In this editorial, I will present a personal perspective on what does it take to become a good interventional pediatric cardiologist. What I write is based on what I have observed in the exceptional mentors under whom I was fortunate to train and my own experience over the past two and half decades. This editorial is especially written for fellows under training and pediatric cardiologists who aspire to become interventionists. While this editorial has been written especially for prospective trainees and early career pediatric cardiologists in India and other low- and middle-income countries, most principles outlined here would apply to all environments.

WHY DOES EVERYONE SEEM TO WANT TO DO CATHETER INTERVENTIONS?

Interventions have, arguably, become the most glamorous facet of pediatric cardiology today. It is a relatively new field and has largely developed in the past three decades. Interestingly, for most of the world outside of high-income countries, the specialty of pediatric cardiology has also acquired a distinct identity in the same period. It is therefore understandable that aspiring pediatric cardiologists all around the globe are especially keen on acquiring the skills to do catheter interventions. Further, like in their adult counterparts, invasive procedures are the most remunerative of all activities, especially in privately funded hospitals. It is also increasingly true among adult cardiologists, particularly in India, that societal rewards, peer recognition, and self-esteem are all linked to the status of an interventional cardiologist.

In addition, interventions are associated with a sense of instant gratification that comes from closing a defect or dilating a narrow valve or vessel. There is also perhaps a sense of independence, of being able to do something in a specialty that still largely depends on surgeons to fix most lesions.

CAN EVERYONE BECOME AN INTERVENTIONIST?

While it is perhaps true that most aspiring pediatric cardiologists would like to acquire interventional skills, not everyone may be suited to become skilled interventionists. Are there specific natural attributes that interventionists possess or is it possible to acquire them?

Quick thinking versus methodological reasoning

According to Daniel Kahneman, the Nobel Prize winning economist and author of the bestseller “Thinking Fast and Thinking Slow,” our brains comprise two characters, one that thinks fast, system 1, and one that thinks slow, system 2. System 1 operates automatically, intuitively, involuntarily, and effortlessly—like when we drive, read an angry facial expression, or recall our age. System 2 requires slowing down, deliberating, solving problems, reasoning, computing, focusing, concentrating, considering other data, and not jumping to quick conclusions—like when we calculate a math problem, choose where to invest money, or fill out a complicated form. These two systems often conflict with one another. System 1 operates on heuristics that may not be accurate. System 2 requires effort evaluating those heuristics.

Intuitively, one is likely to assume that interventional cardiologists are predominantly quick thinkers. If we were to pause and ponder over all the potential consequences of every step that we take during invasive procedures, it is unlikely that we would be effective in cath lab. While it is necessary to be quick and decisive in cath lab, it is also important to be thoughtful and introspective sometimes while performing procedures and almost always while planning in advance or while reflecting on our complications and failures. Hence, it is perhaps necessary to strike a balance between both the systems of thought.

WHAT ARE THE OTHER ATTRIBUTES OF A GOOD INTERVENTIONIST?

Like in the above example, I suspect, being a good interventionist requires a balance between other seemingly opposite attributes:

Courage versus caution

Courage is needed when you venture into doing something that can potentially do harm. If you were too cautious, you would not venture into many things that we routinely do while performing catheter procedures. A fine balance is therefore needed, and the line between being gutsy and being reckless can be quite thin at times. For example, attempting a trans-septal puncture in a small infant requires considerable courage. If one...
is too cautious, this skill would be hard to acquire and it would be impossible to access the left atrium under any circumstance when the atrial septum is intact. A “good interventionist” would strike a balance and perform a trans-septal puncture for situations where the benefits outweigh risks (such as in atrial septal stenting for hypoplastic left heart syndrome). On the other hand, routine puncture of the atrial septum to obtain accurate left atrial pressures when reasonable alternatives are available would be considered somewhat reckless. Courage is a vital attribute while venturing into unchartered territories but this must be tempered with a good dose of caution.

**Organization and planning (wanting to know and plan everything beforehand) versus flexibility and innovation (willingness to deal with uncertainties)**

Meticulous planning of hardware, access, anesthesia, and other elements of catheter interventions is vital to the success of most procedures. However, in spite of the best of planning, unexpected situations happen and have to be dealt with through improvisation and innovation. While complete absence of planning results in chaos, overreliance on the initial plan and fixed protocols results in an inability to deal with unexpected developments. Innovation is vitally essential in low-resource environment where hardware limitations are especially common.

For example, during a device implantation for atrial septal defect with reasonable transthoracic windows if the transesophageal probe stops functioning, it may be reasonable to deviate from institutional protocols mandating transesophageal echo and implant the device under transthoracic guidance.

**Thoroughness versus desire for speed and safety**

Traditional teaching encourages meticulous record of pressures and oximeter readings in every chamber entered during catheterization for “completeness.” There are merits to being thorough but this should not be at the cost of patient safety. For example, while performing balloon dilation in a newborn with critical pulmonary valve stenosis, it is perfectly reasonable to perform balloon dilation soon after crossing the valve without insisting on a pressure record from the pulmonary artery.

**Persistence versus knowing when to stop**

This is a fine balance that is often acquired after some years of experience and in some cases, hard lessons from previous complications. A good example would be attempts at retrieving an embolized device. Unduly prolonged attempts at retrieving the device could come at the cost of substantially prolonging the procedure and compromising patient safety. It is important to know when to stop and send the patient to a surgeon to safely retrieve the device.

**Emotional resilience versus ability to introspect**

Complications in cath lab can leave their scars on some operators. The effects can be potentially devastating and the operator may never want to venture into doing the same procedure again. The most vulnerable may lose their confidence altogether and this may affect other procedures. At the other extreme end of the spectrum, no lessons are learned and complications may continue to happen. Here, again having the right balance would allow for thoughtful introspection of the event and corrective measures to prevent the complication from happening again. The most successful interventional cardiologists have learned valuable and lasting lessons from their complications.

**Independence versus interdependence**

There are many elements of the catheter procedure that we can learn from our colleagues within and outside our specialty. With time, we acquire the skills and confidence to do them ourselves. I will share a few personal examples. When I started performing stenting of the arterial duct, I found it tremendously useful to ask an adult cardiology colleague to scrub in. Their familiarity with coronary hardware enabled a number of challenges to be overcome and we learned a number of tricks that greatly enhanced the safety of this challenging procedure. After about half a dozen occasions, I no longer needed their help except on selected occasions. Similarly, we often need the help of the anesthesiologist to help with ultrasound-guided access for difficult vessels such as the axillary artery. With time, some of us have learned the technique ourselves and our dependence has decreased. Excessive dependence on others to guide us all the time comes at the cost of efficiency. At the other extreme, reluctance to ask for help can considerably limit the scope of what we can accomplish in the cath lab.

**ROLE MODELS**

Like in any other endeavors, role models are vital in showing the way. Not everyone is fortunate to learn by working with a master. I was truly fortunate to work closely with some of the great names in catheter interventions. I thought and tried to identify the common traits among these masters with seemingly diverse personalities. In addition to possessing an excellent balance of the above-mentioned attributes, I have observed that the outstanding interventionists have solid foundations with a deep understanding of cardiovascular anatomy, physiology and hemodynamics, and catheter hardware. They have an accurate mental roadmap of normal and abnormal cardiovascular anatomy in three dimensions and they are able to rapidly integrate information from all imaging modalities. This allows effortless planning of angiographic views and much greater precision with
catheter manipulations. Hemodynamic foundations are vitally essential in case selection, identifying appropriate indications, taking correct on-table decisions, and anticipating specific complications (e.g., postreperfusion pulmonary edema following branch pulmonary artery stenting). A deep understanding of the design and characteristics of available catheter hardware is critical to the success of interventions. Almost all successful and innovative interventionists know their hardware really well.

A mature insight into the natural history of congenital heart disease and modified natural history following catheter interventions learned through objective appraisal of personal experience and published literature completes the picture. This essential attribute allows astute assessment of potential risks of the procedure versus potential benefits and enables correct decision-making in the vast majority of situations. While it is often difficult for those performing the procedure regularly to be truly objective about its benefits, with time, most interventionists mature and often temper their enthusiasm for procedures with borderline benefits.

WHAT ARE THE SPECIFIC CHALLENGES IN TODAY’S TIMES AND HOW CAN THEY BE ADDRESSED?

Today’s trainees have to be mindful of specific challenges that put them at a disadvantage when compared to their seniors. The senior-most interventionists among us trained in the eighties and early nineties performed diagnostic catheterizations regularly. This laid a solid platform for becoming experts in interventional catheterization. Diagnostic catheterization enables excellent practical experience in anatomy, hemodynamics, and catheter hardware. This has changed dramatically with improvements in noninvasive imaging, and the number of diagnostic catheterizations has declined sharply.

With growth in the number of centers performing interventional procedures, case volumes in individual centers have declined and this considerably limits opportunities for prospective trainees. Small case volumes have also come in the way of development of hardware specifically tailored to our needs. Unlike coronary interventions, specialized hardware has not been developed for many pediatric catheter procedures and there is a constant need to improvise with adult hardware. For example, stenting of the arterial duct is largely accomplished using adult coronary hardware that is designed for a different purpose.

Surgical and intensive care backup is critical to the safe performance of catheter interventions, and there are not many pediatric cardiac programs that have all elements in place in the developing world. This limits the development of advanced procedures such as closure of patent duct in preterms, pulmonary valve implantations, and newborn duct stenting to selected centers. Economic challenges are also substantial. Hardware, equipment, and infrastructure costs are substantial and continue to mount by the day.

Recent technological advancements may help address some of the challenges that today’s trainees’ face. Simulation laboratories for catheter interventions are currently expensive but may eventually become affordable and accessible to many. They have the potential of enabling a greatly accelerated learning curve and overcoming some of the challenges that today’s trainees face.

Similarly, three-dimensional (3D)-printed heart models may allow rapid anatomical understanding in normal and abnormal hearts and meticulous planning of procedures and device implants. However, I suspect, these tools will not replace learning from real-life situations, and training by serving as an apprentice to a master may still be the best way to learn catheter interventions.

HAND–EYE COORDINATION: HOW MUCH DOES IT MATTER?

Experience enables greater ease in maneuvering catheters. This is because of improved hand–eye coordination that undoubtedly contributes to both speed and safety. Like with driving automobiles, a great deal of the hand–eye coordination required for catheter manipulation is acquired subconsciously and improves with practice. While learning speeds vary, the skills can eventually be acquired by anybody who is determined and persistent. A high case volume helps in accelerating learning, and spending time in a busy program is almost always very useful.

It is important to recognize that the skills required in manipulating catheters while watching fluoroscopy monitors are quite different from those required while watching echocardiography (such as in device closure of the atrial septal defect).2,3 Today’s interventional cardiologists need to develop both the skills.

DO LIVE INTERVENTIONAL WORKSHOPS HELP?

Live interventional workshops have proliferated across the globe and several of them are conducted annually. It is presumed that live workshops enable learning through having experienced operators demonstrate procedures step by step. Unfortunately, not all live workshops serve to educate. In an effort to include a large number of cases and operators and showcase a variety of products of industrial sponsors, several compromises are made. Cases with borderline indications (e.g., closure of small membranous ventricular septal defects, stenting of borderline coarctation, etc.) are often included. There
is much greater focus on technique than indications and open discussion on appropriateness of case selection, and indications are often not encouraged. This is, in part, because the decision to perform the procedure has already been taken and the patient is on the table. There is also the temptation to get carried away and use the live demonstrations to showcase technical prowess. The less experienced and relatively naïve among the audience are likely to view inclusion of cases with borderline indication in the workshop as a collective endorsement from members of their fraternity.

There are, of course, important ethical considerations. The stress of performing in front of a large audience has the potential of influencing the results and outcomes in live interventional workshops when compared to natural settings.\(^\text{[14,5]}\) It is important to recognize that the most sought-after live operators have actually not depended on such workshops for their learning. Their skills have been honed during their training years through focus and hard work. Their core foundations are solid and set the stage for effective and safe innovations.

Notwithstanding these shortcomings, interventional workshops that are carefully designed can serve to educate. It is not perhaps necessary to have live cases demonstrated all the time. Well-edited simulations can allow many lessons to be learned without stress and time constraints. Open and honest discussions of complications are likely to be particularly educative.

**CONCLUSIONS: TEN COMMANDMENTS FOR THE ASPIRING INTERVENTIONIST**

- Remember that there is much more to pediatric cardiology beyond just doing interventions: This reality check enables you to stay humble and grounded. While interventionists are a vital component of a modern pediatric heart program, the truth is that all members of the team make important contributions to patient outcomes.
- Remain patient centered and not procedure centered: As skills improve, there is a great temptation to perform interventions for borderline clinical indications. Keeping the patient at the center of all decisions helps resolve many difficult clinical dilemmas and ensures greatest attention to safety.
- Acquire solid foundations in anatomy, hemodynamics, and natural history: As indicated above in the section on “role models,” these elements form the core foundations that all truly successful interventionists should possess.
- Investment in thoroughly familiarizing yourself with catheter hardware is truly worthwhile. It contributes greatly to technical mastery and sets the stage for most of your innovations.
- Become familiar with and look to integrate information from all forms of imaging: Today’s interventionists need to be familiar with a host of imaging modalities (2D and 3D echo, transthoracic as well as transesophageal, computed tomography, magnetic resonance imaging, conventional and rotational angiography), both to plan and execute procedures.
- Deeply introspect on your work objectively: Failures, complications, near misses, and even “successful cases.” An honest critical appraisal on one’s own work is at the very essence of quality improvement. Regular mortality and morbidity meetings are essential forums that must be created to enable collective and structured introspection.
- Endeavor to systematically collect data individually for your center and/or collectively through multicenter databases. Given the extraordinary diversity of the cases we deal with, it is essential to learn from each other through shared databases\(^\text{[6]}\).
- Seek opportunities for lifelong learning from within and outside your fraternity (adult cardiologists, interventional radiologists, research and development experts from industry).
- Be willing to innovate all the time and seek to objectively evaluate them and document them through publications.
- Always be mindful of costs: With careful thought, a number of ways can be found to drastically reduce the costs of catheter hardware without any compromise of patient safety.

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