Title: *Current Status of Endovascular Training for Cardiothoracic Surgery Residents in the United States.*

Running Head: Endovascular Training for Residents

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Abstract:

Background: Endovascular interventions for cardiovascular pathology are becoming increasingly relevant to cardiothoracic surgery. The purpose of this study was to assess the perceived prevalence and efficacy of endovascular skills training and to identify differences among training paradigms.

Methods: Trainee responses to questions in the 2016 In-Service Training Examination survey regarding endovascular training were analyzed based on the four different cardiothoracic surgery training pathways: traditional 2- and 3-year thoracic, integrated 6-year, and combined 4+3 general and thoracic residency programs.

Results: Duration of endovascular training was substantially different among programs (median of 17 weeks for integrated 6-year vs. 8.5 for 3-year vs. 6 for 4+3 vs. 4 for 2-year residency; $p<0.0001$). After adjusting for year of training and program type, the duration of endovascular rotations was significantly associated with self-assessed comfort with catheter-based skills ($p<0.0001$). 82% of residents rotated with trainees from other specialties and 58% experienced competition for cases. Residents reported greater exposure to transcatheter aortic valve replacement, as compared to thoracic endovascular aortic repair, cardiac catheterization, percutaneous closure of atrial septal defect, and transcatheter mitral valve surgery ($p<0.0001$). A significant proportion of responders reported feeling uncomfortable performing key steps of transcatheter aortic valve replacement (52%) or thoracic endovascular aortic repair (49%).

Conclusions: Considerable heterogeneity exists in endovascular training among cardiothoracic surgery training pathways, with a significant number of residents having minimal to no exposure to these emerging techniques. These findings highlight the need for a standardized curriculum to improve endovascular exposure and training.

Introduction

Cardiothoracic (CT) surgery has undergone significant evolution in the last decade with the introduction of new percutaneous and transcatheter procedures [1]. The recent development of endovascular techniques for valve or aortic surgery, including transcatheter aortic valve replacement (TAVR), transcatheter mitral valve repair or replacement and thoracic endovascular aortic repair (TEVAR), raises the question of whether or not CT surgery training programs adequately prepare graduates for the future needs of the specialty. Failure to meet this trend and fully adapt to the explosion of new percutaneous technology during training might lead to exclusion of the future generations of CT surgeons from treating the full spectrum of cardiovascular diseases, considering the growing number of patients undergoing these procedures [2]. Concurrently, the proliferation of different training pathways leading to American Board of Thoracic Surgery (ABTS) certification, may lead to a variable experience in endovascular procedures, resulting in a future workforce with a heterogeneous and inconsistent skill set. Considering these concerns and the lack of data from Accreditation Council for Graduate Medical Education (ACGME) residents across the United States, the objective of this study was to assess the perception of the current status of endovascular training and evaluate the variability in training experience among CT surgery trainees.

Material and Methods

As a result of the work of Richard Lee [3], the first Thoracic Surgery Residents Association (TSRA) survey was conducted in 2003. Since then, each year, ACGME CT surgery residents take a survey designed by the Thoracic Surgery Directors Association (TSDA) and the Thoracic Surgery Residents Association (TSRA) prior to the annual In-Service Training Examination (ITE).

This study analyzed demographic information and questions pertaining to training in endovascular techniques from the 2016 TSDA/TSRA survey, which was completed on March 7th, 2016. Responses were anonymous and did not contain any identifying information on the residents or the institutions. ACGME accredited residents self-identified as being part of the four training paradigms: 2-

year (2Y) or 3-year (3Y) traditional thoracic surgery residency, integrated 6-year thoracic surgery residency (I-6) and combined 4+3 general and thoracic surgery residency (4+3).

The survey investigated the perceived importance of learning different endovascular procedures, the degree of exposure to endovascular skills training, and the comfort level in performing key steps of these procedures. Results were stratified by postgraduate year (PGY) and training pathway. Residents were considered in their final years of training ("seniors") if they were PGY-5 and above in the I-6 training pathway, PGY-6 and above in the 4+3, PGY-7 and above in the 2Y and PGY-8 and above in the 3Y pathway. The duration of endovascular training was assessed as total weeks throughout residency training. Comfort level with each key step of TAVR and TEVAR was scored as a categorical variable with a scale of 1 (strongly disagree) to 5 (strongly agree). The comfort level with each procedure was calculated by averaging the comfort level with each key step of the procedure.

Continuous variables were examined either using the Wilcoxon and Kruskal-Wallis tests for skewed variables, or the ANOVA for normally distributed variables. A multivariable linear regression model analyzed the relationship between duration of training with comfort level and number of endovascular procedures performed, adjusting for PGY and residency pathway. Continuous data were represented as medians and interquartile ranges (IQR). Analyses were conducted using commercially available software (SAS University Ed., SAS Institute Inc, Cary, NC). Significance was set at a p-value of <0.05.

Results

The survey was completed by all residents who completed the 2016 ITE (n=379, response rate 100%); 22% of the responders were female. Responders were enrolled in I-6 programs (34.3%), traditional 2Y (33.5%) or 3Y (22.6%) programs, with a minority in 4+3 programs (9.5%) (Table 1).

Perception of importance

Slightly more than half of the residents considered TAVR a very important skill to learn (55.4%), while 17.0% did not consider it an important skill. Residents in the I-6 pathway rated TAVR skills as

more important than residents in other programs (Figure 1). Specifically, 87% of I-6 residents rated TAVR as “important/very important” skill set, compared to 73% of 3Y, 57% of 2Y, and 51% of 4+3 residents ($p<0.001$). TEVAR and coronary catheterization skills were also considered more important by I-6 residents ($p<0.001$ for both). Residents planning a career in cardiac surgery were significantly more likely to consider catheterization and TAVR skills more important than those planning a career in thoracic surgery ($p<0.0001$). Residents planning a career in thoracic vascular surgery were the group who considered TEVAR skills most important ($p=0.001$). Of the responders who were planning further subspecialty training (n=176, 46.4%), only 6.8% planned further training in endovascular/transcatheter aortic valve replacement (n=12), vs. 29.5% in congenital surgery (n=52), 23.3% in transplant (n=41), 18.8% in minimally invasive thoracic surgery (n=33), 10.2% in aortic surgery (n=18), and 3.4% in mitral valve surgery (n=6).

Exposure to endovascular training

The total duration of endovascular training was substantially different among programs (median of 17 weeks for I-6 vs. 8.5 weeks for 3Y vs. 6 weeks for 4+3 vs. 4 weeks for 2Y; $p <0.0001$; Figure 2). Many responders reported no endovascular training (7% vs. 16% vs. 39% vs. 33% respectively). Among the different endovascular procedures, residents reported greater exposure to TAVR (60%) as compared to TEVAR (15%), cardiac catheterization (14%), percutaneous closure of atrial septal defect (8%), and transcatheter mitral valve surgery (2%) ($p<0.0001$). I-6 trainees reported having more training time in cardiac catheterization with a median of 4 weeks (IQR 0-6, maximum of 24 weeks). Residents in I-6 programs had most of their exposure to cardiac catheterization in their first 3 years of training (42.7% reported performing at least one case; 10% reported more than 50 cases); exposure to TAVR and TEVAR was most common in their last 3 years of training. A majority of residents (82%) rotated with trainees from other specialties on endovascular rotations, and 58% experienced competition for cases. Only 16.9% of responders had access to a dedicated curriculum for endovascular skills simulation by their programs, and 84.3% of this group believed simulation was a useful tool. More than half of the residents in 2Y or

3Y programs felt that general surgery residency provided them with sufficient training in endovascular skills (62.9% and 53.5%, respectively).

Comfort level for endovascular procedures

A majority of residents reported feeling uncomfortable performing key steps of TAVR (52%; mean comfort level of 2.6 ± 1.0, with scores ≥ 3 representing being comfortable with the procedure; and for senior residents mean 3.0 ± 1.1) or TEVAR (49%; mean comfort level 2.6 ± 1.1; and for senior residents mean 2.9 ± 1.1). Specifically, only 37.7 % of the responders felt comfortable with access selection for TAVR, 21.9% with valve sizing, and 15.6% with fluoroscopic deployment view selection (Table 2). Similarly, only 19% of residents felt comfortable with aortic graft stents sizing for TEVAR (Table 3). Senior residents reported higher comfort level with basic endovascular skills, such as access selection for TAVR, (67% for I-6 and 59% for 3Y), but the majority felt uncomfortable with more advanced endovascular skills, like aortic valve sizing or fluoroscopic deployment view selection. Residents planning a career in thoracic surgery reported feeling less comfortable with TAVR than those planning to pursue a cardiac or thoracic vascular surgery career ($p<0.0001$). Of the traditional residents who reported having had experience in endovascular skills during their general surgery training, the ones who felt their training was sufficient reported feeling significantly more comfortable with TAVR and TEVAR (mean comfort 2.9 vs 2.5, $p=0.003$ and 2.9 vs 2.3, $p<0.001$, respectively). Trainees reported feeling more comfortable with TAVR and TEVAR as their year of training advanced. Whether residents felt case competition did not significantly predict their comfort with TAVR or TEVAR procedures ($p=0.81$ and 0.40 respectively). After adjusting for year of training and program type, duration of endovascular rotations was significantly associated with self-assessed comfort with catheter-based skills ($p<0.0001$).

Comment

The educational environment for training CT surgery residents has changed significantly during the last 15 years in the United States [1, 4]. Factors that have contributed to this change include ACGME

work hour restriction, establishment of new training paradigms, restricted resident autonomy, greater public scrutiny of training practices, and introduction of endovascular techniques and robotics in CT surgery [4, 5]. In this new environment, the training of the next generations of CT surgeons remains critical. The emergence of new, transcatheter approaches to cardiovascular pathologies has affected the case volume of certain open operative procedures, but has also opened new horizons and expanded the specialty with new skill sets. The role of current training in the development of these skills and the perceived need for further specialization remain poorly characterized. We performed a focused survey to assess the depth of exposure and level of comfort for endovascular procedures performed routinely in the United States.

Since Cribier et al. reported the first TAVR in humans in 2002 [6], the use of trancatheter approach to aortic valve replacement has exponentially increased. According to the Society of Thoracic Surgeons/American College of Cardiology Transcatheter Valve Therapy (STS/ACC TVT) Registry [2], 4590 TAVR were performed in 2012, which grew to 26,414 in 2014, a number that is expected to increase even further in the coming years. The need for training programs to adapt to the rapidly expanding role of TAVR and other endovascular-based technologies is now more apparent than ever. Chu et al recently published data from a voluntary survey distributed to 130 graduates of ACGME-approved thoracic surgery residency programs prior to the ABTS certifying oral examination in June 2014 [7]. Lack of confidence in endovascular procedures was common among all responders (53.8%), and it ranked as the top area in which graduating residents desired additional training. Our study reports similar findings for current residents. Only 36% of all responders reported being familiar and comfortable with selecting the access route for TAVR, and this number dropped even further for selecting the valve size and the best fluoroscopic view for valve deployment. The responses were similar for TEVAR. Of note, although 55% of the residents ranked TAVR as a very important skill set to have, only 6.8% were planning to pursue further training in transcatheter skills. This may reflect that most responders were early in their academic career and had not yet made the decision to pursue further training, or alternatively, that training programs may not mentor residents to achieve a level of practice as an endovascular cardiac surgeon who performs

these procedures independently from other specialists. Chu et al reported responses from only two graduates from an I-6 program; in contrast, 34% of the residents in our study were in the I-6 pathway. Interestingly, the residents in the I-6 pathway, which was in part designed to provide flexibility in the training curriculum and to introduce catheter-based technology early on in training, were the most interested in endovascular skills and had the greatest amount of exposure to endovascular procedures compared to any of the other groups.

The specialty of vascular surgery underwent similar changes years ago when endovascular surgery flourished, with the successful incorporation of endovascular procedures into vascular training programs [8,9]. The specialty took an early and proactive approach adapting its training paradigms to meet the demands of evolving technology while maintaining their case volume and avoiding dilution of cases to other specialties. Part of this approach involved incorporating simulation-based training, which has been adapted by educators to accelerate psychomotor skill acquisition, improve procedural understanding and assess efficiency and proficiency [10,11,12]. Duran et al. reported data from a 2013 national survey distributed to vascular surgery trainees that assessed whether the presence of simulation for endovascular (or open) procedures improved operative confidence independently of resident operative experience [10]. The survey showed that residents with access to simulation on TEVAR self-reported a significantly higher level of confidence versus residents without access to simulation. Our study demonstrates that only 16.9% of the responders have experienced a dedicated simulation curriculum for endovascular skills. However, simulation alone will not be sufficient to narrow the heterogeneity among different training pathways and programs, since its role is adjunctive and should not supplant direct operative experience in residents' education.

CT residents often learn the skill set for endovascular and transcatheter techniques in a hybrid suite, where they share cases and interact with other specialty trainees, reflecting the rules required for current practice [4]. Our study shows that 82% of residents rotate in endovascular rotations with other specialty trainees and 58% experiences competition for cases. Integration of CT surgery trainees in the catheterization lab education curriculum in order to assume adequate exposure and procedural volumes,

as well as a focus on purposeful collaboration with cardiology fellows, is essential. According to the American College of Cardiology Core Cardiovascular Training Statement 4 [13], cardiology fellows typically receive 16 weeks of training in the cardiac catheterization lab during their 3-year cardiovascular disease training program. In order to be certified to perform diagnostic cardiac catheterizations independently, fellows have to train a minimum of 24 weeks and log 300 diagnostic cases. To reach competency for interventional cardiologists, an additional full year of training and 250 therapeutic interventional cardiac procedures is required, after which another year of fellowship in structural heart disease is usually expected for trainees who plan to perform TAVR. In comparison, the endovascular training requirements for vascular surgeons include a minimum of 100 cases of diagnostic peripheral angiograms, 80 interventional cases and the completion of 20 aortic aneurysm endovascular repairs (Table 4). The ABTS requirements for minimum index number of cases for endovascular skills training has been recently updated to 10 TAVR as an assistant, 5 TAVR as a primary operator and 5 interventional wire-based procedures (including heart catheterization or percutaneous intervention, TEVAR, mitral clip). These new requirements, which were published in January 2017, indicates that the ABTS has recognized the need to train competent residents in the new skill set needed for the increasing number of endovascular procedures, which is a step forward for the future of our specialty.

The expectation is that catheter-based procedures will be viable alternatives to open procedures in the near future for a growing population of patients and should be part of armamentarium of CT surgeons in the management of cardiovascular diseases. We believe that because of this, training to achieve competency in endovascular procedures should be optimized during residency, and further subspecialty fellowship should be an adjunct and optional. Our analysis shows that the correlation between duration of endovascular training and self-reported comfort for catheter-based skills was consistent but weak. The number of cases and the duration of endovascular training are essential to achieve competency in catheter-based skills but are not the only important factors. The quality and intensity of training are equally important; the depth of resident’s exposure, the degree of involvement and autonomy during these cases are all important components to optimize the current training model. While we cannot assume a

direct relationship between level of confidence for endovascular procedures and simulation, we believe that a standardized curriculum involving simulation would have a significant impact in introducing these techniques in a manner that fits the individual resident's level of experience. In addition to the formal training programs curriculum, endovascular skills simulation can be supplemented by both didactic and hands-on training courses often offered and available by industry. Furthermore, a training approach based on competency milestones would lead to standardization and advancement to more complex tasks and techniques. This would be in line with the milestones already implemented by ACGME to achieve competency in cardiovascular disease management and related surgical procedures.

Limitations of this study include the nature of its survey design. This study does not investigate objective data on experience, such as resident operative logs, official residency programs rotation schedules and performance evaluations for endovascular procedures, but instead is based on self-reported data on training time and comfort level with these procedures, which is susceptible to recall bias. In addition, training programs were de-identified in the data, and our analysis was not able to account for clustering and site-specific effects. Our analysis was not able to correlate self reported comfort with objective assessment of fundamental knowledge in catheter-based procedures, considering TSDA data on ITE are not available. The survey does not address time spent in endovascular training for the 2Y and 3Y traditional residents during their general surgery rotations, although it reports the level of confidence that general surgery training provided to perform these procedures. The current sample size of 4+3 programs is disproportionally limited in comparison to the I-6, 2Y and 3Y programs. This study was not designed to differentiate cause and effect. Although our analysis showed that residents report more confidence with endovascular skills with increasing amount of training spent in the endovascular suite, this may not be reflective of their actual skill set as it does not take into account their educational environment, the diversity of their programs, the presence or absence of other trainees, etc. Objective assessment tools will be needed to address these questions.

Our study is the first to show a substantial heterogeneity in endovascular skills training among the different CT surgery residency pathways in the United States. This study highlights that CT surgery

trainees have limited operative experience and low self-reported confidence levels in performing standard endovascular procedures. Specialized, extended and dedicated training is required to adapt completely to these emerging techniques of our specialty. Dr. Michael Reardon aptly emphasized the importance of embracing new technology in CT surgery: “Surgeons can ignore what’s going on and be run over by the train, or they can get on board and help drive the train.” Training competent and technically proficient CT surgery residents who master the full breadth of endovascular skills is crucial to the future growth of the specialty.

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Table 1: Stratification of responders by training pathway and post-graduate year (PGY)

	Type of training program			
	4+3	**I-6**	**2Y**	**3Y**
	N=36 (9.5%)	N=130 (34.3%)	N=127 (33.5%)	N=86 (22.6%)
PGY 1	0	23 (17.7%)	0	0
PGY 2	0	30 (23.1%)	0	0
PGY 3	0	32 (24.6%)	0	0
PGY 4	9 (25.0%)	24 (18.5%)	0	0
PGY 5	8 (22.2%)	13 (10%)	0	0
PGY 6	11 (30.6%)	8 (6.2%)	59 (46.6%)	26 (30.2%)
PGY 7	5 (13.9%)	0	61 (48%)	28 (32.5%)
PGY 8	1 (2.8%)	0	4 (3.2%)	24 (27.9%)
PGY 9	2 (5.6%)	0	3 (2.4%)	3 (3.5%)
PGY 10	0	0	0	5 (5.8%)
Senior residents * (N and % of all senior residents)	19 (13.6%)	21 (15%)	68 (48.6%)	32 (22.8%)

Table 2: Comfort level for key steps of TAVR stratified by training pathway and level of training

		Type of training program							
		4+3 (all)	I-6 (all)	2Y (all)	3Y (all)	4+3 (seniors*)	I-6 (seniors*)	2Y (seniors*)	3Y (seniors*)
		N=36	N=130	N=127	N=86	N=19	N=21	N=68	N=32
Access selection**									
	Disagree or neutral	75%	66%	59%	60%	63%	33%	51%	41%
	Agree or strongly agree	25%	34%	41%	40%	37%	67%	49%	59%
Valve sizing***									
	Disagree or neutral	81%	82%	77%	68%	71%	72%	72%	53%
	Agree or strongly agree	19%	18%	23%	28%	32%	29%	28%	47%
Fluoroscopic deployment views selection****									
	Disagree or neutral	92%	88%	81%	84%	84%	71%	78%	78%
	Agree or strongly agree	8%	12%	19%	16%	16%	29%	22%	22%

* Residents were considered in their final years of training ("seniors") if they were PGY-7 and above in the 2Y and PGY-8 and above in the 3Y pathway, PGY-5 and above in the I-6 pathway and PGY-6 and above in the 4+3 pathway.

** p=0.3 (for all residents), p=0.2 (for seniors)

*** p=0.3 (for all residents), p=0.3 (for seniors)

**** p=0.25 (for all residents), p=0.8 (for seniors)

Table 3: Comfort level for key steps of TEVAR stratified by training pathway and level of training

		Type of training program							
		4+3 (all) N=36	I-6 (all) N=130	2Y (all) N=127	3Y (all) N=86	4+3 (seniors*) N=19	I-6 (seniors*) N=21	2Y (seniors*) N=68	3Y (seniors*) N=32
Graft sizing**									
	Disagree or neutral	83%	85%	77%	79%	74%	67%	75%	69%
	Agree or strongly agree	17%	15%	23%	21%	26%	33%	25%	31%
Selection of open vs endovascular approach***									
	Disagree or neutral	81%	70%	57%	70%	79%	38%	54%	53%
	Agree or strongly agree	19%	30%	43%	30%	21%	62%	46%	47%

* Residents were considered in their final years of training ("seniors") if they were PGY-7 and above in the 2Y and PGY-8 and above in the 3Y pathway, PGY-5 and above in the I-6 pathway and PGY-6 and above in the 4+3 pathway.

** p=0.4 (for all residents), p=0.9 (for seniors)

*** p=0.03 (for all residents), p=0.08 (for seniors)

Table 4: Minimum requirements for formal training to achieve competency in peripheral catheter-based interventions

Cardiothoracic surgery trainees*	5 TAVR as primary operator 10 TAVR as an assistant 5 interventional wire-based procedures (left heart catheterization, percutaneous coronary intervention, TEVAR, mitral clip)
Cardiovascular medicine trainees	300 diagnostic coronary angiograms 100 diagnostic peripheral (not carotid) angiograms
Interventional Cardiology trainees	250 therapeutic interventional cardiac procedures during 12 additional months of accredited training
Structural Heart Disease trainees	12 additional months of dedicated structural heart disease training is expected after interventional cardiology (no official requirements for minimum index number of cases)
Vascular surgery trainees	100 diagnostic peripheral angiograms 80 peripheral interventional cases 20 aortic aneurysm endovascular repair

* According to the American Board of Thoracic Surgery Booklet of Information (January 2017)
These requirements are for 2Y and 3Y residents starting thoracic training, 4+3 residents starting thoracic training, or for I-6 residents starting PGY5 on or after July 1, 2017

Figure 1: Reported importance of skill set, stratified by training pathway

Figure 2: Distribution of number of total weeks of endovascular training, by residency pathway

Mdn-Median