'The Digital Cardiologist': How Technology Is Changing the Paradigm of Cardiology Training

Sebastian Vandermolen[a,b], Fabrizio Ricci[c,d,e], C Anwar A Chahal[a,f,g,h], Claudio Capelli[i], Khalid Barakat[a], Artur Fedorowski[d,j], Mark Westwood[b], Riyaz S Patel[a,i], Steffen E Petersen[a,b], Sabina Gallina[c], Francesca Pugliese[a,b], and Mohammed Y Khanji[a,b,k]*

From the [a] Barts Heart Centre, Barts Health NHS Trust, London, West Smithfield, EC1A 7BE, UK, [b] NIHR Barts Biomedical Research Centre, William Harvey Research Institute, Queen Mary University of London, EC1A 7BE, UK, [c] Institute of Advanced Biomedical Technologies, Department of Neuroscience, Imaging and Clinical Sciences, "G.d'Annunzio" University, Chieti, Italy, [d] Department of Clinical Sciences, Lund University, Jan Waldenströms gata 35 – 205 02, Malmö, Sweden, [e] Casa di Cura Villa Serena, Città Sant'Angelo, Pescara, Italy, [f] Center for Inherited Cardiovascular Diseases, WellSpan Health, Lancaster, PA, [g] Cardiac Electrophysiology, Cardiovascular Division, Hospital of the University of Pennsylvania, Philadelphia, PA, [h] Department of Cardiovascular Medicine, Mayo Clinic, Rochester, MN, [i] Institute of Cardiovascular Science, University College London (London, UK)., [j] Department of Cardiology, Karolinska University Hospital, and Department of Medicine, Karolinska Institute, Stockholm, Sweden and [k] Newham University Hospital. Glen Road, Plaistow, Barts Health NHS Trust. London, UK.

Abstract: In the same way that the practice of cardiology has evolved over the years, so too has the way cardiology fellows in training (FITs) are trained. Propelled by recent advances in technology—catalyzed by COVID-19—and the requirement to adapt age-old methods of both teaching and health care delivery, many aspects, or 'domains', of learning have changed. These include the environments in which FITs work (outpatient clinics, 'on-call' inpatient service) and procedures in which they need clinical competency. Further advances in virtual reality are also changing the way FITs learn and interact. The

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proliferation of technology into the cardiology curriculum has led to some describing the need for FITs to develop into 'digital cardiologists', namely those who comfortably use digital tools to aid clinical practice, teaching, and training whilst, at the same time, retain the ability for human analysis and nuanced assessment so important to patient-centred training and clinical care. (Curr Probl Cardiol 2022;47:101394.)

Introduction

In the same way that the practice of cardiology has evolved over the years, so too has the way cardiology fellows in training (FITs) are trained. As technological advances have taken place, changes have been made to every aspect of clinical training. Long-accepted ways of working are constantly changing, catalyzed in part by the COVID-19 pandemic.[1,2] This change has been made possible by the proliferation of internet-based tools, advanced imaging technologies and the ever-increasing advances in computer and smartphone technology.[3]

Key learning environments, or domains, are recognized for FITs, including outpatient clinics, inpatient service, procedural theatres and lectures / conferences. Technology has affected all of these and has changed how FITs now train and how they are likely to train in the future.

While new computer and smartphone technologies can affect all domains as described above, 1 current paradigm shift is the convergence of the real and virtual worlds. Initially a field reserved for computer science enthusiasts in the 1980s, virtual reality has slowly been making increasing footprints in real-world medical applications. Within cardiology training, not only can it help train and teach clinicians, as will be described below, but it is starting to facilitate comprehensive interactions in completely virtual spaces, a theme that is likely to grow in the future. A distinction is often made between virtual reality (where the user is completely immersed in a virtual space), augmented reality (where virtual elements are incorporated into a user's real-world clinical space) and mixed reality (where elements from both physical and virtual spaces combine).[4] Within cardiology, advances have been made in all 3 forms.

Given these changes, the emergence of the so-called 'digital cardiologist' has been suggested to describe a cardiologist who uses digital tools to aid clinical practice, teaching, training, and to improve patient interaction. The key challenge going forward will be to keep digital technologies as a supportive tool, so as not to replace the human analysis and nuanced assessment so important to clinical practice and training.

Learning 'Domains'

1. Outpatient Clinics

Outpatient clinics represent a valued learning environment for FITs as they allow for the development and refinement of key clinical skills: history-taking, clinical examination, ordering of appropriate investigations, and enacting management. Traditionally, they have served as a 'safe' space for FITs to practice clinical cardiology with stable patients with an element of independence, but under the direct supervision of a consultant (attending) who shares the clinic space.

Technological advancement has enabled the proliferation of so-called 'telehealth', and despite an initial reticence, virtual consultations have become more common. The reduction in face-to-face (F2F) appointments was already part of the National Health Service (NHS) Long Term Plan published in 2019, targeting a reduction of visits by one-third over 5 years.[5] Within cardiology, clinicians were already exploring the idea that virtual clinics could be suitable, for example, for cardiac surgery follow-up in the 2010s.[6] Within electrophysiology, clinicians have been monitoring heart rhythms remotely for many years; with implantable loop recorders, pacemakers and implantable defibrillators, teams have the opportunity to contact patients in life-threatening arrhythmic events. However, the key catalyst was provided by the COVID-19 pandemic, in which hospitals were required to implement virtual appointments over a matter of days as it quickly became the default method by which outpatient appointments could be delivered.

Whilst several benefits of telehealth clinics have been described for both patients and clinicians alike, from a training perspective, the 2 main benefits include the flexibility to work from home (and thus help contribute to home/childcare duties in ways clinicians were not previously able to do) and also the ability to be in more than 1 physical place at once. In many regional health care configurations, numerous clinics take place over various geographic locations, and thus conducting these clinics remotely can help FITs save on travel time and money. The above is particularly pertinent given the efforts being made to increase inclusivity in cardiology training, such as the push to increase the number of female trainees within the specialty as endorsed by the Women in Cardiology (WIC) movement.

Despite the benefits, some have recognized some difficulties for FITs with remote clinics. The outpatient clinic experience often allows immediate diagnostic evaluation at the same time as the clinic consult, including ECGs, chest X-rays, and echocardiograms. With virtual consults, these are not immediately accessible and need to be separately ordered after the consult, which can delay decision-making. Further, the use of required technology can be difficult for both practitioners and patients alike, especially for those who are elderly or who have sensory impairment or language barriers. Thus, identifying patients who may be more suited to F2F over virtual consultations is likely to be a key priority to ensure that certain patients' groups are not disadvantaged. In addition, whilst some patients might prefer not travelling to the hospital, for some, virtual appointments are unsatisfactory; for many patients, direct contact with a physician is at least as important as the information relayed or the investigations performed during the clinical consult.

Also lacking is the direct physical supervision of an attending consultant. Whilst often FITs conduct clinics independently, the informal discussions about more complex patients are often absent, if not delayed, especially if clinicians are in different geographic places. This delays decision-making but also takes away from the mentorship-type learning opportunity the clinic provides. Further, a more nuanced implication for FITs of virtual clinics is a change to the so-called 'community of practice'. Initially described by Wenger in the 1990s,[7] this explains that people are accepted into a new community, in this case FITs into the 'cardiology community', by participating traditionally within a shared physical space in simple, observed tasks and then progressing into more complex ones as they become part of said community. The impact of moving this into a virtual space is unclear.

Inpatient Service

Much of the learning for FITs comes from 'on-the-job' exposure when 'on-call'. This often involves the assessment, investigation, and management of unwell cardiac patients. The proliferation of smartphone-based applications has opened access to a range of useful services, including online medical textbooks and resources (such as UpToDate.com by Wolters Kluwer) and clinical calculators (such as MDCalc by MD Aware LLC). For FITs, having immediate access to the above can make diagnoses and treatment plans more appropriate whilst enabling learning at the same time.

An extension to smartphone-based applications is the use of instant messaging systems whilst on clinical duty, such as WhatsApp by WhatsApp Inc, and iMessage from Apple Inc This is often between junior members of a team but can be useful between FITs and supervising consultants. Clinical cardiology is often based on the interpretation of data, commonly ECGs and echocardiographic pictures; being able to send these to supervising consultants can aid decision making and contribute to learning at the same time. Whilst most of these systems utilize end-to-end encryption technology, regulations surrounding information governance and data protection, which are often country-specific, must be followed.

Whilst physical examination remains a pivotal part of clinical assessment, echocardiography has an important role. It can quickly identify gross valvular or ventricular impairment. Traditionally, large echocardiography machines were required, but more recently hand-held echocardiography devices have been developed and are increasingly popular. Some are stand-alone devices, some utilize FITs' own smartphones. These have good accuracy when compared to standard machines in terms of assessment of ventricular systolic and valvular function,[8] and mean bedside echocardiography is available immediately and may even be preferable at times, such as during the pandemics.[9] FITs are thus able to use this technology to acquire the initial images, and use file sharing software on smartphones to share with supervising consultants.

Not only does this aid diagnostic capabilities but also gives FITs to the chance to use the technique regularly, and in doing so, learn constantly. Of note, in using hand-held devices for imaging, FITs must ensure that images are labelled with patient-identifiable information and stored securely within the hospital's imaging archive so they can be reviewed at later dates. This is important from a clinical governance point of view, but also from a training point of view. If images cannot be reviewed and feedback given, there can only be limited learning involved in the process.

Procedural Competencies

One focus of general cardiology training is the development of a theoretical understanding and clinical competence in several procedures, with requirements for proficiencies in non-invasive cardiac imaging techniques, cardiac catheterization and pacemaker device implantation.

Traditionally, procedural training was based on both formal lecture-based learning followed by apprentice-style practice. The phrase ‘see one, do one, teach one’ was often applied to procedure-based specialties and reflected a practice whereby students would attempt to perform a medical procedure after seeing it being done a small number of times. Understandably, patient safety was often a concern given how difficult it is to perform a procedure safely in that context.

Simulation has provided an environment in which to learn, particularly during the early phases of training. Not only do users have the ability to practice technical skills and refine tactile assessment under expert tuition, but simulation also allows for the ‘non-taught’ attributes of working in the clinical environment to be practiced, including communication skills, stress handling, human factor acknowledgement, and team working.[10] The focus on this so-called ‘crisis resource management’ has been proven to improve patient outcomes.[11]

Whilst echocardiography could formerly only be taught using real patients or actors, the advent of simulators with haptic feedback has enabled further training opportunities. HeartWorks by IntelligentUltrasound is one such device, which offers users the ability to practice scanning on a fully interactive model and identify a wide range of cardiac pathologies that junior trainees would rarely encounter in real clinical practice.

Simulation can also be extended to more complex cardiology work environments such as the cardiac catheter laboratory. These immersive in-situ simulations allow users from across the multi-disciplinary team to work together on complex clinical cases – and thereby ‘crash-land’ in practice rather than in real life. The debriefing time is often the most important part of immersive simulation, as it allows participants to reflect back on observed technical and human factors displayed during the exercise.

These environments are particularly suited to FITs at the early stages of their training, where they can learn at their own pace, without the stresses and pressures of a real clinical environment. They are also of particular value at times when procedural volume is affected, such as during the COVID-19 pandemic peaks. In the UK, some centers saw a 50% reduction in cardiology admissions and 40% reduction in patients admitted with myocardial infarction,[12] thereby limiting the amount of hands-on exposure trainees were able to experience. Despite the recognized benefits, access to simulation-based training activities remains limited, with under 20% FITs having the opportunity to learn via simulation in a recent report of European trainees.[13]

Competency in the reporting of cardiac imaging is also a key part of cardiovascular training, with much time spent by FITs on the reporting of cardiac computed tomography, cardiovascular magnetic resonance (CMR) and ultrasound. Technological advances here are also beginning to change the way scans are reported, particularly pertinent given the >500% increase in CMR over the last 10 years.[14] Machine learning programmes are starting to aid FITs in the analysis and interpretation of scans. For example, replacing manual delineation of anatomical contours with artificial intelligence tools has meant that assessment of ventricular volumes on CMR can be quicker and less prone to inter-user variability.[15] This can then allow FITs to analyze more scans in a given time period, thus increasing exposure to cases. The skill of being able to check for quality and adjust machine learning contours or analysis should still be a skill that is learnt.

Multi-disciplinary Meetings / Lectures / Workshops

Attending multi-disciplinary meetings is also an essential part of training for FITs. With the coming together of experts from across a range of disciplines, it has long been a place whereby difficult cases and topics are discussed, providing the FIT with the nuanced art of weighing up the risks and benefits of certain treatments and interventions. These have increasingly been conducted remotely, even using virtual reality in some centers to recreate the experience of being ‘in the room’.[9] These have also allowed FITs to attend when not physically in a certain place, again increasing availability to good learning environments for FITs who may need to cover large geographic areas as part of their service provision.

Didactic teaching has also long been a steadfast method within cardiology curricula. Technology has made the international cardiology world smaller. Again, catalyzed by demands for virtual interaction in the context of COVID-19, not only large-scale cardiology conferences were converted to online web-based platforms, but also regular teaching across institutions. In the UK, FITs brought together global experts for regular teaching on key cardiology concepts.[16] This has implications not only for FITs in countries in which there is a comprehensive cardiology curriculum, but also to FITs from across the world, especially low-middle income health care settings, who otherwise may not get this breadth of expertise in their training.[17] On the other hand, networking and social interactions are lacking with virtual conferences and potential barriers to collaboration and learning through personal interactions with others.

Platforms such as Microsoft Teams have also gained popularity, and not only allow video-based discussions, but facilitate efficient sharing of documents and allow for lectures to be recorded and watched at any time.

Further, virtual and augmented reality is playing an ever-increasing role. From a teaching point of view, 3D visualization and simulation can help reinforce understandings of key concepts. In the UK, the UCL Institute of Cardiovascular Science and Great Ormond Street hospital have recently adopted virtual reality (VR) into their curriculum; a novel VR platform, VheaRts, is designed to explore high-definition, patient-specific models of congenital heart disease. The platform has been used for teaching cardiac anatomy to medical students (Figs 1 and 2).[18] Similarly, in the USA, VR is being increasingly used to teach cardiac anatomy.[19] Beyond anatomy, this technology has also been rolled out to help teach CPR.[20] Given the level of interactivity involved, commentators have described how VR facilitates the 'gamification' of learning, whereby numerous game principles, such as teamwork, task completion, and points collection are incorporated into the learning process. Its popularity can be seen by the increasing body of evidence surrounding the use of VR in the clinical training workplace.[21]

VR also has a role in the training and planning of specific cardiology procedures – which helps FITs engage with the precise anatomical details and procedural techniques involved. In terms of coronary

FIG 1. Students using virtual reality headsets to aid cardiac anatomy teaching (photo acknowledgements: Prof Andrew Cook and Endrit Pajaziti, UCL).

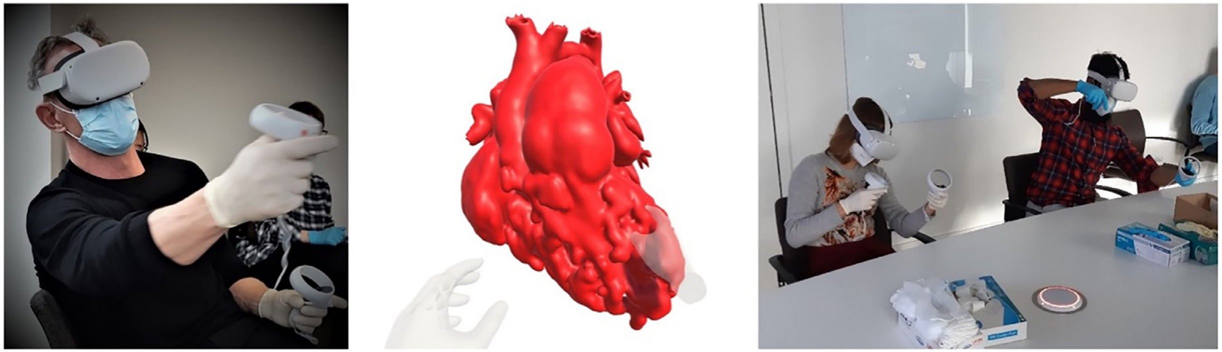

FIG 2. Students using hand consoles to help manoeuvre around 3D cardiac structures whilst emersed within the virtual reality space (photo acknowledgements: Prof Andrew Cook and Endrit Pajaziti, UCL).

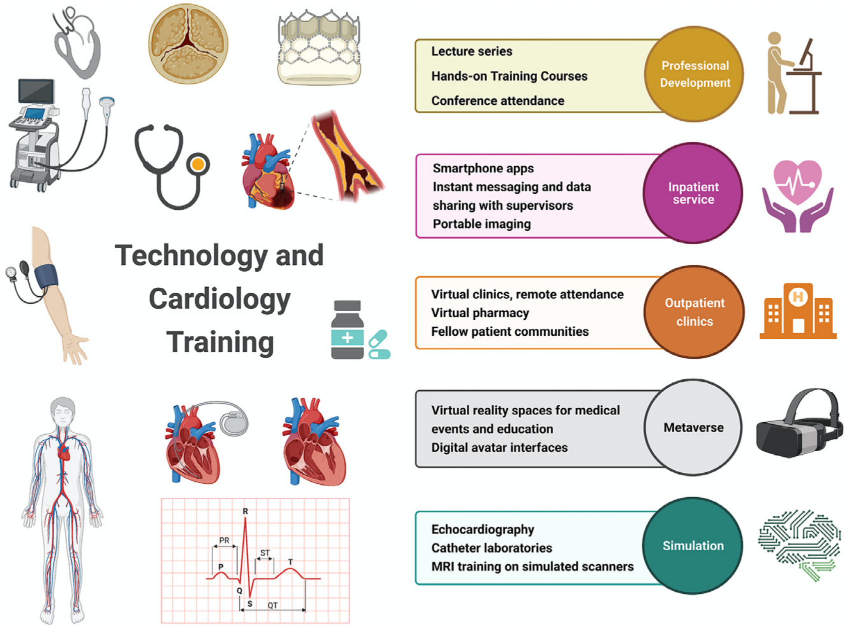

FIG 3. (Central illustration). Summary of different domains relating to cardiology training and the potential impact of technology on each domain (Created using Biorender.com).

intervention, operators have used wearable headsets projecting CT reconstructions of occluded vessels onto the headset glass. This helps operators follow guidewire trajectories without changing the field of view.[22] In terms of structural interventions, VR has been found to improve anatomical understanding and surgical preparedness, improved understanding of spatial relationships and allowed operators to simulate surgical strategies.[23] It can also help predict and prevent recognized complications of specific procedures, such as heart block following TAVI procedures.[24] Also exciting within the structural space is the expanding role of remote proctoring using augmented reality. In one example, operators were equipped with a smart-glass headset consisting of 2 HD cameras, a torch, microphone and speaker, and external visor. Successful proctoring for a complex transcatheter aortic valve replacement was conducted via a remote expert who was able to view both the procedural field and fluoroscopic / hemodynamic views.[25] Within electrophysiology, operators are starting to combine electromagnetic maps with 3D projections to create real-time anatomic maps of patient-specific arrhythmia substrate and catheter locations.[26]

Beyond the use of virtual reality to aid physical and simulated data fusion, with the proliferation of so-called ‘avatars’ living within the ‘metaverse’, completely virtual identities can be created in completely virtual environments. Within cardiology training specifically, there is thus the possibility for virtual cardiology consults by virtual clinicians (representing real physicians) with virtual patients (representing real patients and incorporating real clinical data).[27] The implications for this on cardiology training remain to be seen with potential for clinical governance and privacy breaches, but it opens the door for new potential future routes of health care delivery.

Electronic Portfolios

In the UK, an electronic portfolio (ePortfolios) to document achievement and education was introduced in 2005 and has been updated to follow the updates in the cardiology curriculum, the latest being in 2016. Before this, assessment of FITs was less formal, consisting of more sporadic interactions with trainers with no central control over the type of assessment required for each stage of training.[28]

In its current form, the ePortfolio allows for trainees to systematically chart progress through work-based assessments, procedural competency reports and patient and staff feedback questionnaires. Similar tools exist in other countries.[29]

Beyond training, Internet-based platforms that allow the listing of published papers and achievements, such as ResearchGate (ResearchGate GmbH), Publons (Clarivate Analytics) and ORCID.org (Open Researcher and Contributor ID), allow for increased sharing of knowledge and potentially increased collaboration amongst research groups which continues throughout a medical career.

Future Perspectives

Since restrictions, imposed during the COVID-19 outbreak, have been recently lifted, many have made efforts to return to pre-pandemic levels of activity as quickly as possible. Some of the changes forced on us by the pandemic have allowed not only more flexibility, but also a more comprehensive adoption of technological tools and devices at large in our interactions with patients. This has enabled age-old practices to be revised and in many situations delivered in a better way. Thus, whilst the pandemic may have served as the catalyst, it is likely that many of the changes to the ways of working will continue going forward.

That remote clinics have so far been demonstrated to be as safe as F2F clinics, suggests that a combination of remote and F2F working may be an option for many patient groups.[30] Further, as technology continues to improve in terms of availability and cost, so too will its availability for FITs. This is likely to be experienced with hand-held tools at the bedside, such as ultrasound devices, as well as the proliferation of computer-based systems, such as augmented reality software to aid planning for interventional procedures. Within simulation, opportunities for FITs to engage in virtual environments will continue to expand as the technologies become more widely adopted. One area which may take longer to fully embrace is that of the metaverse. Complete immersion in a virtual world is certainly exciting; in January 2022, medical students at Queen Mary University of London, participated in a surgery lecture within the metaverse, with all students wearing virtual reality headsets.[31] However, going forward, conducting clinical consultations and reviews within a virtual space raises many questions of security and ethics and adoption of its potential from a clinical and training point of view will require further assessment to ensure effective yet safe use.[32]

Conclusions

Technological advancements have impacted every sector within health care delivery. Given the pivotal role cardiology FITs play in this, it has also impacted how FITs train, whether in outpatient clinics, inpatient wards or procedural theatres. The capabilities of modern technology are constantly expanding the capabilities of what clinicians can do not just at the physical bedside, but also increasingly within remote and virtual workspaces too.

Numerous human-to-human interactions take place within medicine; between peers, senior colleagues, teachers and patients. Therefore, as our understanding and adoption of these new technologies increase, so too must our appreciation of their nuanced role alongside, not in place of, clinicians throughout the various sectors of health care delivery.

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