The train has left: Can surgeons still get a ticket to treat structural heart disease?

Tom C. Nguyen, MD,a Gilbert H. L. Tang, MD, MSc, MBA,b Stephanie Nguyen, BA,a Jessica Forcillo, MD, MSc, MPH,c Isaac George, MD,d Tsuyoshi Kaneko, MD,e Vinod H. Thourani, MD,f Joseph E. Bavaria, MD,g Anson W. Cheung, MD, MSc,h Michael J. Reardon, MD,i and Michael J. Mack, MDj

ABSTRACT

With the disruptive advancement of catheter-based technologies and minimally invasive techniques in structural heart disease, surgeons must obtain necessary skills to continue to serve this large patient population. We believe that surgeons are uniquely positioned to offer the full spectrum of therapy in structural heart disease (transcatheter, minimally invasive, and complex redo interventions), making them comprehensive valve specialists. Given the variability in structural heart training, we urgently recommend the establishment of a standardized curriculum and pathways for surgical trainees to gain proficiency in transcatheter technologies. (J Thorac Cardiovasc Surg 2019;157:2369-76)

Central Message

It is critical to establish a formalized transcatheter curriculum to achieve baseline competency among cardiac surgeons and reinforce surgical involvement in the treatment of valvular heart disease.

Perspective

Given the growth of transcatheter technologies, surgeons require a formalized and structured transcatheter curriculum. An emergency overhaul of current structural training must occur to ensure standardized training in SHD. This is vital as surgeons are uniquely positioned to offer the full spectrum of valve therapy, but risk erosion of the heart team concept without urgent action.

In 2011, cardiac surgeon Dr Michael Mack, among others, used the phrase “the train has already left the station and it ain’t coming back,”1 referring to the rapid advancement of transcatheter aortic valve replacement (TAVR). He and others understood the disruptive potential of transcatheter technologies on the field of cardiac surgery and warned surgeons to embrace transcatheter technology, given its potential transformative impact on clinical care of patients with valve disease.

Surgeons are in a unique and advantageous position to offer the full spectrum of therapy for structural heart disease (SHD). In addition to open surgery, surgeons can potentially...
offer transcatheter, minimally invasive, and complex redo interventions to patients with valvular heart disease, making them the complete “valve specialist.” In addition, because many patients with SHD have multiple structures affected by disease, surgeons are also equipped with the ability to provide complete multicomponent therapy to each of these structures in one setting. Acquisition of endovascular wire and catheter skills is essential given the increasing demand for TAVR and its impending expansion to low-risk patients, as well as emerging percutaneous therapies in mitral and tricuspid valve repair and replacement.

Despite the recent evolution and educational gap in the endovascular management of valvular heart disease, a formalized SHD fellowship program accredited by the Accreditation Council on Graduate Medical Education (ACGME) is nonexistent. Moreover, no standardized training programs are available for cardiac surgeons or residents to obtain endovascular training. Rather, training in SHD interventions is fragmented into separate forms, including (1) non-ACGME postgraduate training programs; (2) Food and Drug Administration–mandated industry-sponsored device-specific training courses; (3) on-site device company–employed clinical specialists and physician proctorship; (4) society-sponsored national conferences with interactive live cases and workshops; and (5) limited simulation training. Lack of a formalized SHD curriculum results in significant variability in training and exposure, making it difficult for surgeons to obtain the full set of required skills to meaningfully participate and contribute during SHD procedures.

We believe training paradigms must be revised altogether and that the acquisition of endovascular skills must be paramount and made available in structured, accredited programs for surgeons interested in treating SHD, with an admonition that failing to do so will exclude surgeon involvement in the future. All stakeholders need to realize that this is a “burning platform” issue for our specialty. Last, we provide recommendations and a “call to action” for our leadership in our specialty and our societies to establish a structured and credentialed pathway for cardiac surgeons who want to obtain and use transcatheter skills in their practice. Dialogue must start and continue among all societies and stakeholders that underscore the importance of multidisciplinary collaboration in treating patients with SHD, which cannot be underestimated.

**SURGEONS: DECLINING ROLE IN TRANSCATHETER AORTIC VALVE REPLACEMENT**

Although a recent 2016 Society of Thoracic Surgeons survey revealed active surgeon involvement in TAVRs, several emerging studies suggest diminishing roles of surgeons. Potential reasons include a transition away from alternative access to predominantly transfemoral approaches and surgeon lack of endovascular experience to autonomously perform the procedure in its entirety. This is compounded by the fact that more than 90% of TAVRs are performed via a percutaneous femoral approach, suggestive of the decreasing need for surgeons to obtain access.

In Europe, there is emerging evidence that absence of an on-site surgeon and surgical team from the procedure did not increase TAVR mortality or morbidity. Given the advancement of TAVR to a low-risk procedure, this raises the question as to whether surgical backup is necessary, or will history repeat itself in the elimination of surgeon involvement from TAVR as in percutaneous coronary intervention. There is also a growing debate as to whether having the entire surgical team (ie, surgeon, perfusion, scrub nurses) present in TAVR is economically sustainable or necessary, particularly given the increasingly low risk of coronary occlusion, annular injury, surgical conversion being less than 1%, and transition toward conscious sedation being the preferred approach and default strategy.

By 2017, the volume of TAVR for the first time exceeded the combined volume of isolated surgical aortic valve replacement (SAVR) and SAVR + coronary artery bypass grafting. As SAVR volume declines and TAVR becomes the mainstream therapy for severe acquired aortic stenosis, insights can be learned from our colleagues in vascular surgery who embraced advancements in catheter-based interventions to preserve and diversify their specialty. So too must cardiac surgeons adapt to the expansion of percutaneous technology and recognize their potential to offer a full range of therapies (sternotomy, minimally invasive, and TAVR) to treat this large patient population and evolve into valve specialists. This requires a generational shift in mindset with support from leadership, training programs, and societies. Surgeons of the past must transform into
physicians of the future. It is now more important than ever for surgeons to continue to leverage their knowledge and experience treating valvular disease and obtain the necessary skill sets to actively participate in SHD. The more difficult conceptual question that must be answered is to what extent any individual adult cardiac surgeon should be proficient in TAVR: Is it necessary to be fully independent in TAVR? Is teamwork with a complementary set of skills with interventional cardiology but shared decision making adequate and appropriate? Is TAVR a procedure that should be known to all surgeons while more advanced mitral and tricuspid procedures be relegated to tertiary centers, or will that happen naturally? Is a full transformation of the field necessary or does endovascular structural heart occupy a new subspecialty field? These answers require sincere discussion, input from academics and practicing surgeons, large- and small-volume sites, and urban and rural centers. These changes will not only help define our practice for 5 years but also have implications far beyond.

**PREREQUISITES**

Surgeons performing transcatheter interventions must possess fundamental skills to manage patients throughout their disease cycle. Suggested recommended skill sets are listed in Table 1. In addition to training experience, it is important that our multidisciplinary societies jointly develop training guidelines to facilitate hospital credentialing committees to establish requirements for participation in SHD procedures.

As part of an SHD heart team, surgeons should be active participants in patient selection, case planning, and postoperative care. This involves identifying patients who would benefit from surgical, minimally invasive, hybrid, or transcatheter intervention. As transcatheter therapies inevitably expand to include mitral and tricuspid valves, surgeons equipped with transcatheter and minimally invasive techniques are uniquely positioned to provide equipoise and unbiased management decisions.

Surgeons should also possess the ability to interpret multiple cardiac imaging modalities, including fluoroscopy, transthoracic and transesophageal echocardiography, and computed tomography, as part of precise screening and performing the transcatheter procedure. Procedural skills vary depending on the type of transcatheter intervention performed. Surgeons should have a firm understanding of the sequence of steps, imaging equipment, endovascular equipment, and devices. Analogous to cannulation being a critical skill in open surgery, transseptal access is a critical skill in transcatheter mitral valve intervention. Such procedural skills and scenarios can be practiced using simulators with milestones counting toward device certification.

**CHALLENGES**

The greatest challenge facing cardiac surgeons who want to obtain endovascular training is the lack of access to formalized structured training. Catheter-based elective rotations remain highly variable among programs and usually inadequate to gain full proficiency in transcatheter techniques and technologies. Residents report experiencing resistance in arranging catheter-based rotations, because they must compete for cases with interventional cardiology trainees, who spend an additional 6 months to 1 year in a

---

**TABLE 1. Recommended skill sets for surgeons to acquire in transcatheter valve therapy**

<table>
<thead>
<tr>
<th>Skill Sets</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Precase planning</strong></td>
<td>Understanding of anatomy, pathophysiology, and hemodynamics of SHD</td>
</tr>
<tr>
<td></td>
<td>Patient screening and optimization</td>
</tr>
<tr>
<td></td>
<td>Interpretation of multimodal cardiac imaging (TEE, TTE, CT, MRI, fluoroscopy)</td>
</tr>
<tr>
<td></td>
<td>Team planning to prevent, anticipate, and manage procedural complications</td>
</tr>
<tr>
<td></td>
<td>Management of multivalve disease via surgical, hybrid, and transcatheter approaches</td>
</tr>
<tr>
<td><strong>Procedural skills</strong></td>
<td>Aortic/mitral/tricuspid:</td>
</tr>
<tr>
<td></td>
<td>- Understanding of equipment and device function, sequence, and troubleshooting</td>
</tr>
<tr>
<td></td>
<td>- Obtaining vascular access and closure (including alternative access)</td>
</tr>
<tr>
<td></td>
<td>- Intraoperative imaging acquisition (intracardiac echocardiography, rotational angiography, fusion imaging)</td>
</tr>
<tr>
<td></td>
<td>- Integrating multimodal imaging (fluoroscopy, echocardiography) to guide procedure</td>
</tr>
<tr>
<td></td>
<td>- Insertion and removal of large-bore sheaths</td>
</tr>
<tr>
<td></td>
<td>- Valve crossing, delivery system manipulation, valve positioning and deployment</td>
</tr>
<tr>
<td></td>
<td>- Bailout strategies and management of complex cases</td>
</tr>
<tr>
<td></td>
<td>- Cerebral embolic protection</td>
</tr>
<tr>
<td></td>
<td>Mitral/tricuspid:</td>
</tr>
<tr>
<td></td>
<td>- Open positioning and deployment of transcatheter valves</td>
</tr>
<tr>
<td></td>
<td>Mitral:</td>
</tr>
<tr>
<td></td>
<td>- Transseptal access</td>
</tr>
<tr>
<td><strong>Postprocedural management</strong></td>
<td>Fast-track cardiac care</td>
</tr>
<tr>
<td></td>
<td>Management of postprocedural complications</td>
</tr>
<tr>
<td></td>
<td>Knowledge of conditions that require ongoing surveillance</td>
</tr>
</tbody>
</table>

SHD, Structural heart disease; TEE, transesophageal echocardiography; TTE, transthoracic echocardiography; CT, computed tomography; MRI, magnetic resonance imaging.
dedicated SHD fellowship to hone their skills, whereas cardiac surgery residents typically spend only a few months learning the basics. Indeed, interventional cardiology programs now offer an additional year of training in SHD to those trainees interested in this specialty. This lack of a similar standardized endovascular curriculum in cardiothoracic surgery residency results in major discrepancies in exposure and experience.15

Given the considerable heterogeneity in current residency programs, surgeons seeking expertise in catheter-based procedures are encouraged to pursue additional postgraduate SHD training at high-volume centers.4,16 Examples of such SHD fellowship programs for surgeons are listed in Appendix E1. Although completion of an advanced SHD fellowship offers a more comprehensive SHD training experience comparable to that of interventional cardiologists, lack of accessibility remains a major obstacle. First, the number of centers that offer an SHD fellowship program is extremely limited, and before this article, a comprehensive list has not been made available to surgeons. Second, these fellowship programs are not ACGME accredited, resulting in significant variability because they are not bound by ACGME guidelines or a standardized curriculum. As such, completion of an SHD fellowship does not lead to formal certification from the American Board of Medical Science with a focused practice certificate.

The third challenge facing surgeons is the lack of incentive for cardiologists to share the stage. It is clear that individuals in a catheterization laboratory or operating room must add value to patient care. Cardiology programs understandably heavily prioritize training interventionalists over surgeons, and because most do not have interventional credentials or certification, they are immediately at a disadvantage in any formal SHD training program. However, if surgeons were to possess the required skills, cardiologists would be more willing to collaborate, because surgeons can offer additional complementary skills to strengthen the heart team and improve patient care.

Last but equally important, the lack of funding and time remain a major obstacle for surgeons, whether a recent graduate or senior faculty, to seek postgraduate SHD training. Surgery programs are reluctant to fund training for surgeons at the expense of their manpower and volume, especially in an economic environment heavily driven by relative value units. Therefore, they are forced to learn while “on-the-job” or take time off to learn transcatheter techniques at another institution. Although the structural heart job market is strong, surgeons report a reduced desire to pursue such positions because of diminishing reimbursements with TAVR, while facing strong financial allures for more accessible subspecialties (eg, aortic, heart failure/transplant), especially after extensive residency training.

**STATUS QUO**

There are currently 3 main pathways (Figure 1) for surgeons to undergo training in SHD: (1) elective rotations during cardiac surgery residency; (2) dedicated 6-month to 1-year postgraduate SHD fellowship; and (3) proctorship at an established SHD program. Although these pathways provide multiple options for trainees to pursue SHD experience, the curriculum in each pathway is highly variable and individually insufficient.

The American Board of Thoracic Surgery (ABTS) and the ACGME Residency Review Committee in Thoracic Surgery (RRC-TS) have recognized the need to improve endovascular training by increasing the minimum requirements of interventional procedures/skills for residents. Currently, the ABTS requires cardiac-track residents to perform a minimum index number of 10 TAVR cases as an assistant, 5 TAVR cases as a primary operator, and 15 interventional wire-based procedures, including 5 left heart catheterizations, percutaneous coronary interventions, thoracic endovascular aortic repairs, or MitraClips (Abbott, St Paul, Minn), and 10 intra-aortic balloon pump placements.17 Although a start, attainment of this requirement will by no means adequately prepare new graduates to proficiently perform transcatheter procedures, because current literature suggests a minimum of 26 TAVR cases to become proficient and achieve benchmark outcomes.18,19 Therefore, we urge the ACGME and RRC-TS to increase current requirements to ensure trainees are proficient in at least TAVR before graduating, because TAVR will become the mainstream therapy to treat severe aortic stenosis.

Although a 6- to 12-month postgraduate SHD fellowship specifically for cardiac surgeons offers a more comprehensive training experience, there are only 9 known programs established in the United States, none of which are ACGME accredited (Appendix E1). Surgeons may also receive SHD training through a formal proctorship at an established center. Those interested in transcatheter mitral and tricuspid therapy (eg, MitraClip, valve-in-valve) should set aside time away from the operating room to participate in those procedures alongside interventionalists, particularly if the patients were initially referred to them. This is an ideal approach for surgeons to become active participants on the heart team, driving joint decision-making in treatment recommendation and procedural involvement. By the end of the proctorship, surgeons will be ready to function as an equal partner to interventional cardiologists in a range of transcatheter procedures. A handful of traveling fellowships also exist for recent graduates or practicing surgeons to learn transcatheter therapies. Such society or industry-sponsored fellowships, including the Michael J. Davidson Fellowship award, allow 2 visiting surgeons per year to work at dedicated SHD centers to obtain cross-training in
interventional cardiology under the close supervision of experts.\textsuperscript{18}

Another pathway for surgeons to gain experience in catheter-based interventions is through organized educational programs. Food and Drug Administration–mandated, device-specific industry-sponsored, and academic society-sponsored courses (Table 2) offer online and hands-on learning, and didactic teaching to provide and supplement training.\textsuperscript{3} Site training and proctorship with expert physicians are also available for clinician education and training to help reduce the learning curve. Moreover, industry has trained specialists in transcatheter technologies who attend TAVR and MitraClip cases to provide preprocedural and intraoperative technical support. Recently, the Society of Thoracic Surgeons and American Association for Thoracic Surgery have also started offering training courses at their annual meetings (Table 2).

**CHANGE TO THE STATUS QUO AND A “CALL TO ACTION”**

To address the gaps in catheter-based training among surgeons, considerable changes must be made to the current structure of graduate and postgraduate education.

We strongly recommend the development of a new standardized curriculum for subspecialty training in SHD to increase exposure and experience in SHD interventions. This will require collaboration among the ABTS, ACGME RRC-TS, and Thoracic Surgery Directors Association to create a new training structure with increased minimal requirements in endovascular and minimally invasive approaches. We propose the following sample set of rotations to prepare residents and fellows to understand the basics of SHD interventions (Table 3).

With the requirements for transcatheter technologies and techniques exceeding current endovascular training, time is running out for cardiac surgeons interested in treating SHD to continue to participate in a meaningful way. Therefore, we are calling for an urgent summit of all stakeholders in cardiac surgery residency education to address this issue immediately to preserve and augment the role of cardiac surgeons in the treatment of valvular heart disease. Another broader and longer-term recommendation is to convene a “visioning conference” to determine what the future of our specialty should look like. The conference should be spearheaded by the ABTS and leaders in cardiothoracic surgery with a focus in SHD, ischemic heart disease, heart failure, thoracic aortic disease, thoracic disease, and arrhythmia surgery. We believe that our field is at a crossroads of a paradigm shift, and without actionable changes, there will be no progress and the role of our specialty will diminish. To achieve this, we propose holding an initial planning session with a small number of attendees to establish an initial concept of a strategic plan. The envisioned output of that meeting would be to convene a subsequent half or full-day retreat in which executable strategies and solutions are developed. To spark discussion, we propose administration of a survey to all current practicing surgeons and cardiac surgery trainees to capture the current landscape and identify practice gaps and areas of unmet needs and vision of their future. This information can then be
used to enhance SHD training and aid in the development of a standardized residency curriculum.

Given the heterogeneity of SHD interventions and the unique skill sets required to perform each procedure (eg, TAVR vs MitraClip), specific training objectives and criteria will need to be established for greater proficiency in a wide range of transcatheter procedures by the time of graduation. An example of stricter ABTS requirements for a cardiac-track graduate is summarized in Table 4. However, time constraints and other limitations may preclude the opportunity to learn these essential skills. In such cases, the trainee who wants to subspecialize in SHD should seek an additional year of SHD fellowship at a high-volume dedicated training center, so-called center of excellence (Appendix E1), for an enhanced experience with greater depth and volume.

### TABLE 2. Examples of industry- and society-sponsored transcatheter training programs

<table>
<thead>
<tr>
<th>Manufacturer</th>
<th>Training programs</th>
</tr>
</thead>
</table>
| Abbott Structural Heart (St Paul, Minn) | - MitraClip 101*
- MitraClip 202*
- Intracardiac echo/transseptal access workshops
- Conference-specific training programs (eg, STS, ACC, AATS, TVT, TCT) |
| Baylis (Montreal, QC) | - Transseptal access courses, offered independently year-round and at society conferences in partnership with Boston Scientific Corp (Marlborough, Mass) and Siemens Healthineers (Erlangen, Germany) (eg, STS, AATS, SCAI, TVT, TCT)
- Gloves-on training, offered in partnership with Boston Scientific Corp |
| Biosense Webster (Irvine, Calif) (part of Johnson and Johnson) | Intracardiac echocardiography course |
| Edwards Lifesciences (Irvine, Calif) | - TAVR fundamentals*
- TAVR optimentals*
- Mitral valve-in-valve fundamentals*
- Fellows course |
| Medtronic (Minneapolis, Minn) | - TAVR product and procedure training*
- TAVR fundamentals for fellows
- TAVR symposia for advanced implanters*
- Proctoring support
- Case observations
- Imaging programs
- Conference-specific training programs
- Webinars (global ground rounds)
- Local Medtronic education programs |

Programs are continually under review and new offerings being developed

<table>
<thead>
<tr>
<th>Academic Society</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>AATS</td>
<td>Transseptal training course</td>
</tr>
<tr>
<td>CRF</td>
<td>Echocardiography conference (including workshops)</td>
</tr>
<tr>
<td>SCAI</td>
<td>Transseptal training course</td>
</tr>
</tbody>
</table>
| STS              | STS University courses *
- TAVR
- Transseptal access
- Minimally invasive valve surgery |
| TVT              | Transseptal training course |
| TCT              | Echocardiography and CT imaging training |
| ISMICS           | Transseptal training course *
- MitraClip NTR/XTR training
- Bicuspid TAVR imaging training
- TAVR fundamentals
- Minimally invasive valve surgery |

STS, Society of Thoracic Surgeons; ACC, American College of Cardiology; AATS, American Association for Thoracic Surgery; TVT, Transcatheter Valve Therapeutics; TCT, Transcatheter Cardiovascular Therapeutics; SCAI, Society for Cardiovascular Angiography and Interventions; TAVR, transcatheter aortic valve replacement; CRF, Cardiovascular Research Foundation; CT, computed tomography; ISMICS, International Society of Minimally Invasive Cardiac Surgery. *Subject to eligibility. Please contact local company representative for further inquiry.
We also encourage partnering with the American College of Cardiology to create new and standardized SHD training programs within the integrated and traditional training paradigms, as well as ACCME and non-ACCME-accredited SHD fellowship programs. These programs should encourage cross-pollination, whereas surgeons rotate on the cardiology service and vascular surgery. As shown earlier and in Appendix E2, residency programs should offer catheter-based and cardiac imaging rotations in the junior years as building blocks to allow trainees early and frequent exposure to SHD, developing fundamental skills such as wire selection, obtaining access, and image interpretation. Transcatheter skills may also be acquired while learning components of thoracic endovascular aortic repairs on vascular surgery rotations. Dedicated rotations on the SHD service should be required during the senior years of residency among the cardiology-track trainees, in which senior-level residents are given greater autonomy under an attending operator’s supervision and transfemoral TAVR or MitraClip under the operator’s supervision. Interventional cardiologists in SHD fellowships should spend at least 1 month in the operating room to observe surgical valve cases to better understand anatomy and pathologies. Our suggestions on structural heart training programs and suggested rotations are based on the experience of some of the authors and not intended to be comprehensive or inclusive of the many other programs and rotational alternatives available at other institutions.

We suggest convening a meeting with industry sponsors to solicit their crucial input on the development of this training paradigm for cardiac surgeons, because they play a critical role in disseminating new technologies to enable clinicians to better treat their patients.

Last, this article is not a final solution to this dilemma but a means to kick-start the conversation on how to keep surgeons involved in this space and provide the optimum care for our patients. We believe that a strong heart team provides the best platform for delivering the care needed for SHD. Surgeons are essential for the complex decision making needed in many patients. Complex anatomy, aortopathy, reinterventions, and concomitant cardiac disease needing treatment are areas where cardiac surgeons have provided the necessary decision making and should continue to be involved in these decisions. However, to be considered an equal member of the heart team, they need to master the technical skills required.

CONCLUSIONS

As catheter-based technologies and minimally invasive techniques continue to revolutionize the field of cardiac
surgery and SHD, training programs must take action to prepare surgeons to evolve into valve specialists with endovascular, minimally invasive, and complex open skills at their armamentarium. Physicians with these combinations represent the true “triple-threat” with pure equipoise in treating patients with SHD. Rather than a few months of casual observation, surgical trainees require a formalized and structured curriculum to obtain the necessary skill sets or otherwise risk being sidelined in the management of SHD. For trainees to gain proficiency in transcatheter techniques by the time of graduation, we must establish a standardized curriculum to enable surgeons to remain relevant and stand out as valve specialists. Overall, it is increasingly clear that the future of treating SHD will predominantly involve endovascular and minimally invasive techniques. Whether it be cardiologists, surgeons, or both driving the train remains to be seen. At this point for surgeons, it is important that they at least have a ticket for the ride. The “aha moment” for our specialty is here; it is the critical time for us to decide what our specialty will look like in the future.

Conflict of Interest Statement

T.C.N. reports receiving consultant fees from Edwards Lifesciences, Abbott, and LivaNova. G.H.L.T. reports receiving consultant fees from Abbott and proctoring fees from Edwards Lifesciences and Medtronic. J.F. reports receiving consultant fees from Edwards Lifesciences, Medtronic, and Boston Scientific. I.G. reports receiving speaker and consultant fees from Edwards Lifesciences, Medtronic, institutional training grants from Edwards and Medtronic, consultant fees from Bolton Medical, Abbott, WL Gore and Associates, and Boston Scientific. T.K. reports receiving consultant and proctoring fees from Edwards Lifesciences, Medtronic, and Abbott. V.H.T. reports receiving consultant fees from Abbott, Boston Scientific, Edwards Lifesciences, and Gore Vascular. J.E.B. reports receiving consultant fees from WL Gore and Associates. A.W.C. reports receiving consultant fees from Abbott. M.J.R. reports receiving fees from Medtronic for providing educational services. All other authors have nothing to disclose with regard to commercial support. The authors have carefully reviewed the contributions from each author to ensure that commercial relations did not limit or restrict the discussions to those devices or companies, and the products and courses offered by companies were described here without limitation or selection based on commercial relations of the authors.

References


Key Words: structural heart disease, transcatheter, endovascular, minimally invasive, standardized curriculum, residency, fellowship
APPENDIX E1
Selected postgraduate structural heart fellowship programs for cardiac surgeons in the United States

1. Brigham and Women’s Hospital (Boston, Mass)
   Number of positions: 1
   Fellowship length: 1 y
   Program director: Tsuyoshi Kaneko, MD
   E-mail: tkaneko2@bwh.harvard.edu

2. Emory University (Atlanta, Ga)
   Number of positions: 1
   Fellowship length: 1 y
   Program director: Kendra Grubb, MD
   E-mail: kendra.janel.grubb@emory.edu

3. The Heart Hospital Baylor Plano (Plano, Tex)
   Number of positions: 1
   Fellowship length: 1 y
   Program director: Michael DiMaio, MD
   E-mail: Michael.DiMaio@bswhealth.org

4. Houston Methodist Hospital (Houston, Tex)
   Number of positions: 1
   Fellowship length: 1 y
   Program director: Michael Reardon, MD
   E-mail: mreardon@houstonmethodist.org

5. MedStar Washington Hospital Center (Washington, DC)
   Number of positions: 1
   Fellowship length: 1 y
   Program director: Vinod Thourani, MD
   E-mail: vinod.h.thourani@medstar.net

6. New York University Langone Medical Center (New York, NY)
   Number of positions: 1
   Fellowship length: 1 y
   Program director: Mathew Williams, MD
   E-mail: mathew.williams@nymc.org

   Number of positions: 1
   Fellowship length: 6 mo (TAVR only)
   Program director: Nimesh Desai, MD
   E-mail: Nimesh.Desai@uphs.upenn.edu

8. University of Texas McGovern Medical School (Houston, Tex)
   Number of positions: 2
   Fellowship length: 1-2 y
   Program director: Tom C. Nguyen, MD
   E-mail: tom.c.nguyen@gmail.com

9. University of Virginia (Charlottesville, Va)
   Number of positions: 1
   Fellowship length: 1 y
   Program Director: Gorav Ailawadi, MD
   E-mail: gorav@virginia.edu

APPENDIX E2
Université de Montréal introductory structural heart disease (SHD) program is a 3-mo rotation with an endovascular attending learning structural procedures. Program objectives are based on competencies assessed by the Royal College of Physicians and Surgeons of Canada:

1. Professionalism:
   - Capability to establish priorities in his/her professional obligations in regard to the patients and their problems

2. Expert:
   - Master theoretic and clinical skills in the field of percutaneous valves
   - Master the clinical assessment of patients who present with severe aortic stenosis
   - Exploration of all therapeutic options with patients and their family
   - Ability to select the appropriate patients for a procedure (surgical or transcatheter)
   - Ability to perform 3-dimensional computed tomography scan reconstructions to assess anatomy for valve selection and vascular approach
   - Participation in a mandatory 1-d simulation training on the different types of percutaneous transcatheter valves used in our center (sponsored by industry)
   - Perform arterial and venous percutaneous femoral punctures
   - Perform surgical alternative accesses, eg, transapical, transcarotid, transaxillary, and direct aortic (mini-sternotomy)
   - Knowledge of the steps of a transcatheter aortic valve replacement (TAVR) procedure
- Ability to control the table used to perform the procedures
- Perform some steps of TAVR according to trainee skill level
- Management of complications related to TAVR
- Ability to anticipate, plan, and perform surgical conversion in case of complications
- Attendance of other structural procedures, such as MitraClip, left appendage closure, paravalvular leak closures, percutaneous mitral valve replacement, aortic coarctation stenting, closure of patent foramen ovale (PFO) and atrial septal defect (ASD) and thoracic endovascular aortic repair (TEVAR)
- Postoperative management of patients who underwent a transcatheter procedure

3. Communicator:
- Active participant in the weekly heart team meeting, contributing to patient selection and optimal vascular approach
- Effective communication with many professionals within a multidisciplinary team

4. Manager:
- Ability to establish realistic goals and demonstrate time management skills to maximize professional efficiency

5. Collaborator:
- Collaboration with all the members of the heart team and allied professionals

6. Health promoter:
- Ability to assess risk factors related to heart valve diseases and provide recommendations on appropriate interventions

7. Scholar:
- Stay current with the major literature related to TAVR and MitraClip
- Complete at least 1 research project related to structural procedures
- Participation in at least 1 local, national, or international structural conference