

Original Article

Paediatric cardiac surgical education: which are the important elements?*

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Abstract Pediatric cardiac surgical education and the associated requirements for certification vary considerably from one country to another. Evolution and standardization for pediatric cardiac surgical education may not have kept pace with the evolution of other aspects of the specialty. Restriction of work hours and disqualification of foreign training experience constitute potential threats to our specialty. A global strategy for qualification and certification may help to address some of these difficult issues.

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Don't limit a child to your own learning, for he was born in another time (Rabindranath Tagore, Nobel Laureate in literature, 1913).

AN INVITATION TO DISCUSS EDUCATION MIGHT BE VIEWED suspiciously by cardiac surgeons; however in our particular case, we feel that we may have some qualifications in this area. We are past and current students of surgery, and we are beneficiaries of surgical education in both the United States of America and the United Kingdom. The senior author has a qualification in secondary education and is a former high school teacher. The authors are certified by the American Board of Thoracic Surgery (T.R.K. and J.P.J.) and the Royal Australian College of Surgeons (T.R.K.). Between the two of us, we have been employed in three countries, and

worked and taught temporarily in 12 others. We have together participated in teaching more than 50 paediatric cardiac surgical fellows, plus countless residents, registrars, medical students, etc. This sort of qualification is not unusual for paediatric cardiac surgeons of our era. Most importantly, we share a lifelong appreciation and affection for our own outstanding mentors: Jaroslav Stark, Marc de Leval, Martin Elliott, William Glenn, Roger B. B. Mee, Hillel Laks, Richard Perryman, et al.

Residency and fellowship in paediatric cardiac surgery, as in other specialties, are meant to transform a medical student into an independent practitioner. The basic strategy varies from country to country, but is always fundamental to the continuum of medical education. Cardiac surgical education can be physically, emotionally, socially, and intellectually demanding for those who accept the challenge. The same can be said regarding sponsoring institutions and their faculty. That having been said, we recognise that all cardiac surgeons, and their institutions, have a teaching obligation, which should insure the future of the specialty against extrinsic and intrinsic

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pressures. For cardiac surgeons, this teaching responsibility is indeed a professional responsibility.

To us, the Zen of cardiac surgery is the importance of both knowledge and experience. At its most basic interpretation, this implies that surgeons with knowledge and useful experience can and do perform better. Knowledge, experience, and the ability to help others find their best balance are also the attributes of our best surgical teachers.

Training and education are related but not synonymous, and the difference may be subtle. As an oft-cited example, let us say that your young daughter tells you that she is enrolled in a “sex education” course at school. You may well consider this to be an excellent idea. On the other hand, if she announces instead that she is going to have “sex training” at school, your reaction might be different.

Training specifically implies teaching vocational or practical skills relating to a specific competence – for example, an apprenticeship. Such arrangements date back to the era of craft guilds, and were usually meant for the lower and middle classes. Education involves helping someone to learn how to think and solve problems. The origins lie in the medieval university system, which allowed young men from wealthy families to study theology or philosophy before embarking on any chosen profession – hence the concept of the “renaissance man”.¹

As a modern example relevant to our specialty, obstruction of the left ventricular outflow tract in a neonate is a relatively rare but an important problem, which will invariably be presented to a paediatric cardiac surgeon for a solution. One way to deal with this problem is a neonatal Ross–Konno operation, which – most would agree – is technically as demanding as it gets in our specialty. Performing this procedure effectively requires intensive preparation and a broad fund of knowledge that usually has been acquired – and often hard won – over many years. It is not typically a procedure performed by a trainee, and even most senior surgeons will have limited experience. The outcome can be rewarding, but the risk is significant, and failure will not be tolerated by families, colleagues, or society. How can we learn to perform and teach this operation in less than 20 years? How can our students and trainees learn from the errors that we have made, without repeating the scenario? What sort of educational initiative is required?

To understand cardiac surgical education in the United States of America, it is helpful to consider the history. The American Association for Thoracic Surgery was founded in 1917, and 1928 marked the first formal training programme in thoracic surgery – University of Michigan – with a rapid evolution to an organised 2-year curriculum. The American Board of

- Endoscopy
- Pulmonary operations, TB surgery
- Esophageal operations
- Simple closed congenital heart operations
- Open heart operations
- Heart valve operations
- Complex congenital heart operations
- Coronary artery bypass
- Pacemaker and AICD implants
- Arrhythmia surgery
- Heart and lung transplantation
- Ventricular assist devices and ECMO
- Video assisted and robotic thoracic surgery
- Minimally invasive procedures
- Hybrid and endovascular procedures
- Catheter delivered valve implants



Figure 1.

Evolution of thoracic surgical procedures performed in the United States of America.

Thoracic Surgery was formed in 1948, and became a freestanding organisation in 1971.

It is sobering to consider that many of the procedures that were mainstays of practice during the early evolution of formal surgical training in the United States of America are now performed relatively infrequently, or not at all (Fig 1). The nature of thoracic operations today reflects evolution – if not revolution – in both science and technology, as well as all of the changing non-surgical considerations that affect cardiothoracic surgeons; however, are paediatric cardiac surgeons themselves really different today? This question has probably been debated in every era, but the constant features seem to be the high valuation of technical excellence as well as an ability to use the available tools to the best advantage. Beyond this, the (sometimes) tiresome politics of surgical life seem to transcend all eras.

The “traditional” training sequence in the United States of America for paediatric cardiothoracic surgery is as follows (PGY = post-graduate year):

- University and medical school education: 8 years
- PGY-1 through PGY-5 or 6: general surgery
- PGY-6 or 7 through PGY-8 or 9: cardiothoracic surgery
- PGY-8 or 9 or 10: paediatric cardiothoracic surgery
- Research requirement: additional 1–3 years

Interestingly, no formal experience in paediatrics or cardiology is required during the sequence. Before 2009, there was no specific credentialing for paediatric cardiac surgery in the United States of America (see below). How does this training requirement compare with that encountered in other parts of the world?

We have recently conducted a survey regarding this question, and the results are summarised in Figure 2,

Training sequence in the real world

Karl TR et al 2016 (unpublished data)

	Range (years)	Median	Mean	SD
Medical school graduation to first staff posting	6 - 14	10	10.2	2
General surgery	0.5 - 7	3	3.1	1.8
Age (1 st staff post)	29 - 47	35	35.6	3.5
Age (1 st VSD)	28 - 49	34	34.5	4.23
Age (1 st TOF)	29 - 49	35	35.4	4.0
Age (1 st ASO)	32 - 52	36.5	37.5	4.2
Age (1 st Norwood)	32 - 61	39.5	39.7	5.8

Sample from USA, Canada, Colombia, France, Germany, Italy, Spain, UK, Portugal, India, Australia, New Zealand, Turkey, Sweden, Brazil, Japan, South Africa

Figure 2.

Training sequence for paediatric cardiac surgery in various countries.

with responses from the United States of America, Canada, Brazil, Colombia, United Kingdom, Spain, Portugal, France, Germany, Italy, Sweden, Turkey, India, Australia, New Zealand, Japan, and South Africa. The median time from medical school graduation (qualification) to first staff posting varied from 10 years (8–10.5) in the United States of America, to 12 years (7–13) in Europe, and 11 years (6–12) elsewhere. The median time spent learning general surgery – before commencing cardiac training – also varied, from 5 years (4–6) in the United States of America, to 1 year (1–3) in Europe, and 2 years (0.5–4) elsewhere. Relative uniformity in surgical outcomes – Society of Thoracic Surgery Congenital Heart Surgery Database and European Congenital Heart Surgeons Association Congenital Heart Surgery Database – would suggest that all of these schemata have been successful to some extent. The question, to us, relates more to efficiency and the best use of the precious years allotted to the training exercise.

In America, for example, life at 36 years of age for a paediatric cardiac surgeon finishing training might be characterised by a \$250,000.00 debt, with no good job on the horizon. A lawyer, on the other hand, would have a reasonable chance of already being a partner in a firm, with 6–10 years of experience in the profession and a substantial salary. Some successful young entrepreneurs would already be enjoying retirement from their own information technology-based start-up companies.

Looking further at the current system in the United States of America, the American Board of Thoracic Surgery has now formalised paediatric cardiac surgical training with a specific 1-year curriculum.² There are written and oral examinations involved, and the overall probability of successful completion is ~75%. At present, this experience can only be acquired in

12 North American institutions approved by the Accreditation Council for Graduate Medical Education. Primary operative experience is required for 75 cases within a single 12-month period.²

One might ask why this experience is based on time – rather than competence. Certainly, various initiatives and therapies in traditional medicine, some persisting even today, have their basis on the motion of moons, stars, and planets. Infectious endocarditis, for example, might require antibiotic therapy for one lunar cycle, and chemotherapy for tuberculosis typically lasts for one revolution of the earth around the sun. A lot can happen during this time span. In the United States of America, the passage of a typical year is marked by the following:

- 4 million births,
- 2.5 million deaths,
- 1.17 million violent crimes,
- 30,000 deaths by firearms,
- 1.56 million drug-related arrests,
- 600,000 new millionaires,
- 32,600 deaths in road accidents,
- \$618 billion spent on military initiatives,
- \$3.1 trillion spent on healthcare, and
- 2000 heart transplants.

The short 1-year time frame for paediatric cardiac surgical training, however, makes the United States of America an outlier, and this, in part, relates to the substantially longer time requirement for general surgical training before commencing cardiac training. We all have our limits, self-imposed or otherwise.

Another background concern is how hospitals, institutions, and payers in the United States of America will use the credentialing initiative to their respective advantages. The “volume–outcome” challenge in our specialty has implications for how we teach and how we learn. Analysis of the Society of Thoracic Surgeons Congenital Heart Surgery Database has revealed an inverse association between paediatric cardiac surgical programmatic volume and mortality that became increasingly important as case complexity increased.³ In this analysis, there was an inverse relationship between overall surgical programmatic volume as a continuous variable and mortality ($p=0.002$), with an inflection point between 200 and 300 cases per year.³ Lower volume institutions are known to have greater variability in outcome, although notable outliers exist at both extremes. It therefore has been suggested that in smaller units, case selection is especially important; however, maintaining appropriate case numbers for rare lesions might require restriction of involvement to a limited group of surgeons, even in large units. This posture has implications for patient care, clinical

research, systems of reimbursement, various intra-institutional agendas, and, very importantly, for the teaching of cardiac surgery.

The minimal requirement for case numbers within an institution is controversial. In the United Kingdom (“Safe and Sustainable” initiative) it has been suggested that each paediatric cardiac unit should have four or more surgeons, with a critical mass of 500 cases, and an absolute minimum of 400.⁴ For the United States of America, official recommendations are not currently available. The European Association for Cardio-Thoracic Surgery (Consensus Committee for Congenital Heart Disease) suggests that in a given unit two or more fully trained staff surgeons should perform >250 operations per year, including more than 100 infants. For Germany, the suggestion is similar to that of the European Association for Cardio-Thoracic Surgery.⁵ In France, there are currently five centres performing >400 cases, one centre performing >700 cases, and one centre performing >800 cases.

Clearly this variation in opinion and practice is rooted in many local factors, including economics and the basic structure of the various systems of healthcare. As a reality check, creation and maintenance of high-volume centres require consolidation and/or elimination of lower-volume centres, which, based on recent experience in the United Kingdom, is more easily said than accomplished. In the United States of America, closing half of the centres currently performing paediatric cardiac surgery – if it were even remotely possible – would still not achieve the 500 case/year goal stated above for the remaining centres. It has been said that the United States of America has a manpower crisis in healthcare, but is it more the lack of an affordable, effective, and rational system of healthcare? Rightly or not, public attention is focussed on our expensive boutique specialty, which may have dramatic benefits for patients and families, but very little effect on child health worldwide. This situation detracts in turn from any real public sympathy for trainees struggling through the system.

Returning to the relatively recently established paediatric cardiac surgical training system in the United States of America, early data suggest some important success in the attempt to standardise paediatric cardiac surgical education and training.⁶ Case numbers and distribution have improved, and the initiative seems to have been accepted by most of the paediatric cardiac community – or at least those aware of it. On the other hand, all non-North American centres have been excluded as institutions approved to train candidates for the Congenital Heart Surgery Certificate offered by the American Board of Thoracic Surgery. The training remains time based rather than competence based – you get a year!

Paediatric Cardiac Surgery advances realised primarily outside the USA

- Arterial switch (Brazil)
- Current concepts of mitral and tricuspid valve repair (France, Brazil)
- Senning and Mustard operations (Switzerland, Canada)
- REV (Lecompte) operation (France)
- Sung repair for TOF (Korea, Japan)
- MBTS (UK)
- Fontan operation and BCPS (Argentina, France, USSR, Italy)
- Kawashima operation(s) (Japan)
- Barbero-Marcial operation (Brazil)
- Marceletti operation (EC Fontan) (Italy)
- Cardiac transplantation (South Africa)
- Double switch and Senning-Rastelli for ccTGA (Japan, Australia, USA)
- Melody and Cribier catheter delivered valves (France, UK)
- Berlin and Medos paediatric VADs (Germany)
- Ross operation (UK)
- Unifocalisation of MAPCAs (UK, Australia)
- LV conditioning and Senning to ASO conversion (Australia)
- Nomenclature systems (UK, Netherlands, Japan, USA)

Figure 3.

Examples of paediatric cardiac surgical advances realised primarily outside the United States of America – partial list.

Requirements are still based on many original concepts of the Accreditation Council for Graduate Medical Education and the American Board of Thoracic Surgery. What remains to be shown is whether competence can actually be guaranteed by this system, and when, how, and by whom that might be judged.

Paediatric cardiac surgery, almost since its birth, has been characterised by advances realised both inside the United States of America and outside the United States of America. Some notable examples of the latter are shown below (Fig 3). Likewise, many prominent paediatric cardiac surgeons working in the United States of America have had at least a portion of their surgical education outside the country. It goes without saying that major contributions have and will come from distant individuals and centres of excellence. Paediatric cardiac surgery is therefore inextricably linked to international cooperation and exchange of ideas. Many past trainees have derived great personal and career benefit from training and work experience outside their native countries, and for some it has actually been a requirement. For trainees from the United States of America, since the creation of the Congenital Heart Surgery Certificate by the American Board of Thoracic Surgery, this phenomenon has all but disappeared – for example, The Great Ormond Street Hospital for Children, once a highly desirable training institution for North American paediatric cardiac surgeons, has had no trainee from the United States of America since 2005.⁷ Surgeons in the United States of America, therefore, may be at risk for intellectual and technical isolation – in paediatric cardiac surgery and healthcare in general. This situation is an unfortunate and direct consequence of the creation of the Congenital

Heart Surgery Certificate offered by the American Board of Thoracic Surgery, although this certificate does not prevent a candidate from obtaining additional training overseas before or after the year dedicated to qualifying for the certificate.

In the current era, the requirement for transparency in the analysis of outcome and public reporting undoubtedly affects attitudes towards educating young cardiac surgeons, especially in the more complex aspects. It has been said that paediatric cardiac surgery is not for the weak willed, the thin skinned, or the resource challenged. Failure can have devastating consequences for patients, families, and of course for the surgical team itself. Surveillance and criticism from every level is the new standard, and idealism in enforcing this standard seems to be directly proportional to distance from the clinical issues. This challenge has always been our cross to bear, although over the time of our own careers, the escalation has been astounding. The Society of Thoracic Surgeons Congenital Heart Surgery Database currently contains information from 127 hospitals in North America – 124 in the United States of America and three in Canada.⁸ These institutions represent over 95% of the hospitals in the United States of America that perform paediatric cardiac surgery. Variation in outcome between centres may create important opportunities for collaboration to improve global results, but who should have access to this detailed information? Full public reporting may be disruptive in some ways, but the concept is becoming more widely accepted among medical practitioners, and there is great public demand as well. We should be proactive to ensure the quality of the data and analysis. The implications for surgical education are obvious. Patients, families, and our own colleagues demand excellence, but there is limited support for providing opportunities for trainees to perform complex paediatric cardiac surgical procedures.

In this era, an early unfavourable experience with, for example, the arterial switch operation, even for a single case, could have lasting negative effects for a surgeon recently out of training, even to the point of prematurely ending a career. Furthermore, although full disclosure to families is now expected, very few parents would choose to engage an inexperienced surgeon over one with a good track record for the arterial switch operation. We wonder how many surgeons listening to or reading this lecture have ever helped a trainee perform an arterial switch operation. For those who have, was this disclosed to referring cardiologists and parents before the operation? Was any special consent obtained?

In any case, the pressure is both real and intense. This issue has been addressed recently in a report from Birmingham, United Kingdom.⁹ The analysis of outcome for neonatal arterial switch operation

suggested no compromise in quality for less-experienced, consultant-level surgeons – the study did not include trainees per se. The operations were performed within a highly structured programme of graded supervision from more senior consultants in the unit. Whether or not this approach can be generalised across institutions and healthcare systems, and for operations other than the arterial switch operation, remains to be demonstrated.

At day's end, what is really important in paediatric cardiac surgical education? We propose a balanced and structured training programme that emphasises knowledge and competence over time alone. There should be a dramatic increase in time spent in specific areas of general and specialised paediatric training (versus general surgery). As cardiology and cardiac surgery move towards a unified discipline, novel teaching methods and curriculum will be required. We must develop realistic guidelines for experience that will be accepted by patients, families, and members of the team, as well as the trainees themselves. Ideally, we should evolve to embrace an international “board certification” or equivalent, and to a system that could ensure a basic level of competence independent of any one healthcare model. Such a system would include a peer reviewed mode of assessment for maintenance of competence. It is fundamental that continuation of mentorship^{10,11} at some level across the lifetime of all surgeons should be promoted and recognised.

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