'The digital cardiologist': how technology is changing the paradigm of cardiology training

Sebastian Vandermolen[1,2], Fabrizio Ricci[3,4,5], C Anwar A Chahal[1,6,7,8]. Claudio Capelli[9], Khalid Barakat[2], Artur Fedorowski[4,10], Mark Westwood[2], Riyaz S Patel[2], Steffen E Petersen[1,2], Sabina Gallina[3], Francesca Pugliese[1,2], Mohammed Y Khanji[1,2,11]

[1] Barts Heart Centre, Barts Health NHS Trust, London, West Smithfield, EC1A 7BE, UK
[2] NIHR Barts Biomedical Research Centre, William Harvey Research Institute, Queen Mary University of London, EC1A 7BE, UK
[3] Institute of Advanced Biomedical Technologies, Department of Neuroscience, Imaging and Clinical Sciences, "G.d'Annunzio" University, 66100 Chieti, Italy
[4] Department of Clinical Sciences, Lund University, Jan Waldenströms gata 35 – 205 02, Malmö, Sweden
[5] Casa di Cura Villa Serena, Città Sant'Angelo, Pescara, Italy
[6] Center for Inherited Cardiovascular Diseases, WellSpan Health, Lancaster, PA, USA
[7] Cardiac Electrophysiology, Cardiovascular Division, Hospital of the University of Pennsylvania, Philadelphia, PA, USA
[8] Department of Cardiovascular Medicine, Mayo Clinic, Rochester, MN, USA
[9] Institute of Cardiovascular Science, University College London (London, UK).
[10] Department of Cardiology, Karolinska University Hospital, and Department of Medicine, Karolinska Institute, Stockholm, Sweden
[11] Newham University Hospital. Glen Road, Plaistow, Barts Health NHS Trust. London E13 8SL, UK

Address for Correspondence
Mohammed Y Khanji
Department of Cardiology
Newham University Hospital
Barts Health NHS Trust
Glen Road
London E13 8SL
United Kingdom

Email: m.khanji@qmul.ac.uk
Phone: +44(0)20 7476 4000

Statements and Declarations - Competing interests and funding
MK, SV, FR, CAAC, CC, KB, MW, RP, SP, SG, FP: none
AF: consultant and lecture fees from Medtronic Inc, Argenx BV and Finapres Medical Systems.

Abstract (149 words)

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—catalysed by COVID-19—and the requirement to adapt age-old methods of both teaching and healthcare 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 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.

Keywords: Technology, training, competency, virtual, telehealth

Word count: 3264 words (Excluding abstract, figure legends and references)

Introduction

In the same way that the practise 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, catalysed 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 recognised 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, one 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 three 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'

(i) 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 practise 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.

Of course, 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. Pre-pandemic, general practitioners in the UK were conducting around 3 million telephone appointments per month, but during the pandemic it rose to over 10 million (7).

Several benefits have been seen with the proliferation of telehealth outpatient reviews. Of course, patient convenience is key, as are cost savings (fewer investigations ordered and more patients discharged (8)), but from a training perspective, the two 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 one place at once. In many regional healthcare set-ups, numerous clinics take place over various geographic locations. The ability to consult patients via telemedicine allows FITs to conduct outpatient clinics whilst also being able to be, for example, near the cardiac catheter laboratories for an afternoon list.

Further, attending multi-disciplinary meetings (MDTs) 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 centres 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.

Despite the benefits, some have recognised 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 (10), 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 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 utilise 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 utilise FITs’ own smartphones. These have good accuracy when compared to standard machines in terms of assessment of ventricular systolic and valvular function (11), and mean bedside echocardiography is available immediately and may even be preferable at times, such as during the pandemics (12). This allows the FIT to use the technique broadly, 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 catheterisation 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. Whilst there is nothing exactly like training on real patients, there is often no second chance and the potential costs due to complications can be significant for the patient.

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 (13).

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 practise 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 centres saw a 50% reduction in cardiology admissions and 40% reduction in patients admitted with myocardial infarction (14), thereby limiting the amount of hands-on exposure trainees were able to experience. Despite the recognised 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 (15).

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 (CT), 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 (16). 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 (17). This can then allow FITs to analyse 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.

Lectures / workshops

Didactic teaching has long been a steadfast method within cardiology curricula. Technology has made the international cardiology world smaller. Again, catalysed 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 (18). 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 healthcare settings, who otherwise may not get this breadth of expertise in their training (19). 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 visualisation and simulation can help reenforce 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 (**Figures 1 and 2**) (20). Similarly, in the USA, VR is being increasingly used to teach cardiac anatomy (21). Beyond anatomy, this technology has also been rolled out to help teach CPR (22). 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 (23).

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 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 (24). 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 (25). It can also help predict and prevent recognised complications of specific procedures, such as heart block following TAVI procedures (26). Also exciting within the structural space is the expanding role of remote proctoring using augmented reality (AR). 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 / haemodynamic views (27). 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 (28).

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) (29). 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 healthcare 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 (30).

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 (31).

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 (32). 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 (33). 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 (34).

Conclusions

Technological advancements have impacted every sector within healthcare 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 healthcare delivery.

Figure Legends

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

Figure 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)

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

References

1. Chong JH, Chahal A, Ricci F et al. The Transformation of Cardiology Training in Response to the COVID-19 Pandemic: Enhancing Current and Future Standards to Deliver Optimal Patient Care. Can J Cardiol. 2021;37(3):519-522.

2. Chong JH, Chahal A, Gupta A et al. COVID-19 and the Digitilisation of Cardiovascular Training and Education – A Review of Guiding Themes for Equitable and Effective Post-graduate Telelearning. Front Cardiovasc. Med 8:666119. Doi 10:3389/fcvm.2021.666119

3. Chong JH, Ricci F, Petersen SE et al. Cardiology training using technology. Eur Heart J 2021;42(15): 1453-1455

4. Silva JNA, Southworth M, Raptis C et al. Emerging Applications of Virtual Reality in Cardiovascular Medicine. JACC Basic TranslSci 2018;3(3):420-430.

5. National Health Service. The NHS long term plan. Health document 2019.

6. Athanosopoulos LV and Athanasiou T. Are virtual clinics an applicable model for service improvement in cardiac surgery? Eur J Cardiothorac Surg 2017;51:201-2.

7. https://www.kingsfund.org.uk/audio-video/key-facts-figures-nhs

8. Offiah G, O'Connor C, Waters M et al. The impact of a virtual cardiology outpatient clinic in the COVID-!9 era. Ir J Med Sci 2021.https://doi.org/10.1007/s11845-021-02617-z

9. Sadeghi A, Wahadat A, Dereci A et al. Remote multidisciplinary heart team meetings in immersive virtual reality: a first experience during the COVID-19 pandemic. BMJ Innov 2021; 7(2):311-315

10. Wenger E. How we learn. Communities of practice. The social fabric of a learning organization. Healthcare Forum Journal 1996;39:20-26.

11. Andersen GN, Haugen BO, Salvesen O et al. Feasibility and reliability of point-of-care pocket-sized echocardiography. Eur J Echocardiogr 2011; 12: 665-670

12. Khanji MY, Ricci F, Patel RS et al. Special Article – The role of hand-held ultrasound for cardiopulmonary assessment during a pandemic. Prog Cardiovasc Dis 2020;63(5):690-695

13. Joshi A and Wragg A. Simulator Training in Interventional Cardiology. Interv Cardiol 2016;11(1):70-73

14. Fersia O, Bryant S, Nicholson R et al. The impact of the COVID-19 pandemic on cardiology services. Open Heart 2020;7:1-6

15. Czerwinska-Jelonkiewicz K, Montero S, Baneras J. The voice of young cardiologists. Eur Heart J 2020;41(29):2723-25

16. Keenan NG, Captur G, McCann GP et al. Regional variation in cardiovascular magnetic resonance service delivery across the UK. Heart 2021. Doi: 10.1136/heartjnl-2020-318667

17. Ruijsink B, Puyol-Anton E, Oksuz I et al. Fully automated, quality-controlled cardiac analysis from CMR: validation and large-scale application to characterize cardiac function. JACC Cardiovasc Imaging 2020;13: 684-95

18. COVID-19: education in the time of coronavirus. https://cardiovascularnews.com/covid-19-education-in-the-time-of-coronavirus (27 September 2020)

19. Haynes NA, Saint-Joy V, Swain J et al. Implementation of a virtual international cardiology curriculum to address the deficit of cardiovascular education in Haiti: a pilot study. BMJ Open 2021;11:e048690

20. Pajaziti E, Schievano S, Sauvage E, Cook A, Capelli C. Investigating the Feasibility of Virtual Reality (VR) for Teaching Cardiac Morphology. Electronics. 2021 Aug 6;10(16):1889

21. Wish-Baratz S, Gubatina AP, Enterline R et al. A new supplement to gross anatomy dissection: HoloAnatomy. Med Educ 2019;53(5):522-523.

22. Balian S, McGovern SK, Abella BS et al. Feasibility of an augmented reality cardiopulmonary resuscitation training system for health care providers. Heliyon 2019;5(8):e02205

23. Jung C, Wolff G, Wernly B et al. Virtual and Augmented Reality in Cardiovascular Care. J Am Coll Cardiol Img 2022;15:519-532.

24. Opolski M, Debski A, Borucki B et al. First-in-Man Computed Tomography-Guided Percutaneous Revascularization of Coronary Chronic Total Occlusion Using a Wearable Computer: Proof of Concept. Can J Cardiol 2016;32(6):829.e11-3.

25. Milano E, Kostolny M, Pajaziti E et al. Enhanced 3D visualisation for planning biventricular repair of double outlet right ventricle: a pilot study on the advantages of virtual reality. Eur H J (Digital Health) 2021; 2(4): 667-675

26. Dowling C, Gooley R, McCormick L et al. Patient-Specific Computer Simulation to Predict Conduction Disturbance With Current-Generation Self-Expanding Transcatheter Heart Valves. Structural Heart 2022. doi.org/10.1016/j.shj.2022.100010.

27. Arslan F and Gerkens U. Virtual support for remote proctoring in TAVR during COVID-19. Catheter Cardiovasc Interv 2021 (E-published). https://doi.org/10.1002/ccd.29504

28. Silva JN, Southworth MK, Dalal A et al. Abstract 15358: Improving visualization and interaction during transcatheter ablation using an augmented reality system: first-in-human experience. Circulation 2017;136(suppl1):A15358.

29. Mesko B. The promise of the metaverse in cardiovascular health. Eur Heart J 2022. ehac231. https://doi.org/10.1093/eurheartj/ehac231

30. Tailor A, Dubrey S, Das S. Opinions of the ePortfolio and workplace-based assessments: a survey of core medical trainees and their supervisors. Clin Med J R Coll Physicians London 2014;14:510-516

31. Peeraer G, Van Humbeeck B, De Leyn P et al. The Development of an Electronic Portfolio for Postgraduate Surgical Training in Flanders. Acta Chir Belg 2015;115:68-75.

32. Bauer BS, Nguyen-Phan AL, Ong MK et al. Cardiology electronic consultations: Efficient and safe but consultant satisfaction is equivocal. J Telemed Telecare. 2020;26(6):341-348 .

33. Queen Mary University of London. Queen Mary students receive first lecture in the metaverse. Accessed online: July 2022: https://www.qmul.ac.uk/media/news/2022/pr/queen-mary-students-receive-first-lecture--in-the-metaverse.html

34.

35. Skalidis I, Muller O and Fournier S. CardioVerse: The cardiovascular medicine in the era of Metaverse. Trends Cardiovasc Med 2022. https://doi.org/10.1016/j.tcm.2022..05.004