Paediatric/congenital cardiology physician scientists—An endangered species

Abstract
Producing excellent physician scientists starts with the active discovery of talent and dedication, supported by the strong belief that physician involvement in biomedical research is essential to make fundamental discoveries that improve human health. The revolution of surgical and interventional therapy of structural heart disease has had ‘profoundly positive effects on survival and quality of life over the decades. (…) Small increments in clinical improvement will still be possible in the future, but for the most part, the potential for major advancement using these techniques has been exhausted’ (Frank Hanley, MD; Stanford). Personalized medicine, rapid genetic diagnostics, RNA and extracellular vesicle biology, epigenetics, gene editing, gene and stem cell-derived therapy are exemplary areas where specialized training for paediatric/congenital cardiology physician scientists will be increasingly needed to further advance the field. About a decade ago, a series in Circulation discussed academic career models and highlighted the major challenges facing the cardiovascular ‘clinician scientist’ (syn. physician scientist), which have not abated since. To develop the skills and expertise in both clinical congenital cardiology and basic research, the training of fellows must be focused and integrated. The current pandemic COVID-19 puts additional pressure and hurdles on fellows-in-training (FIT) and early career investigators (ECI) who aim to establish, consolidate or expand their own research group. Here, we discuss the major challenges, opportunities and necessary changes for academic institutions to sustain and recruit physician scientists in paediatric/congenital cardiology in the years to come.

1 | INTRODUCTION
Producing excellent physician scientists starts with the active discovery of talent and dedication, supported by the strong belief that physician involvement in biomedical research is essential to make fundamental discoveries that improve human health.1,2 The revolution of surgical and interventional therapy of structural heart disease has had ‘profoundly positive effects on survival and quality of life over the decades. (…) Small increments in clinical improvement will still be possible in the future, but for the most part, the potential for major advancement using these techniques has been exhausted’ (Frank Hanley, MD; Stanford).3 Personalized medicine, rapid genetic diagnostics, RNA and extracellular vesicle biology, epigenetics, gene editing, gene and stem cell-derived therapy are exemplary areas where specialized training for paediatric/congenital cardiology physician scientists will be increasingly needed to further advance the field.4 About a decade ago, a series in Circulation discussed academic career models and highlighted the major challenges facing the cardiovascular ‘clinician scientist’ (syn. physician scientist),5 which have not abated since. To develop the skills and expertise in both clinical congenital cardiology and basic research, the training of fellows must be focused and integrated. The current pandemic COVID-19 puts additional pressure and hurdles on fellows-in-training (FIT) and early career investigators (ECI) who aim to establish, consolidate or expand their own research group. Here, we discuss the major challenges, opportunities and necessary changes for academic institutions to sustain and recruit physician scientists in paediatric/congenital cardiology in the years to come.

2 | THE FIELD OF PAEDIATRIC/CONGENITAL CARDIOLOGY IN 2020
Congenital heart disease (CHD) is probably one of the most rapidly developing fields among all subspecialties
in cardiology, if not in clinical medicine. Nowadays, congenital and adult cardiologists encounter a delicate patient group—the adult survivors, so-called “grown-up’s”, with CHD (abbrev: GUCH or ACHD). Indeed, based on basic, translational and clinical research, great progress has been made in the refinement of diagnostic tools and therapies that had major impact on clinical outcome, far beyond the field of paediatric cardiology and CHD. For example, transcatheter aortic valve implantation (TAVI) in the elderly would have never been developed and applied so quickly and broadly in adult cardiology without the seminal engineering and first-in-human clinical application of percutaneous pulmonary valve implantation (PPVI) by paediatric cardiologists 20 years ago. Survival in children with CHD has increased substantially since the 1980s, so that currently, over 97% of children with CHD can be expected to reach adulthood, highlighting the need of life-time management. However, no significant, additional improvement in CHD survival has been observed in the last century, based on a recent pre-print publication on the Swedish health registry (1980-2017). This observation implies that novel, courageous and innovative steps in translational research are needed not only to improve long-term survival but also quality of life in patients with congenital/paediatric cardiovascular disease.

3 | DEFINITION OF A PAEDIATRIC/CONGENITAL CARDIOLOGY PHYSICIAN SCIENTIST

The well-trained, independent physician scientist in paediatric/congenital cardiology (MD or MD/PhD) leads a research group or programme in industry or academia, related to congenital heart disease and/or other cardiovascular disorders. We estimate that currently less than 20 cardiologists in N. America and Europe fulfil the criteria of an independent paediatric/congenital cardiology physician scientist (Figure 1).

4 | MAJOR CHALLENGES AND AREAS OF CONCERNS FOR FIT/ECI IN PAEDIATRIC/CONGENITAL CARDIOLOGY

4.1 | Combining clinical and research training

All trainees in paediatric/congenital cardiology must demonstrate productive research and scholarly activity in order to be board-eligible in the United States. Outstanding training programmes have the flexibility to allow their FIT to explore different subspecialties within the first 18-24 months of clinical training. The transition to a dedicated basic and/or translational laboratory researcher usually is scheduled after the completion of clinical core requirements and should be largely uninterrupted. Trainees may pursue such a postdoctoral research fellowship in the period between medical school and residency, during residency (research-in-residency programmes, RiRs), between residency and fellowship, or in physician scientist training programmes (PSTPs), spanning residency and fellowship. Fellows-in-training pursuing procedural subspecialties such as intensive care, electrophysiology or interventional cardiology may have to increase their clinical volume, but this should be scheduled after the core clinical training and after the 24 months basic research training.

You can do this all, but not at the same time!
(Jane Newburger, MD, MPH; Boston)

4.2 | Combining clinical and research responsibilities as junior faculty

Adjusting clinical responsibilities will facilitate this successful transition by allowing young faculty to focus on developing their research programmes. For United States-based neonatology and paediatric critical care physician scientist faculty, an upper limit of 10-12 annual clinical weeks, and an in-house (or equivalent) call coverage of maximal 24 nights per year was recently proposed. Ongoing refinement of clinical skills and experience is essential and possible by finding/creating a ‘clinical niche’ that parallels the ECI’s research interest (e.g., specialty clinics).

4.3 | Funding and transition to independence

The transition to independence must be carefully planned because of the additional responsibilities inherent to clinical medicine, and the critical risk of attrition, particularly in this period. After the completion of clinical training, FIT/ECI might be hired as ‘instructors’ or assistant professors while continuing their research in a mentored environment. Successfully obtaining transitional funding such as a K-awards from the National Institutes of Health (NIH), or similar federal grants, is often an important step towards independence (Table 1).

4.4 | Barriers to sustained physician scientist research programmes

The European Research Council (ERC) is the only funding agency in Europe that provides grants that are similar in
volume to NIH R01 grants, that is, Starting Grants (STG) and Consolidator Grants (COG). Unfortunately, in 2019, the ERC has limited the eligibility window for applicants by only acknowledging 4 years of clinical training as an add-on to a maximum of 7 (STG) or 12 (COG) years after obtaining the first eligible degree (MD or PhD). We had 6-9 years of clinical and 3-5 years of postdoctoral basic science training. The implemented change prevents us and other well-trained clinicians from applying to current STG or COG ERC grants. If sustained funding of physician scientists is a serious endeavour, the ERC should reconsider and revise the recent short cut in training time so that more than 4 years of training can be used to expand the period of grant eligibility (Table 1).

5 | OPPORTUNITIES FOR IMPROVEMENT AND AREAS OF GROWTH

5.1 | Scientific oversight and advice

Formal selection of appropriate, clinical and research mentors is critical for the successful development of paediatric/congenital cardiology physician scientists. A formal scholarship oversight committee (SOC) should be implemented for each FIT at the institutions. Regular follow-up with the trainee—or even junior faculty—by the SOC during the dedicated research training should focus on whether there is adequate support within the research environment, progression
| Area of Concern          | Challenges                                                                                                                                                                                                 | Possible Solutions/Opportunities                                                                                                                                                                                                                     |
|-------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Innovation              | • Cardiovascular physician scientists must keep current on rapid developments in multiple areas including genomics, developmental biology, molecular biology, metabolism and physiology.                             | *Institutional Level:* Develop training programmes for bioinformatics, machine learning and bio-engineering.  
*National/International level:* Establish networking solutions to improve collaboration across disciplines.                                                                                                                                         |
| Early career support     | • Clinical responsibilities and lack of formal career development and mentorship often lead to attrition of EC physician scientists.  
• In Europe, more than 50% protected research time for EC physician scientist is extremely rare, although required for transition to independence.  
• Limited international postgraduate programmes for physician scientists.  
• Risk of attrition and burn-out is high in nonsupportive research environments.  | *Institutional Level:* Establish scholarship oversight committees (SOC) comprised of senior faculty to advise EC physician scientists in career planning/development and grant writing.  
• The SOC helps prioritizing responsibilities and learning when to limit external requests.  
• Clinical responsibilities should be limited to ensure EC physician scientists have dedicated time to build a research career.  
• Pursue collaborative leadership and open networking.  
*National/International level:* Establish advanced physician scientist programmes (PGYs 5-12).                                                                                                                  |
| Barriers to independent funding | • Time limitations on applying for career development grants precludes many physician scientists from obtaining critical independent funding.  
• In Europe, most national grants are too small in volume to secure independence for the establishment of an innovative research group.  
• In the United States, currently, there is an enormous backlog of successful NIH K08 grant holders awaiting positive decisions on independent grant funding. | *Institutional Level:* Increase the allowed time for physician scientists after completion of training to prepare and submit independent research grants.  
*National/International level:*  
United States:  
• Training: Multiple grants are available including the institutional T32, postdoctoral F32, the medical research investigator training KL2 grant and AHA-sponsored postdoctoral training grants.  
• Transition: Traditional transition NIH grants include the K08 and K99/R00 awards for basic investigation with the K23 for patient-oriented research. AHA career development grant (formerly fellow-to-faculty)  
• Independence: The first independent grants are typically NIH R01, R00 portion of K99/R00 and occasionally R21. The AHA Transformative grant offers 3 y of programme support.  
Europe:  
• Training: European Training Network (ETN), that is non-PhD holders that may work for 3 y with a contract in a clinic/industry/ fundamental research institution aiming to a doctoral degree. Research and Innovation Staff Exchange (RISE) action (few months of paid experience in a basic research laboratory or industry), ESCI grants.  
• Transition: Marie Sklodowska-Curie EU actions, national EC/physician scientist grants, international advanced PostDoc programmes  
• Independence: ERC grants (STG, COG), large national grants | |
| Limited career pathways  | • Traditional physician scientist pathways have limited innovation in healthcare delivery or integration with industry.  
• Traditional healthcare innovation has focused on the development of new diagnostics, drugs and devices.                                                                                       | *Institutional level:* Establish formal criteria for academic advancement and funding support for investigators engaged in this area.  
*National/International level:* Establish an ecosystem where clinician innovators can interface with industry partners and academia to improve systems of healthcare delivery. |

Abbreviations: EC, early career; ERC, European Research Council; PGY, postgraduate year.
to publication and/or funding, and resolution of any problems that may occur.

5.2 Academic culture

The academic culture of ‘seeing and supporting ECIs develop and blossom’\(^{14}\) is less developed in Europe than in N. America. The *European Heart Journal* just published a series of articles on the need for culture change and collaborative leadership,\(^ {15}\) culminating in the statement ‘If physicians in leadership roles have to pull others down for them to shine, there are fundamental fault lines in the foundation of that department or division’\(^ {14}\). It is the duty of the SOC of each FIT/ECI to detect and eliminate such unhealthy and unproductive constellations. Implementing departmental and institutional ECI committees, consisting of senior fellows and ECI faculty, and an independent ombudsperson, can be important steps to meet these needs.

5.3 Physician scientists and clinician innovators in academia, start-ups and industry

The emergence of digital health technologies, coinciding with the rapid growth of personal and population ‘big data’, may help us diagnose and treat cardiovascular disease more effectively and efficiently. Besides career tracks for physician scientists and clinician educators, more recently, the clinician innovator pathway was proposed as a new career path within academic medicine that may be ideal for trainees interested in the intersection of healthcare delivery and emerging healthcare technologies.\(^ {16,17}\) Clinician innovators have diverse experiences and are responsible for creating desirable, sustainable, and scalable solutions and thus can bridge the gap between academia and industry\(^ {16}\) (Table 1). The Medical Intelligence and Innovation Institute (MI3) in Orange County, California, for example, has a major focus on paediatric cardiology, cardiac surgery and critical care.\(^ {18}\)

5.4 Open networking and support of the physician scientist workforce

The *Physician Scientist Support Foundation* (www.thepsf.org) has the mission to build a sustainable and diverse physician scientist workforce, but depends on partners to finance the implementation of this plan.\(^ {2}\) Mentoring networks may assist those pursuing hybrid careers (*William Guy Forbeck Research Foundation*).\(^ {19}\) The *Children’s Heart Foundation, AHA and ACC* occasionally offer moderate grant programmes specifically for FIT/ECI in paediatric/congenital cardiology. Given the length of subspecialty training, federal loan repayment programmes should be extended and easily accessible for physician scientists and MD/PhD students. The *American Society of Clinical Investigation (ASCI)* gives physician scientists a good platform to present their research, but cannot assist much in improving career perspectives on institutional/national level. The alike *European Society for Clinical Investigation (ESCI)* would greatly benefit from solid EU funding, boosting the reputation and scientific impact of its scientific journal and meetings. Active collaborations among ASCI, ESCI and other societies via international postgraduate programmes are desirable.

6 Conclusions and perspectives

Ongoing changes in the healthcare systems, limited access to research facilities due to COVID-19, and decreases in research funding threaten the career path as physician scientist in North America and Europe. Barriers to successful cardiovascular physician scientist careers include (a) increased medical specialization (particularly in paediatric/congenital cardiology), (b) unscheduled clinical duties during ‘protected’ research periods, (c) limited loan repayment programmes, (d) nonsupportive academic environments and (e) decreased/stagnant research funding. Opportunities for improvement and areas of growth include the formal implementation of powerful SOC and ECI committees that guide FIT/EC investigators, academic cultural change that drives individual development and productivity, new clinician innovator pathways in cardiac critical care (side-by-side with physician scientists), and intensified, open networking and support of physician scientists in the field of paediatric/congenital cardiology.

**KEYWORDS**

adults, children, clinician innovator, clinician scientist, congenital heart disease, early career development, mentoring, paediatric cardiology, physician scientist

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