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FELLOWS-IN-TRAINING & EARLY CAREER PAGE

Innovation in Cardiology Fellowship and Early Careers

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For many cardiologists-in-training, fellowship can seem to be just another educational stepping stone on the way to becoming the experts we all aspire to be. A primary purpose of this stage in training is, of course, the acquisition of specialized knowledge skills in cardiovascular medicine. Beyond this, however, I would argue that it also provides trainees with a critical window for creativity that is not to be overlooked. Perhaps paradoxically, it is the lack of expertise in a field that can enable fellows to discover inefficiencies in tools, systems, and methods that more seasoned clinicians have grown accustomed to working around. As part of my fellowship education, I have been fortunate to receive mentorship in cardiovascular innovation from my teachers at the Cleveland Clinic and Cleveland Clinic Innovations, its commercialization arm. Key lessons learned from them are summarized in **Table 1**.

Improvements in prevention, diagnosis, and treatment of cardiovascular disease have allowed for a multifold decrease in age-adjusted cardiac death rates since the 1950s (1), much of which has been directly related to the incorporation of disruptive tools and techniques. From introduction of the intra-aortic balloon pumps pioneered by Kantrowitz et al. (2), defibrillators promoted by Zoll, Lown, and others (3,4), coronary angiography developed by Sones (5) in the 1960s, right heart catheterization perfected by Ganz and Swan in the 1970s (6), percutaneous intervention developed by Grüntzig in the 1970s and 1980s (7), and transcutaneous aortic valve insertion by Cribier et al. in the 2000s (8), to name a few, development and adoption of novel tools have allowed for remarkable progress in outcomes of everyday patient care. Many of these innovations were discovered by physicians in their early careers. Famously, DeBakey developed his roller pump, which later became a crucial part of the heart-lung machine, at the age of 25 as a medical student (9).

One common feature of all of the aforementioned medical devices, as well as many other successful innovations, is that they all provide solutions for important clinical problems. Hence, it is safe to say that devices, medications, and workflow alterations that meaningfully improve clinical outcomes and patient experience are well positioned to be commercially successful, as well as to help improve the standard of care. Because physicians face patient challenges on a daily basis, they have an excellent insight that allows them to identify crucial issues and define effective solutions. Therefore, it is not surprising that doctors authored almost 20% of medical device patents filed in the United States between the years 1990 and 1996. Moreover, physician patents had a greater impact on subsequent inventive activity than nonphysician patents (10).

Another crucial tool in a budding inventor's armamentarium is the ability to collaborate productively. Even the most versatile individual is unlikely to possess all of the requisite skills warranted for a successful start-up. Frequently, off-the-shelf solutions to a question posed by 1 member of the team (e.g., a physician dealing with a clinical problem) may exist in an unrelated area of technology well-known to another team member, such as an engineer or information technology professional. This allows for faster, more cost-effective development. Alternatively, limitations that may seem to be an unavoidable part of a tool or process by some participants could be recognized as historical and arbitrary to those with different backgrounds. Additionally, products developed for use in medicine and health care may have a broader potential utility in other areas of human endeavor, maximizing the possible impact of a given solution. Finally, commercialization

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TABLE 1 Strategies for Successful Innovations in Cardiology

Strategy	Example of an Approach
Focus on patient-centered solutions	Identify and address challenges patients face
Collaborate as a part of a multidisciplinary team	Seek out like-minded engineers, scientists, and business executives to help address clinical problems
Engage well-known as well as newly arising challenges	Test established notions against the current understanding of processes
Understand how to utilize existing resources	Reach out to a technology transfer office, consider grant options
Rationally deal with failure	Accept reality, alter idea to useful form

Strategies and examples for cardiologists to address new and long-standing patient challenges.

expertise is crucial in helping to raise development funds, organize the workflow, identify the scope of the solution, decide on licensing a technology, develop collaboration, or spin off a new company.

As fellows in training aspire to have academic careers, it is useful to understand the crucial role that academic institutions can play in new technology development. Most nonprofit universities, teaching hospitals, and research laboratories have technology transfer offices. In many cases, these offices have been focused on maximizing revenue through intellectual property creation and patent licensing (11). However, this strategy can be limited by a costly and convoluted patenting process, a need to predict solutions that will be successful in the marketplace, and reliance on the goodwill of industry partners, who may have substantial investments in alternate approaches. On the other hand, although rare, academic spin-offs can be very successful (12) as they de-risk novel concepts and are able to rapidly alter approaches in response to emerging data. Moreover, because they do not need to focus on large market solutions and lack the pressure to be immediately commercially viable from shareholder or venture capital obligations, academic start-ups can create a whole host of facilitating inventions. Some of these advances, although too small to satisfy for-profit market demands, can oftentimes be crucial for enabling future innovation. Last, support structure, including research and development facilities, prototyping, administrative support, fund-raising, and marketing costs, could be shared by a number of projects supported by a forward-looking technology transfer office. This can help with decreasing overhead costs, minimizing the physician's nonclinical involvement, and ultimately, maximizing efficiency.

Another important component of an inventor's success is the willingness to tackle previously established challenges. How does this apply to fellows? They are facing age-old clinical problems in the course of education, during which time it should become habit to test any accepted truisms and preconceived notions against the current understanding of underlying processes. It is also important to consider alternate uses of available modern technology, such as the use of social media in patient education or the role that smartphones can play in the improvement of medication compliance. As many young physicians often have diverse undergraduate educational backgrounds, it may be useful to utilize their knowledge to facilitate formulation of unorthodox solutions to problems. Additionally, as fellows enjoy easy access to the expertise of their advisers, they have a tremendous opportunity for rapid idea vetting, which can help save valuable time and resources.

Finally, it is important to understand that failure is an option. As the founder of the online payment processor PayPal, electric car company Tesla, and a space transport service company SpaceX, Elon Musk has stated, "If things are not failing, you are not innovating enough" (13). The key is to stay open minded and be able to accept reality if the initial direction ends up being a dead end, which can allow you to pivot the idea into a useful form.

As has been the case for the field of cardiology over the past 6 decades, technological progress will continue to play an important role in molding future clinical practice. Cardiology fellows can and should actively participate in this process. To be able to provide relevant innovations, inventors should focus on patient-centered solutions, be able to effectively collaborate as a part of a multidisciplinary team, know how to utilize existing resources, be willing to engage in well-known and new challenges, and most importantly, be able to rationally deal with (and build upon) inevitable failures.

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