Embolic capture with updated intra-aortic filter during coronary artery bypass grafting and transaortic transcatheter aortic valve implantation: First-in-human experience

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Objective: We report our first-in-human clinical experience in the use of the new version of the EMBOL-X intra-aortic filter (Edwards Lifesciences Corporation, Irvine, Calif) to capture embolic material during transaortic transcatheter aortic valve implantation and cardiac surgery.

Method: Five patients were enrolled into the first-in-human clinical assessment of the new version of the EMBOL-X intra-aortic filter. Three patients underwent coronary artery bypass grafting, and 2 patients underwent transaortic transcatheter aortic valve implantation. During coronary artery bypass grafting, the filter was deployed before clamping of the aorta and removal of the aortic clamp. In contrast, the filter was deployed before aortic puncture for transaortic transcatheter aortic valve implantation and kept in the aorta throughout the entire procedure.

Results: The filter introducer sheath and filter were easily placed and removed without difficulty. There were no complications related to the use of the filter. Postoperative examination of the retrieved filters revealed the presence of multiple microemboli in the filters from all 5 cases. Histologic study revealed various kinds of tissue and thrombus.

Conclusions: This first-in-human clinical experience has demonstrated the safety and feasibility of using the new version of the EMBOL-X intra-aortic filter during either cardiac surgery or transaortic transcatheter aortic valve implantation. We believe that the combination of the transaortic approach without aortic arch manipulation and the use of the EMBOL-X filter with a high capture rate is a promising strategy to reduce the incidence of embolic complications during transcatheter aortic valve implantation. (*J Thorac Cardiovasc Surg* 2014;148:2905-10)

Atherosclerotic disease of the aorta is common and associated with particulate emboli during aortic manipulation, clamping, and declamping.¹⁻⁴ Neurologic complications have been demonstrated to be directly linked to embolism during cardiac surgery.^{5,6} Transcatheter aortic valve implantation (TAVI) is a minimally invasive technology that has been accepted as an alternative treatment for symptomatic severe aortic stenosis in high-risk patients. Stroke, however, remains a concern and is associated with significant perioperative morbidity and mortality. Stroke has been reported in 2% to 11% of patients⁷⁻¹⁰ and is associated with a 3.5-fold increased mortality within the first 30 days.¹¹ In the randomized PARTNER trial, stroke and transient ischemic attack were more frequent after

TAVI than after conventional aortic valve replacement (AVR).¹² Magnetic resonance imaging has revealed new cerebral ischemic lesions after TAVI in as many as 84% of patients.¹³

Filter systems have been suggested to reduce the amount of solid cerebral embolic material. Clinical studies have demonstrated that the older version of the EMBOL-X intra-aortic filter (Edwards Lifesciences Corporation, Irvine, Calif) effectively captures embolic material¹⁴⁻¹⁷ and may decrease postoperative neurologic complications after on-pump coronary artery bypass grafting (CABG).¹⁸ The older version of the EMBOL-X intra-aortic filter is attached to a large aortic cannula, which is designed for use during cardiac surgery. The new version of the EMBOL-X intra-aortic filter (Edwards Lifesciences) has been modified to be suitable for standard cardiac surgery, ministernotomy cardiac surgery, and transaortic TAVI. We report our first-in-human clinical experience in using the new version of the EMBOL-X intra-aortic filter to capture embolic material during both transaortic TAVI and cardiac surgery.

MATERIALS AND METHODS

New Version of EMBOL-X Intra-Aortic Filter

The new version of the EMBOL-X intra-aortic filter is no longer attached to a 24F intra-aortic cannula and therefore requires a much smaller

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Abbreviations and Acronyms

AVR	= aortic valve replacement
CABG	= coronary artery bypass grafting
CPB	= cardiopulmonary bypass
TAVI	= transcatheter aortic valve implantation

introducer sheath (17F; [Figure 1](#)). The device includes an EMBOL-X intra-aortic filter and introducer sheath. The filter consists of a heparin-coated, 120- μ m polyester mesh, surrounded by a flexible nitinol frame designed to conform to the interior of the aorta. The available filter sizes range from 26 to 37 mm ([Figure 2](#)).

Techniques for Insertion of the Filter

[Figure 3](#) illustrates the cannulation site for an EMBOL-X introducer sheath in the ascending aorta in patients undergoing cardiac surgery with full sternotomy or transaortic TAVI with upper ministernotomy (manubrium only). During cardiac surgery, double purse-string sutures with non-pledgeted 3-0 or 4-0 polypropylene sutures were placed in the ascending aorta proximal to the cardiopulmonary bypass (CPB) aortic cannula site and distal to the cardioplegic cannula site. A sufficient distance between the filter introducer site and the cardioplegic cannula site is required for the placement of an aortic crossclamp. If a patient with a short ascending aorta is undergoing conventional AVR or CABG, the aortic cannulation site for CPB should be at the proximal aortic arch to accommodate the placement of an EMBOL-X introducer sheath, cardioplegic cannula, and proximal anastomoses of bypass grafts (CABG) or aortotomy (AVR) in the ascending aorta. In contrast, during transaortic TAVI the filter introducer sheath should be placed in the distal ascending aorta near the aortic arch but proximal to the origin of the brachiocephalic artery. Furthermore, the filter introducer sheath needs to be placed at the medial side of the ascending aorta, which leaves more space at the lateral side of the ascending aorta for the placement of an ASCENDRA delivery sheath for

TAVI. Pledgeted 4-0 or 3-0 polypropylene sutures would be preferable for double purse-string sutures for the filter introducer sheath.

The size of the distal ascending aorta was determined either by computed tomographic scan or intraoperative direct aortic measurement. The filter size was then selected on the basis of the measured aortic size ([Figure 2](#)). The filter was prepared and kept in water until it was ready to be loaded into the filter introducer sheath to minimize potential air bubbles in the filter. During the cardiac surgery, the filter was deployed just before clamping of the aorta and removal of the aortic clamp. In contrast, the filter was deployed immediately before aortic puncture for transcatheter valve procedures and was kept in the aorta throughout the entire procedure of transaortic TAVI (insertion of 6F sheath, retrograde crossing of the aortic valve with guide wires, insertion of ASCENDRA delivery sheath, balloon aortic valvuloplasty, insertion and deployment of the Edwards SAPIEN valve, and removal of the ASCENDRA delivery sheath; [Figure 4](#)). The filter has to be placed perpendicularly to the long axis of the distal ascending aorta, achieving maximal sealing of the aortic lumen by the filter.

Patients

After informed consent was obtained, 5 patients were enrolled into this first-in-human clinical assessment of the new version of the EMBOL-X intra-aortic filter. Three patients underwent conventional CABG, and the other 2 patients were accepted for transaortic TAVI. All the 5 patients had no significant calcification in the ascending aorta, and the 2 patients undergoing TAVI had significant peripheral vascular disease. None had a history of stroke. In the 3 patients undergoing CABG, single aortic crossclamping was used for proximal anastomoses of the vein grafts.

RESULTS

In each case, there was a sufficient space in the ascending aorta for the placement of the filter introducer sheath. The filter introducer sheath was easily placed and removed without difficulty or complications. The filter could also be inserted and retrieved quite smoothly through the introducer sheath. There were no complications related to the use

FIGURE 1. The old and new versions of the EMBOL-X intra-aortic filter.

Filter Sizes	Minimum Aortic Inner Diameter (mm)	Maximum Aortic Inner Diameter (mm)
X-Small (26mm)	22 mm	26 mm
Small (29 mm)	26 mm	29 mm
Medium (32 mm)	29 mm	32 mm
Large (34 mm)	32 mm	35 mm
X-Large (37 mm)	35 mm	40 mm

FIGURE 2. Description of the new version of the EMBOL-X intra-aortic filter (A) and the introducer sheath (B). OD, Outer diameter.

of the filter. Determining the completeness of the sealing of the aortic lumen by the filter was challenging, because transesophageal echocardiographic visualization of the

distal ascending aorta was limited. The use of the filter did not interfere with the usual surgical procedures. Postoperatively, no clinical neurologic complications, embolic

FIGURE 3. Placement of the EMBOL-X intra-aortic filter and other cannulas in the ascending aorta during conventional cardiac surgery (A) and trans-aortic transcatheter aortic valve implantation (TAVI) (B). CPB, Cardiopulmonary bypass.

FIGURE 4. Insertion of EMBOL-X intra-aortic filter and transaortic transcatheter aortic valve implantation. A, EMBOL-X introducer sheath and filter and ASCENDRA delivery sheath. B, Deployed filter seen on fluoroscopic image. C, Performing transcatheter aortic valve implantation.

events, aortic dissections, or other complications related to the use of the filter were observed in any case. Careful postoperative examination of the retrieved filters revealed the presence of multiple microemboli in the filters from all 5 study patients (capture rate 100%). The largest embolic debris piece was approximately 2×2 mm; it was captured in the filter from a patient who underwent CABG (Figure 5). Histologic study of the 5 captured microemboli from 1 patient who underwent transaortic

TAVI revealed elastic arterial wall, elastic arterial wall with intimal tissue, and fibrin platelet thrombus with admixed red blood cells (Figure 6).

DISCUSSION

Despite advances in technology and surgical techniques (anesthesia, CPB circuits, better materials and instrumentation, and avoidance of CPB and aortic crossclamping), neurologic injury still occurs after both conventional

FIGURE 5. Captured embolic material during aortic crossclamping (A) and removal of aortic crossclamp (B) from a patient undergoing coronary artery bypass grafting.

FIGURE 6. Histologic study of 5 captured emboli from a patient undergoing transaortic transcatheter aortic valve replacement. A, Gross image of the filter. B-F, Hematoxylin and eosin–stained slides showing elastic arterial wall (B, C, and F), elastic arterial wall and intimal tissue (D), and fibrin platelet thrombus with admixed red blood cells (E).

cardiac surgery and TAVI. The incidences of silent embolic events after surgical AVR and TAVI have been reported to be as great as 47%^{19,20} and 84%.¹³ Several cerebral protection devices have therefore been developed in an attempt to reduce these adverse events. These devices are designed to maintain normal cerebral perfusion while reducing embolic events, either by filtration or by diversion of debris away from the cerebral circulation. These devices include the TriGuard Cerebral Protection Device (Keystone Heart Ltd, Herzliya Pituach, Israel), the Embrella Embolic Deflector device (Edwards Lifesciences), and the Claret Montage Dual Filter System (Claret Medical Inc, Santa Clara, Calif). These devices are primarily designed for the use during endovascular procedures, rather than during cardiac surgery. The first 2 devices (TriGuard and Embrella) do not remove embolic material, and all 3 devices do not prevent embolism to the rest of body, so renal, visceral, or peripheral vascular embolism remains a concern with these devices.²¹ In contrast, the EMBOL-X intra-aortic filter does capture and remove embolic material, which results in a reduction of the embolic burden in the entire body. Theoretically, this kind of device is better than a deflector. The old version of the EMBOL-X filter was designed for the use during conventional cardiac surgery and has already been well studied. The multi-center randomized trial comprising 1289 patients showed a presence of emboli in 96.8% of the filters

removed after the procedure, a 74% reduction of cerebral injury in high-risk patients, and a reduction of renal complications from 24% to 14%.¹⁷ Another study, in which the old version of the EMBOL-X filter was inserted before aortic crossclamping or declamping, showed a microembolic capture rate of 67%.²² One concern about the use of the old version of the EMBOL-X filter has been the potential risk of iatrogenic injury to the ascending aorta, although this was not observed in previous studies.^{17,22} In addition, the use of the filter could introduce additional gaseous microbubbles,²³ a common concern for all embolic deflectors and capture devices.

Generally speaking, calcification and atherosclerosis are more commonly seen in the aortic arch than in the ascending aorta in elderly patients. Avoiding instrumentation in the aortic arch would theoretically prevent potential dislodgment of debris from the diseased aortic arch during TAVI. The transaortic approach for TAVI without aortic arch guidewires or instrumentation may decrease embolic events relative to the transfemoral and transapical approaches for TAVI. The transaortic approach cannot, however, eliminate instrumentation in the ascending aorta. More importantly, a considerable amount of embolic material also emerges from the aortic valve manipulations.²⁴ There has been a case report on the use of the old version of the EMBOL-X intra-aortic filter during transaortic

TAVI showing capture of multiple microemboli.²⁵ In addition, the old device, which is attached to a large aortic cannula, is not amenable to use during TAVI because of limited exposure of the ascending aorta. The new version of the EMBOL-X intra-aortic filter system is much smaller and requires a very small aortic space for its insertion. Our first-in-human clinical experience has shown that the new version of the EMBOL-X system can be used easily during both conventional cardiac surgery and transaortic TAVI. No enlargement of the upper ministernotomy is required to accommodate the use of the filter system during transaortic TAVI. Stabilization of the introducer sheath and filter could be easily achieved, which might avoid injury to the aorta. We did not observe any minor or major complications related to the use of the device in our cases. A high capture rate of emboli was also demonstrated in this very small case series. As seen in all embolic protection devices, some potential limitations exist, such as the introduction of air micro emboli, residual flow around the device, and possibility of causing damage to the vessel wall. Further optimization of the delivery system and the filter is required to achieve ideal sealing of the aortic lumen and maximal capture of embolic material.

CONCLUSIONS

This first-in-human clinical experience has demonstrated the feasibility of using the new version of the EMBOL-X intra-aortic filter during either conventional cardiac surgery or transaortic TAVI. An upper ministernotomy (manubrium only) is sufficient for placement of the filter during transaortic TAVI. We believe that the combination of the transaortic approach without aortic arch manipulation and the use of the EMBOL-X filter with its high capture rate appears a promising strategy to reduce the incidence of embolic complications during TAVI. A clinical trial with a larger series of patients will be necessary to confirm the safety and efficacy of this embolic capture device in preventing systemic embolization and neurologic complications during either conventional cardiac surgery or transaortic TAVI.

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