pulmonary valves. The atretic tissue is traversed with a guidewire during brief application of radiofrequency energy.
The technique has been used to recanalize central and peripheral vascular occlusions. Particularly pertinent to the interventional cardiologist, transcatheter electrosurgery has also been reported to recanalize an ostial right coronary artery chronic total occlusion when re-entry was not feasible using tapered stiff guidewires. In this report, a Confiance guidewire (Asahi), insulated in a Piggyback microcatheter, was briefly electrified to achieve successful luminal re-entry.

TRANSSEPTAL PUNCTURE

Perhaps the commonest application of electrosurgery in interventional cardiology is for transseptal puncture for left atrial access. By vaporizing a target on the fossa ovalis, the interatrial septum can be traversed without mechanical force, which may cause sliding of the needle and imprecise puncture or atrial back wall injury from forced advancement of the needle.

Electrosurgery-assisted transseptal puncture may be performed by electrifying a transseptal needle, electrifying a coronary guidewire, or using dedicated devices.

Radiofrequency access was found to be superior to needle transseptal puncture in a randomized trial, with reduced procedure time, reduced procedure failure, and reduced plastic particulate matter with the radiofrequency system (NRG Transseptal needle, Baylis).

TRANSCAVAL ACCESS

Clinical need

Large bore arterial access may be required for transcatheter aortic valve replacement (TAVR), transcatheter endovascular aortic repair (TEVAR), or mechanical circulatory support. Large bore femoral arterial access is not feasible due to diseased iliofemoral arteries in 4.7% of all patients undergoing TAVR and up to 30% of patients undergoing TEVAR.

Transcaval access provides an ergonomic, completely percutaneous transfemoral venous access to the infrarenal aorta which can be performed under local anesthesia and moderate sedation.

Procedure technique

Preprocedure computed tomography (CT) scanning is required to assess suitability for transcaval access. This typically requires a calcium-free window for traversal in the right infrarenal aortic wall, facing the inferior vena cava (IVC), and a suitable landing zone for a covered stent if bailout is needed. Orthogonal projection angles for transcaval crossing are derived and cranio-caudal height of crossing is mapped onto the lumbar vertebrae for easy reference.

Femoral venous access is obtained to deliver an internal mammary-shaped guide catheter (Fig. 1). Femoral arterial access is obtained to deliver a JR4 guide catheter and Gooseneck snare into the infrarenal aorta. An Astato guidewire sheathed in Piggyback and NaviCross (Terumo, NJ) microcatheters is advanced through the venous guide to the preselected
crossing level and directed toward the snare. During brief electrification at 50W, the Astato guidewire is advanced through the IVC and aortic walls into the snare. The guidewire is snared and advanced up toward the aortic arch. With snare countertraction on the guidewire, the Piggyback and NaviCross microcatheters are sequentially advanced into the aorta. The Piggyback and Astato guidewire are then exchanged for a stiff 0.035″ Lunderquist guidewire (Cook Medical, IN) through the NaviCross microcatheter. A large-bore vascular sheath is advanced over the Lunderquist guidewire securing central arterial access.

Access port closure is attempted after full reversal of heparin with protamine. A pigtail catheter in the aorta marks the transcaval crossing site. A 10/8 Amplatzer Duct Occluder (ADO, Abbott, IL) in an Agilis small curl deflectable sheath (Abbott) is advanced through the transcaval access sheath alongside a 0.014″ safety buddy wire. The transcaval sheath is briskly withdrawn all the way back into the IVC. The aortic disc of the ADO is exposed in the aorta. The system is withdrawn and the deflectable sheath is flexed to position the aortic disc flush against the aortic wall at the transcaval access site. While maintaining gentle tension on the ADO cable, the deflectable sheath is withdrawn and unflexed to expose the body of the ADO device. Aortography is performed to confirm adequate device position and the ADO is released. Final cineangiography is performed and closure assessed. In rare cases of retroperitoneal extravasation, balloon aortic tamponade should be performed, followed by covered stent deployment if needed.

In cases of emergency transcaval access for mechanical circulatory support, some modifications to this procedure may be required. In lieu of a preprocedure CT, 2 pigtail catheters, in the IVC and infrarenal aorta, are aligned in orthogonal projections to determine the optimal transcaval crossing fluoroscopic projection angles. A 24F >33cm sheath is inserted to accommodate a 5.0 Impella device (Abiomed, MA). On removal, the transcaval sheath is thoroughly aspirated for clot. The same sequence for closure is followed as above but a 12/10 ADO is used for closure due to access and increased sheath size.

**Clinical evidence**

In the prospective 100 patient NHLBI Transcaval TAVR trial, transcaval access was successful in 99% of subjects, inpatient survival was 96%, and the rate of life-threatening bleeding was 7%. The median hospital stay was 4 days in this early experience. There was no late bleeding associated with transcaval tracts at 1 year.

TEVAR has been successfully performed via transcaval access, which provides an attractive percutaneous alternative in patients with diseased iliofemoral arteries.

Transcaval access is feasible for emergency percutaneous implantation of a 7mm Impella 5.0 mechanical circulatory support device. In a single-center series, 10 patients with progressive or refractive cardiogenic shock underwent Impella 5.0 device implantation via transcaval access without preprocedural CT guidance. Six patients survived to access port closure and discharge.
BASILICA

Clinical need

TAVR causes coronary obstruction in about 1% of all cases, with a 40% to 50% mortality\textsuperscript{14}. It is commoner in patients with smaller anatomy and in the setting of bioprosthetic valve failure. The mechanism of obstruction is usually the displacement of the diseased aortic leaflet which may either lie flush against the coronary artery ostium (coronary ostial obstruction) or against the sinotubular junction (sinus sequestration).

Coronary obstruction can be predicted on preprocedure CT. The simplified algorithm we use is shown in Fig. 2.

Bioprosthetic or native Aortic Scallop Intentional Laceration to prevent Iatrogenic Coronary Artery obstruction (BASILICA) is a transcatheter electrosurgical technique to lacerate diseased aortic valve leaflets immediately before TAVR in patients at risk of coronary obstruction\textsuperscript{15}.

Procedure technique

Orthogonal fluoroscopic projection angles for the target leaflet are derived from preprocedure CT.\textsuperscript{16} General anesthesia and TEE guidance may help with catheter positioning, troubleshooting, and early recognition of complications, but is not mandatory.

A 14F sheath with balloon inflatable hemostatic hub (Gore DrySeal Flex, Gore Medical, DE) is inserted in the femoral artery used for TAVR. If performing solo BASILICA, a 6F sheath is placed in the contralateral femoral artery. For doppio BASILICA, the contralateral sheath is upsized to a second 14F sheath.

The first step is positioning of the snare (Fig. 3). The aortic valve is crossed using standard techniques from the contralateral arterial access. A multipurpose guiding catheter is positioned in the left ventricular outflow tract (LVOT) and stabilized with a 0.018\textquotedbl{} guidewire in the left ventricle. An appropriately sized Gooseneck snare (typically 20mm or 25mm) is positioned to circumscribe the LVOT.

The second step is positioning of the traversal system. We recommend the catheter escalation strategy outlined in Fig. 4 to obtain orthogonal traversal catheter position in the target leaflet.

The third step is to traverse the leaflet. The Astato guidewire and Piggyback microcatheter are introduced and the leaflet gently palpated with the guidewire. If the position is satisfactory, the Astato guidewire is pushed through the leaflet during brief application of current at 30 to 50W. The guidewire tip is snared in the LVOT. Care is taken not to snare below the anterior mitral valve leaflet as this risks entrapping chords that would result in chord laceration during BASILICA.

The fourth step is to create the flying V. With the guidewire tip snared, the Piggyback microcatheter is withdrawn to the proximal half of the guidewire. The mid-shaft of the guidewire adjacent to the Piggyback tip is denuded and kinked as previously described. The
flying V is then inserted into the body while retrieving the snared end of the guidewire and advanced till it straddles the target aortic leaflet. The microcatheter and guiding catheter positions are secured by tightening the hemostatic hubs and locking with the help of torque devices.

The fifth step is crossing the valve through the 14F sheath, adjacent to the BASILICA catheter, to position a pigtail catheter in the left ventricle.

The sixth step is leaflet laceration. Gentle tension is applied to both limbs of the catheter-guidewire system. When all the slack has been removed, 5% dextrose is infused through the catheters and current delivered at 70W for the 1 to 2 seconds required for complete laceration. The system is disassembled and withdrawn from the body. Hemodynamic compromise is rare at this stage because of the coaptation of the split leaflet during diastole.

The final step is TAVR over a stiff guidewire introduced through the prepositioned pigtail. The 14F sheath is either replaced with a balloon-expandable TAVR sheath or simply removed if using an in-line system.

**Clinical evidence**

The NHLBI-sponsored BASILICA IDE trial enrolled 30 subjects who required TAVR but were at high risk of coronary artery obstruction\textsuperscript{17}. BASILICA was successfully performed in 93%, demonstrating procedure feasibility. No patient had coronary obstruction despite a central core laboratory predicting high risk in all, demonstrating procedure efficacy. There was 1 disabling (3%) and 2 nondisabling (7%) strokes following BASILICA and TAVR. There were no late events related to BASILICA between 30 days and 1 year\textsuperscript{18}.

A 214 patient BASILICA Registry assessed procedure safety in a large number of patients, as well as feasibility in the real world\textsuperscript{19}. BASILICA was successful in 94.4% of patients. There was no culprit coronary artery obstruction in 95.3%. At 30 days, there was 2.8% death and 2.8% stroke (0.5% disabling stroke). One year survival was 83.9%. There were no differences in outcomes between native and bioprosthetic valves, solo or doppio BASILICA, or in patients whereby cerebral embolic protection was used, though this was not randomized. This registry demonstrated the safety of the BASILICA procedure.

Benchtop experiments suggest BASILICA may not be suitable for all cases of TAV-in-TAV\textsuperscript{20}. Balloon-assisted BASILICA may overcome some of these limitations\textsuperscript{21}.

BASILICA may also be used to improve TAVR implantation and expansion in bicuspid valves (Bi-SILICA).\textsuperscript{22} Though this is feasible, the evidence to support this approach is lacking.

**LAMPOON**

**Clinical need**

LVOT obstruction is a common and often fatal complication of transcatheter mitral valve replacement (TMVR). The mitral valve prosthesis pushes the anterior mitral valve leaflet toward septum, causing fixed/LVOT obstruction. Furthermore, the narrowed LVOT creates
Bernoulli forces that may cause systolic anterior motion (SAM) of the anterior mitral valve leaflet and dynamic LVOT obstruction. The problem is common both when implanting TAVR valves in the mitral position, and with dedicated TMVR devices, and is a leading cause of screen failure in the early trials for these devices. Preprocedure CT is key for predicting LVOT obstruction. Preprocedure CT is key for predicting LVOT obstruction. Preprocedure CT is key for predicting LVOT obstruction. 

Laceration of the Anterior Mitral leaflet to Prevent Outflow Obstruction (LAMPOON) is a transcatheter electrosurgical technique performed immediately before TMVR. The anterior leaflet is lacerated down the centerline, preserving chords, allowing the leaflet to splay away from the LVOT.

**Procedure technique**

The LAMPOON procedure has undergone a few iterations since conception, each with its advantages and uses in special situations. We will review each in turn.

**Retrograde LAMPOON**—Two 6-7F JL3.5P (posterior curve) catheters are advanced either side of the anterior mitral valve leaflet from two femoral arterial sheaths. A transseptal puncture is performed in a posterior inferior location on the fossa ovalis. A balloon-wedge end-hole catheter is floated through the major mitral valve orifice into the ascending aorta. A guidewire through this catheter is snared from the femoral artery, establishing a veno-arterial rail along a chord-free trajectory. A JL3.5P catheter is advanced over this rail into the left atrium and snare is placed. A second JL3.5P catheter is positioned at the center and base of the anterior mitral leaflet, guided by TEE. An Astato guidewire and Piggyback microcatheter are advanced to the anterior mitral leaflet through the traversal guide. The guidewire is briefly electrified at 50W and pushed through the leaflet from LVOT into the left atrium, whereby it is snared. The flying V is then formed and positioned to straddle the anterior mitral leaflet. The catheter and microcatheter positions are secured, tension is applied to both catheters and current is applied for 1–2s at 70W during a 5% dextrose infusion till the leaflet is lacerated.

The advantage of this technique is that it reproducibly creates a centerline laceration and enables prepositioning of the mitral valve prosthesis. The major drawback is difficulty positioning the traversal catheter.

**Antegrade LAMPOON**—Two 6F guide catheters are positioned on either side of the anterior mitral leaflet from 2 deflectable sheaths positioned across the same septostomy and femoral venous sheath.

Transseptal access is obtained and 2 deflectable sheaths (Agilis medium curl or similar) are positioned in the left atrium. A veno-arterial rail along a chord-free trajectory is established through one deflectable sheath as described above. A snare and JL3.5 guiding catheter is then advanced along this rail through the deflectable sheath to sit in the LVOT. A JR4 guiding catheter is advanced through the second deflectable sheath and positioned at the base of the A2 scallop of the anterior mitral leaflet. The Astato guidewire and Piggyback microcatheter are introduced and traversal proceeds from left atrium into LVOT during brief
electrification at 30 to 50W. The flying V is then formed, positioned, insulated, and secured as before. Care is taken to align the laceration trajectory down the centerline by positioning the deflectable sheaths at A2. The guiding catheters are then pulled into the deflectable sheaths during laceration.

The advantage of this technique is that it provides greater stability and control for leaflet traversal. The drawback is the potential for eccentric laceration.

**Tip to base and rescue LAMPOON**—In the setting of a bioprosthetic mitral valve or complete ring, the traversal step can be skipped and laceration proceeds from tip to base. Progression of laceration is prevented when there is a suitable “backstop.”

Transseptal access is obtained with a deflectable sheath and a veno-arterial rail is created (Fig. 5). A flying V is created on the guidewire used for the rail and positioned at the tip of the anterior mitral leaflet. Tension is applied on both arterial and transseptal guiding catheters and guidewire limbs during electrification at 70W and 5% dextrose infusion. Longer and multiple burns may be required for complete laceration.

The advantage of this technique is the simplicity of the procedure. It may also be used as a rescue after TMVR when there is SAM. The drawback is that it is limited to cases with a safe backstop.

**Clinical evidence**

The prospective NHLBI LAMPOON IDE trial investigated LAMPOON in the 30 subjects at high risk of LVOT obstruction from TMVR. LAMPOON was successful in 100% of subjects, in both the setting of valve-in-ring and valve-in-mitral annular calcification. LVOT obstruction was evident in only 3% on exit from the catheter laboratory despite the prohibitive risk in all. However, subjects with a small skirt neo-LVOT did require alcohol septal ablation in addition to LAMPOON, and this was later introduced as exclusion criteria to enrollment. There were no strokes and 30-day survival was 93% in this high-risk cohort.

A retrospective analysis of 21 patients who underwent tip to base LAMPOON (19 preventative, 2 rescue) demonstrated successful leaflet laceration and prevention of LVOT obstruction in all cases. There were 2 cases of aortic valve injury and both cases had a supra-annular mitral bioprosthetic ring with a small distance between the ring and the aortic valve. In summary, this technique was simple and effective, and safe in the appropriate anatomy.

**ELASTA-CLIP**

**Clinical need**

Transcatheter edge-to-edge repair (TEER) is increasingly used as a percutaneous treatment of both primary and functional mitral regurgitation. However, this therapy may prevent future TMVR. The ability to manage the TEER device using transcatheter electrosurgery is, therefore, very timely. Electrosurgical Laceration and Stabilization of Clip devices
(ELASTA-Clip) is a transcatheter electrosurgical technique to create a single orifice mitral valve and enable TMVR.

**Procedure technique**

Transseptal access is obtained and 2 deflectable sheaths (Agilis medium curl or similar) are positioned across a single septostomy (Fig. 6). The deflectable sheaths direct 2 guiding catheters through the lateral and medial mitral valve orifices, respectively. A guidewire is advanced through one catheter (internal mammary-shaped guide or similar) into a snare through the second catheter (a Multipurpose shaped guide or similar). A flying V is created at the mid-shaft of the guidewire and advanced to straddle the TEER devices. The flying V is adjusted so it rests on the anterior mitral leaflet attachment to the TEER devices. Tension is applied to both catheters and guidewire limbs during brief electrification at 70W and 5% dextrose infusion. The TEER devices are liberated from the anterior leaflet while still attached to the posterior leaflet.

The ELASTA-Clip system is disassembled and TMVR is performed according to device-specific guidelines. The TMVR device secures the clip between the cage of the valve and the posterior left ventricular wall.

**Clinical evidence**

A single-center series of 5 patients with mitral valve failure in the setting of previous MitraClip (Abbott) implantation underwent ELASTA-Clip and TMVR with the investigational Tendyne valve (Abbott) on a compassionate basis. All patients had successful clip detachment and TMVR, and all survived to 30 days.

**SUMMARY**

Transcatheter electrosurgery encompasses a diverse portfolio of procedures to enable therapies in patients with complex structural heart disease. The techniques described in this review explore some of the applications, including transseptal puncture for left heart procedures, transcaval for large-bore arterial access from the femoral vein, BASILICA to prevent coronary artery obstruction from TAVR, LAMPOON to prevent LVOT obstruction from TMVR, and ELASTA-Clip to enable TMVR after TEER.

**ACKNOWLEDGMENTS**

Supported by the National Heart Lung and Blood Institute, National Institutes of Health, USA (Z01-HL006040).

**REFERENCES**


## KEY POINTS

- Transcatheter Electrosurgery enables precise tissue traversal and laceration through charge concentration at the target tissue.
- BASILICA mitigates coronary artery obstruction from TAVR in native or bioprosthetic valves.
- LAMPOON mitigates LVOT obstruction from TMVR, particularly when using valves with an open-cell design.
- ELASTA-Clip enables TMVR after TEER by liberating the device from the anterior mitral leaflet.
CLINICS CARE POINTS

- Radiofrequency-assisted transseptal access is a simple and safe introduction to transcatheter electrosurgery
- Transcaval access enables large bore arterial access from the femoral vein and has been used for TAVR, TEVAR, and 5.0 Impella insertion
- BASILICA is feasible, safe, and effective at preventing coronary obstruction from TAVR
- LAMPOON prevents LVOT obstruction from TMVR and the appropriate iteration should be considered given the anatomy of each patient
- ELASTA-Clip is a timely novel technique that enables TMVR after TEER
Fig. 1. Transcaval access. (A) An electrified guidewire traverses from a guide in the IVC to a snare in the infra-renal aorta. (B) Sequential microcatheters are advanced into the aorta during snare countertraction. (C) The large sheath is introduced. (D) The aortotomy is closed with a nitinol mesh device.
Fig. 2.
Algorithm for predicting coronary obstruction.
Fig. 3.
BASILICA procedure steps (A) An electrified guidewire traverses from a guide in the aorta through the target aortic valve leaflet into a snare in the LVOT. (B and C) The flying V is electrified, lacerating the leaflet. (D) The leaflet splays after TAVR, maintaining coronary perfusion.
Fig. 4.
Catheter escalation strategy for BASILICA.
Fig. 5.
Tip to Base LAMPOON (A). A veno-arterial rail is created through a transseptal deflectable sheath. (B). The flying V is positioned at the tip of the anterior leaflet of the bioprosthetic mitral valve. (C). The leaflet is lacerated and the flying V is stopped from further progression by the valve sewing ring. (D). Successful mitral valve-in-valve TMVR.
Fig. 6.
ELASTA-Clip. (A). The flying V (black arrow) is positioned on the anterior edge of 2 MitraClip devices (white arrows). (B and C) The MitraClip devices are secure on the posterior ventricular wall and Tendyne TMVR valve is fully expanded.
Table 1

Tissue effects at rising temperatures

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Tissue Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>49° C</td>
<td>Tissue coagulates</td>
</tr>
<tr>
<td>60° C</td>
<td>Protein denatures</td>
</tr>
<tr>
<td>70° C</td>
<td>Cells desiccate</td>
</tr>
<tr>
<td>100° C</td>
<td>Cells rupture from the vaporization of intracellular water</td>
</tr>
</tbody>
</table>