SYSTEMATIC REVIEW

Medical Education in a Post COVID-19 era – remote teaching methods for cardiovascular knowledge and skills [version 1]

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Abstract
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Introduction
As traditional clinical teaching faces major obstacles during the COVID-19 pandemic, medical educators look toward remote teaching methods to provide solutions to allow continuation of teaching. Remote methods, teaching delivered other than face-to-face, align with the transformation seen within pedagogy over the last 20 years.

Aim
The aim of this scoping review was to i) identify existing teaching methods available to remotely teach cardiovascular knowledge or skills and ii) identify if they have been evaluated.

Methods
A scoping review of the literature was undertaken to synthesise available evidence and examine remote teaching methods for application to undergraduate medical education.

Results
Forty-two articles were identified which presented remote teaching methods using either teaching based online, computer-programs, digital resources, mobile-phone technology, podcasts, serious gaming, social media or resources to aid self-directed learning. Although results were heterogenous, they gave an indication of the method’s usefulness. However, evaluations were not consistent and if they were, would have strengthened the value of the findings.

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Conclusion

Various remote teaching methods are available to replace face-to-face cardiovascular teaching where this is not possible. Evidence for effectiveness and engagement of individual platforms are variable. Given the ongoing COVID-19 pandemic, medical educators should prioritise ongoing evaluation of remote teaching methods and share best practice.

Keywords
Cardiovascular, undergraduate, remote teaching, curriculum planning
**Introduction**

During the ongoing worldwide pandemic of COVID-19, traditional clinical teaching faces major obstacles. Medical students are frequently unable to attend university or clinical placements. A major challenge for medical educators is to adapt to using remote teaching methods, defined as teaching delivered by means other than face-to-face, while replicating the experience of clinical encounters (Goh and Sanders, 2020).

For over a decade, medical schools have been transforming pedagogy, moving from didactic lectures to increasing use of technology and self-directed learning (SDL) (Shochelak and Stack, 2017). The pandemic has accelerated this process, where the rapidity of transition to remote learning has moved much faster than current innovation and identification of the evidence for different teaching methods. With such major pedagogical changes, monitoring and evaluation is integral to ensuring quality, improvement and meeting learner needs (Jayawickramarajah, 2001).

Within this scoping review, we focus on the cardiovascular system as a broad category, including both knowledge and skill-based learning. Cardiovascular disease (CVD) is the main cause of mortality worldwide and thus, appropriate acquisition of knowledge and skills are essential for practising clinicians (World Health Organisation, 2020). Face-to-face teaching has traditionally been important in CVD and alternative teaching methods have had to be sought during the pandemic. During the ongoing pandemic, there is an opportunity and necessity to evaluate whether alternative remote learning methods for medical education sufficiently meet student and curriculum needs. We utilised a methodological framework to scope the literature.

This scoping review aims to search the available literature to identify teaching methods which address cardiovascular knowledge, skills or both and inform undergraduate medical educators of the evidence for remote teaching methods.

**Method**

This scoping review followed a 5-stage framework for scoping review proposed by Arksey and O’Malley presented within the Joanna Briggs Institute review methods manual (Arksey and O’Malley, 2005; Peters et al., 2020). In keeping with scoping review guidance, gaps in the evidence base were identified including topics for future research and methodological quality was not formally assessed.

**Planned approach**

A study protocol was published on The Open Science Framework on the 7th July 2020 and can be accessed at https://osf.io/9vxd6/

**Identification of a research question**

This review was guided by the research question - what are the existing methods available to remotely teach cardiovascular knowledge or skills that could be employed in undergraduate teaching and have they been evaluated?

**Identifying relevant articles**

Literature searches were conducted in MEDLINE, CINAHL, Embase, ERIC from 2000 until present (5th May 2020, updated on 15th July 2020) using a search strategy (Supplementary File 1). This time point was chosen as medical school curriculum has evolved greatly since 2000. Additional grey literature was identified by targeting academic website domains using Google Search. Results were supplemented by scanning the references of relevant articles.

**Study Selection**

Article relevance was judged by the following criteria 1) teaching methods aimed to improve cardiovascular skills or knowledge 2) partially/fully remote methods 3) article in English 4) full text articles. All publication types were included, from any location worldwide to ensure a full scope of available teaching methods. Two reviewers performed study selection and data abstraction independently. Discrepancies were resolved through discussion.

**Data charting**

All records were managed using EndNote (version X9) bibliographic software. The data collection form for intervention reviews of non-randomised studies presented by the Cochrane collaboration was adapted for use within this review (The Cochrane Collaboration, 2021). This captured publication data, setting, method used, method delivery and any evaluation of the method.

**Collating, summarising and reporting the results**

Review findings were tabulated and grouped into teaching method categories. The Kirkpatrick model of Training Evaluation was used as a framework for describing the learning outcomes and evaluation in each study. Informed by our
research questions, we adopted a narrative approach to summarise and report the data to provide insight regarding the content of each teaching method.

Results

Of 1018 articles identified, 41 articles were included (PRISMA) (Figure 1). The PRIMSA diagram details our search and selection process applied during the analysis. A summary of the results is presented in Table 1. There were eight methods of teaching delivery which included online teaching; digital resources; computer programmes; mobile learning; serious gaming; podcasts; social media and resources assisted self-directed learning (SDL).

Adaption of PRISMA model - (Moher, Liberati, Tetzlaff and Altman for the PRISMA Group, 2009)

Online teaching

Twenty-two studies featured online access to cardiovascular learning resources. Here, learning was accessed and undertaken through the internet and intended to both support and replace face-to-face teaching. A popular method was a virtual learning environment (VLE) (n=6), a broad description for an online space to access teaching material though interactive text, photographs, videos, self-assessment and live-video sessions (Khogali et al., 2011; Kaelber, Bierer and Carter, 2001; Gomez-Arbones et al., 2004; Warriner et al., 2017; Sacar et al., 2013; Raupach et al., 2010). This was used to deliver general cardiology themes through to specific topics such as hypertension, cardiac failure and

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**Figure 1. Schematic presentation of studies selected in the review**
| Author       | Topic                          | Method              | Supplement teaching | Kirkpatrick level | Educational theory |
|--------------|-------------------------------|---------------------|---------------------|-------------------|--------------------|
| **Online teaching** |                               |                     |                     |                   |                    |
| Khogali      | General cardiology            | VLE                 | Yes                 | 1 (positive)      | Yes                |
| Kaelber      | General cardiology            | VLE                 | Yes                 | 1 (positive)      | No                 |
| Gómez-Arbonés| General cardiology            | VLE                 | Yes                 | 1 (positive)      | No                 |
| Bell         | General cardiology            | Self-Study          | Yes                 | 2 (positive)      | Yes                |
| Warriner     | Hypertension, cardiac failure, haemorrhagic shock | VLE | Yes | 1 (positive) | Yes |
| Sacar        | Peripheral arterial disease   | VLE                 | Yes                 | 1 (positive)      | No                 |
| Raupach      | Dyspnoea                      | VLE                 | Yes                 | 2 (positive)      | Yes                |
| Pourmand     | ECG teaching                  | Online learning module | Yes               | 2 (positive)      | Yes                |
| Zayed        | Aorta-iliac disease, Carotid disease, DVT | Interactive learning module | Yes | 1 (positive) | No |
| Weston       | Heart Failure, Diabetes       | Online seminars     | Yes                 | 3 (positive)      | No                 |
| Maheshwari   | Paediatric cardiology         | E-learning          | Yes                 | 1 (positive)      | No                 |
| McClusky     | Cardiac anatomy               | E-tutorial          | Yes                 | 1 (positive)      | No                 |
| Dubner       | General cardiology            | Virtual symposium   | No                  | None              | No                 |
| Tuchinda     | Cardiac auscultation          | Online data base    | Yes                 | None              | No                 |
| Oliviera     | Cardiac auscultation          | Virtual interactive thorax | Yes | None | No |
| Sprick       | Cardiac auscultation          | Virtual patient interface | Yes | 1 (positive) | No |
| Montassier   | Cardiac auscultation          | E-learning          | Yes                 | 2 (positive)      | Yes                |
| Peterssson   | Vascular anatomy              | Quick time virtual reality movie | Yes | 1 (negative) | No |
| Casillas     | Cardiac rehabilitation        | A website with commented slideshows | No | 2 (negative) | No |
| **Computer based** |                               |                     |                     |                   |                    |
| Rothe        | Cardiovascular knowledge      | Interactive tutorials | Yes | 1 (positive) | Yes |
| Karnath      | Cardiovascular knowledge      | Interactive heart model | Yes | 2 (positive) | No |
| Butter       | Cardiac auscultation          | Computer tutorial   | Yes                 | 2 (positive)      | No                 |
| Mahnke       | Cardiac auscultation          | Computer programme  | Yes                 | 2 (positive)      | No                 |
| Criley       | ECG                           | Computer programme  | Yes                 | 1 (positive)      | No                 |
peripheral arterial disease (PAD). Access to online learning did not deter student participation within timetabled teaching sessions; indeed it actively promoted engagement and participation (Gomez-Arbones et al., 2004).

Online modules, focused on specific subjects to gain knowledge and practical skills including vessel disease and ECG interpretation, were evaluated by four articles (Pourmand et al., 2015; Montassier et al., 2018; Casillas and Gremeaux, 2012; Zayed, Lilo and Lee 2017). Compared to face-to-face teaching, e-learning demonstrated non-inferiority compared with lecture-based learning (Montassier et al., 2015). Although participants found modules favourable, they identified a maximal learning session time of 90 minutes (Casillas and Gremeaux, 2012).

Online seminars (live and recorded), tutorials and symposia presented as slides, webcasts, radio interviews and case presentations with self-assessment were used to deliver teaching multiple subjects (Weston, Sciamanna and Nash, 2008;
Dubner et al., 2007; McCluskey et al., 2015; Maheshwari et al., 2015). These were provided for post-graduate teaching and no evaluation was offered. A fourth article compared tutorials with a graphic add-on to printed guidelines for undergraduate teaching (Bell et al., 2000). Learning efficiency was improved, students required less time to study to achieve the same outcome in comparison to attending a tutorial and demonstrated greater learning satisfaction even over 6 months.

Online virtual patient interfaces were employed by three studies (Tuchinda and Thompson, 2001; Oliveira et al., 2015; Sprick et al., 2008), useful for practical and knowledge skills, e.g. applying ECG pads and interpreting the results. Participant interaction was a key component and could be used within a group or self-learning session. A fourth article recreated vascular models from CT/MRI of prosections and compared them to an anatomy textbook to aid SDL however participants preferred dissection-based learning (Peteresson et al., 2008).

The majority of these studies (n=10, 53%) reported Kirkpatrick 1 learning outcomes although 3 reported no Kirkpatrick outcomes, summarised in Table 1. Five reported level 2 and one reported level 3 outcomes which demonstrated value in the content, accessibility and self-assessment. Five studies articulated eLearning theory which was appropriate for this method.

### Digital resources

Three articles focused on cardiovascular knowledge within the digital resources, Youtube, Wikipedia and eMedicine (Camm, Sunderland and Camm, 2013; Azer, 2014; Azer et al., 2015) aimed to compliment face-to-face teaching. None reported Kirkpatrick outcomes or educational theory with a general lack of quality regulation and low academic accuracy and readability. Authors acknowledge Wikipedia is not intended to meet the needs of a medical audience. Although these resources allow a potential platform to disseminate learning resources for undergraduate teaching, they are in the public domain and susceptible to corruption by other users.

### Computer programs

Five articles focused on computer programs designed to provide teaching on specific subjects (Rothe and Gersting, 2002; Karnath, Thornton and Das Carlo, 2003; Mahnke et al., 2004; Criley and Nelson, 2006; Butter et al., 2010). These included interactive tutorials, an animated heart, an interactive virtual patient simulator which allowed virtual auscultation and an interactive ECG analyser. These were intended for group-work and SDL. Kirkpatrick 2 outcomes were reported for 3 articles with outcome 1 with the remaining 2. Only one article articulated educational theory. The programs allowed repetitive and deliberate practice by participants to improve skills, particularly patient auscultation skills and could be a useful remediation tool for poorly achieving students (Mahnke et al., 2004; Butter et al., 2010).

### Mobile-learning (M-learning)

Three articles presented mobile applications (apps), designed to be downloaded onto a handheld device and accessed on-the-go and one utilised mobile phones to deliver remote teaching and assessment (Al-Jundi et al., 2017; Torabi, Khemka and Bateman, 2020; Bhatheja et al., 2018; Brewer et al., 2016). Apps included a cardiology handbook and two surgical training skills apps, designed as supplemental teaching to improve learning experiences. These reported that knowledge was gained in comparison to traditional reading although no understanding of accessibility and usability by their users was noted.

Kirkpatrick 1 learning outcomes were reported for 3 articles and level 2 outcome for one article. All articulated mobile learning theory. Ongoing assessment provided educators with real-time understanding of participant’s knowledge and resulted in a responsive and focused ongoing learning experience. Participants were satisfied with using this and engaged with the social aspects of teaching within this small group.

### Serious Gaming

Three articles focused on serious gaming, where a game is designed for a primary purpose other than entertainment and is designed to replace face-to-face teaching (de Sena et al., 2020; Drummond et al., 2017; Coskun, Adiguzel and Catak, 2019). All focused on practical skills - cardio-pulmonary resuscitation (CPR) and auscultation skills. For CPR training, skills gained through the serious game was equivocal to face-to-face and videos, although not statistically significant (de Sena et al., 2020; Drummond et al., 2017). For auscultation training, participants were exposed to repetitive heart sounds with knowledge retention to progress with the game. Although participants felt the ‘fun-factor’ was missing for this game, they continued to play as they were in a playful and competitive environment, which comply with medical students’ character (de Sena et al., 2020). All reported Kirkpatrick 2 outcomes, although one applied articulated design and development research methodology (Coskun, Adiguzel and Catak, 2019).
Social media
These are websites and apps that users can use to share content and participate in a social network. One article used two sources, Facebook and Twitter, aiming to engage a virtual audience over a number of months for participant-only interaction (Liu et al., 2017). A number of clinical vignettes were pre-agreed and ‘released’ to the audience weekly. The full capacity of the ‘social’ aspect of the network was not utilised, e.g. the vignettes were released without access to discussion or engagement with other users. This article demonstrated Kirkpatrick 1 outcome although did not articulate educational theory. Engagement decreased over the weeks. Those remaining at the end, were likely to be motivated learners and already had high scores pre-intervention with little knowledge improvement post-intervention.

Self-directed learning (SDL) and resourced-assisted SDL
Six articles described SDL which may include methods described above (Mahler et al., 2011; Roppolo et al., 2011; Pedersen et al., 2018; Fuchs et al., 2018; Lam et al., 2004; Raupach et al., 2016). SDL was used to teach ECG interpretation and CPR training and compared these to face-to-face teaching methods which showed equivocal outcomes (Mahler et al., 2011; Roppolo et al., 2011; Pedersen et al., 2018). Four articles utilised resources to complement the SDL and aimed to replace face-to-face teaching, which for CPR was an instructional DVD, blow-up manikin and cardboard training automated external defibrillator (Roppolo et al., 2011; Pedersen et al., 2018; Fuchs et al., 2018; Lam et al., 2004). Other SDL resources included a pocket cardiac ultrasound device and an electronic stethoscope both with the capacity to be used in isolation or with others. All demonstrated Kirkpatrick 2 outcomes, though no education theory. These allowed participants to practice cardiovascular skills under instruction, usually a video. These enabled greater learning exposure and practice and greater knowledge retention compared to instructor lead teaching, over time. When learning alone without the distraction of a group, participants may be more focused on the task, including higher self-monitoring resulting in favourable long-term effects of learning.

Discussion
Cardiovascular teaching encompasses acquisition of knowledge and skills which has traditionally relied on contact teaching. Within this scoping review, we have presented 41 articles that described methods to teach cardiovascular knowledge or skills remotely which were intended for both self-directed and group work and have assessed learning outcomes using the Kirkpatrick framework.

These findings provide educators with an overview of the available literature and are transferable to other subjects. The relatively small number of articles is not surprising given this was previously a developing area of providing medical education. Although self-assessment was often incorporated in many studies, evaluation of individual teaching methods by each study was not always undertaken which is a missed opportunity. Clear factors which determine feasible transfer of teaching from contact into a remote forum have not been fully identified.

Most of the methods rely on technology, aligning with the adoption of the on-the-go learning embraced by the portability of smartphones and owned by more than 90% of the undergraduate population (Gavali et al., 2017). They were intended to compliment or/and replace face-to-face teaching. Despite access to online learning, students have not been deterred from engaging with timetabled teaching sessions and remote learning can promote engagement with improved knowledge and confidence (Gomez-Arbones et al., 2004). However the development of resources particularly M-learning/phone apps, is often costly and time-consuming meaning during the current pandemic medical schools seeking to adopt these methods would have to utilise existing platforms (Chase, 2013).

Remote teaching methods are useful within multiple-environments, addressing teaching constraints including patient-exhaustion of multiple exams and lack of florid disease signs. These methods may allow participants within low and middle-income countries to access new teaching environments. However, articles only tested their method within a single cohort, timeframe and centre, thus does not address considerations such as quality assurance across cohorts, method longevity and how to accommodate content updates. Evaluation should also include feasibility, learner preference and cost-benefit e.g. learners may find a home resuscitation model beneficial but not feasible in many settings and incurs potentially substantial cost.

Our review associated VLEs, a popular method of decentralised learning, with cardiovascular knowledge improvement. A previous review identified that students already possess information technology and communication skills thus the ability to use online learning and social media effectively (Ludmerer and Johns, 2005; Phungsuk, Vitiyaveuakul and Ratanaolarn, 2017). Yet the ability to appropriately engage with remote SDL methods is not inherent and future research must be on how students can best utilise these resources for effective learning (Agudo-Peregrina et al., 2014). However, the onus is on medical schools to ensure VLEs are learner-focused, have clear instruction and learning outcomes, and are easily navigated.
Investigation of social media, video-conferencing and online communication platforms such as Zoom and Google Teams, as methods of teaching are required which should exploit the far-reaching potential of such a media. The platforms may allow useful peer learning/small-group teaching particularly with the application of educational theory to guide its design, which demonstrates beneficial learning rather than a top-down teacher-learner tool (Drummond and Delval, 2017). This has been seen within post-COVID-19 education with online small group configurations (Rose, 2020). These tools could transcend geographic and program-specific boundaries (Drummond et al., 2017).

Methods used for practical skills have reflected a practical component utilising virtual patients and serious gaming, which have largely resulted in a positive improvement. Virtual-reality and online-gaming are accessible and playable, hence popular and familiar. They create hype and motivation for further learning, especially if they have a fun-element (Brewer et al., 2016). Having repetitive, one-to-one learning with feedback improved skills, confidence and satisfaction correlated with Gagne’s learning and the self-determination theory (Coskun, Adiguzel and Catak, 2019). However, require specific equipment and software which reduces feasibility especially to a large learner cohort.

YouTube is currently the top three visited websites on the internet and has value within education as it is easily accessible even remotely, has relative ease to produce and upload content, and is complimented by free content. Users look to YouTube to seek information and entertainment. When evaluating CVD mechanisms on YouTube and Wikipedia, evaluation was not positive. However, as a platform, it may be an effective tool to enhance the learning experience if produced by educators for a specific purpose or as a complement to a learning session (Moghavvemi et al., 2018).

Self-directed methods compared to face-to-face had mixed outcomes, aligning with previous findings (Murad et al., 2010). Those which utilised specific resources were well received and improved cardiovascular knowledge/skills. These were designed for a specific skill or purpose with more defined instruction compared to SDL directed at a wider-focused subject. SDL is considered an important component of life-long learning and is a key competency in medical school curricula (Eva et al., 2004). However relevant skills for SDL should be taught to ensure participants can successfully engage with these activities rather than assuming they are inherent (Gaines et al., 2018). Moreover, collaborating with other participants for peer support or utilising resources such as medical librarians may offer alternative avenues to gain these skills (Gaines et al., 2018; Leslie, 2017; Minuti et al., 2018).

Remote teaching does confer several challenges. Aside from the additional workload to convert some or all of the educational material into an appropriate remote method, requiring time and funding investment, there are logistical considerations including appropriate platforms to deliver teaching, adequate internet access and learner skills to engage with these tools. As future doctors, teaching aims to provide learners with the knowledge and skills to provide a compassionate, patient-centred medical service. Students and teachers alike thrive from the interaction and experience of face-to-face teaching, particularly authentic patient experiences, which is difficult to reproduce remotely.

Review limitations
Firstly scoping literature for cardiovascular teaching may not be generalisable to other areas of the curriculum. As a broad review, it lacks focus on specific methods of remote learning. As only undergraduate studies were included, methods employed in other groups were not included. Finally, it is possible that we could have missed evidence of possible methods that may have never been reflected in the published or grey literature but are instead used in practice.

Conclusion
The COVID-19 pandemic may be a watershed moment in medical education with the rapid, potentially permanent transition to remote provision of learning to compliment or substitute traditional teaching. However, significant gaps exist in the published literature regarding the feasibility, effectiveness and engagement with different remote learning methods. It is essential that medical educators conduct and report ongoing evaluations of remote teaching methods adopted during the COVID-19 pandemic to share experience and best-practice.

Implications of the findings for research and practice
What should and can be done during the pandemic to fill research gaps including conducting remote student assessment/examination?

What should be undertaken once remote learning can be evaluated properly in comparison with more traditional methods of teaching?

What is the impact of remote learning on clinical performance?
What resources/equipment/skills are needed to deliver effective remote learning and can these be provided in low- and middle-income countries?

**Take Home Messages**
- Remote teaching methods are available to compliment or replace face-to-face cardiovascular teaching if this is not available
- Medical educators may utilise a variety of methods including online, digital resources and teaching
- These methods may provide educators with options to reach medical students in both high, and low and middle income countries

**Notes On Contributors**

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Sultan Qaboos University

This review has been migrated. The reviewer awarded 4 stars out of 5

A useful scoping literature review on remote teaching methods for cardiovascular knowledge and skills. The authors clearly lay out the context in which the advent of Covid-19 has led to a need for online cardiovascular teaching, and the scoping review sets out to determine the range and value of material available to medical educators. The study has been well-conducted, and Table 1 and the accompanying descriptive analysis gives a useful overview of the relevant material found. Two small issues I would like to see addressed:
• Figure 1 should give some details of the 882 records removed in the screening process.
• Table 1 should give the date of publication so that readers can have some idea of the chronological scope of the sources. Overall, however, a very useful read for understanding the range of literature currently available for online cardiovascular teaching and learning.

Competing Interests: No conflicts of interest were disclosed.

Reviewer Report 09 March 2021

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Deb Halder

This review has been migrated. The reviewer awarded 4 stars out of 5
The paper has drawn thorough planning of how it tends to proceed to the online medical education owing to the experiences of incapacity from any party involved in acquiring and providing medical education. The paper needs to explain the limitation of on-line process of learning and teaching where blended learning has been thought the suitable way of dissemination education. Challenges are there in every type of method. But the arrangement of the paper how it evaluates the idea is satisfactory enough.

**Competing Interests:** No conflicts of interest were disclosed.

Reviewer Report 03 March 2021

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Subha Ramani
Harvard Medical School, Brigham and Women's Hospital

This review has been migrated. The reviewer awarded 4 stars out of 5

Being someone whose clinical skills training was entirely face to face, I found this article interesting to read. The authors have done a very good job in their scoping review and provided a variety of options for virtual teaching of cardiovascular examination skills. The covid pandemic has necessitated these creative approaches. The options described can be applied to the teaching of clinical exam of other organ systems. The paper is well written and well referenced. The methods listed could supplement in-person teaching and exam post pandemic. I have a couple of comments for reflection: 1. How can live teaching build on the multimedia strategies. Eventually, we all need to get accustomed to in-person exam and all clinicians need these vital skills. Some things just cannot be done virtually in the clinical environment. 2. We have a list of virtual strategies, we do not know the impact of each of these and need robust program evaluation to know what works and what does not. This article will be useful to all clinical teachers engaged in teaching clinical skills and wish to supplement virtual strategies to live teaching.

**Competing Interests:** No conflicts of interest were disclosed.