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Remote multidisciplinary heart team meetings in immersive virtual reality: a first experience during the COVID-19 pandemic

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INTRODUCTION

Virtual reality (VR) is an emerging technology that enables creation of digital objects and virtual animations in a digital immersive environment that can be visualised and interacted with through head mounted displays (HMD) and controllers.^{1 2} In the fields of cardiovascular medicine and surgery, an increasing number of reports have become available to demonstrate potential benefits of VR for education, surgical planning and simulation.^{2–7} In addition, VR has made its entrance into the world of communication and is an ongoing topic of interest in scientific research and promising new tools are being developed.⁸

Due to the recent COVID-19 outbreak, local authorities have implemented several protective measures such as physical distancing and gathering restrictions. These restrictions have also been partly implemented in hospitals, however, in the fields of cardiology and cardiac surgery, full restrictions could potentially be harmful to patients, and therefore, alternative meeting methods should be implemented locally. Recently, we have published an article in which we present examples of alternative methods for multidisciplinary meetings to minimise the risk of viral infection and to ensure good and ongoing regular patient care.⁸

By combining VR meeting platforms with various HMD's, the user is able to immerse in a reality-like and fully 3D digital environment. VR-meeting platforms enable the users to get immersed in

Summary box

What are the new findings?

- Due to COVID-19 pandemic, gathering restrictions have challenged the organisation of physical multidisciplinary meetings, requiring innovative remote meeting methods, such as the immersive virtual reality (VR)-based method presented in this article.
- Immersive VR-based coronary revascularisation meetings were organised to enable remote multidisciplinary discussion between cardiac surgeons and cardiologists.

How might it impact on healthcare in the future?

- In the near future, extended reality platforms could overcome social distancing and gathering restrictions by enabling remote multidisciplinary collaboration for healthcare providers.
- VR-technology could have the potential to positively impact developments in pre-procedural medical planning, telementoring and digital health solutions that could benefit both patients and physicians.

a virtual environment and provide them with digital tools (such as laser pointers and various meeting rooms) that enable VR-guided remote digital conferencing and telementoring. By organising remote multidisciplinary meetings, direct physical interaction can be avoided, and the risk of viral transmission can be minimised. Until now, no studies on the organisation of clinical multidisciplinary heart team meetings in immersive VR are available in the

literature. In order to study the feasibility, effectiveness and user experience of a VR-based multidisciplinary heart team meeting, we have set up an observational proof-of-concept study, which was accelerated by the COVID-19 pandemic. Here, we describe our first experience on the application of VR meeting platforms in the setting of multidisciplinary coronary revascularisation heart team meetings.

METHODS

Experimental setup

At the Erasmus University Medical Center, a heart team meeting is held with at least an interventional cardiologist and a cardiothoracic surgeon. Five cardiothoracic surgeons (one in training) and five cardiologists were invited to participate in this study. Before the VR-meetings, all participants were briefed (5 min) on how to use the hardware and software. Immersive VR-based remote multidisciplinary coronary revascularisation heart team meetings were simulated according to local principles and with adherence to local gathering restriction rules (figure 1). Each VR-meeting consisted of at least two participants from both cardiology and cardiothoracic surgery department. A total of 10 meetings were organised consisting of at least one study participant (cardiologist/cardiac surgeon) and one resident cardiology/cardiothoracic surgery physician. Participants remotely joined a virtual room in a VR-based meeting platform (MeetinVR, Copenhagen, Denmark) by using VR-1 (Varjo, Helsinki, Finland) and Rift S (Oculus, Irvine, California, USA) HMD's, VR-controllers, and high-performance Thinkstation (Lenovo, Quarry Bay, Hong Kong) computers. Experienced VR-users were on site to provide technical support during the meetings. During the VR-meetings, a coordinator (resident physician) provided heart team participants anonymised medical images (coronary angiography, echocardiogram, ECG and chest X-ray) of a patient with confirmed three-vessel coronary artery disease (history of hypertension, diabetes and good left ventricular function) who already had been discussed in an earlier heart team meeting.

Objectives and questionnaires

The objective of this proof-of-concept study was to evaluate the feasibility and efficacy (being able to assess a case in VR) of organising remote VR-meetings to simulate heart team meetings. We defined feasibility as the ability to create a multidisciplinary meeting in VR to enable review of clinical imaging data remotely. Second, our aim was to study the subjective VR-experience and benefits of immersive meetings through questionnaires (online supplemental file S1) focused on: ease-of-use, immersiveness (engagement), usefulness and effectiveness, attitude toward (future) use, usefulness and effectiveness, and attitude toward (future) use. Questionnaires were created based on existing literature.^{9–13} A total of 25 questions were created and

a Likert rating scale was used with items rated between 1 and 5 (online supplemental file S1). In addition, the final decision and recommendation of all virtual heart teams were documented and compared with the clinical recommendation of the physical meeting.

Data analysis

Data were analysed by using Excel 2020 V.16.43 (Microsoft, Redmond, Washington, DC, USA). Categorical discrete data (Likert rating scales) are represented as counts/proportions.

RESULTS

Participants

Nine participants were men and one was female. Eight out of ten participants had at least 5 years of experience in physical heart team meetings on a weekly basis. Two had >3 years of experience for at least 1–2 times a month. Most study participants (n=6) did not have any VR experience before, 3 had basic VR experience and 1 uses VR on a regular basis. None of the participants did have any experience in immersive VR-based remote meetings.

Feasibility

All VR-heart team meetings were organised successfully. All clinical imaging data were successfully

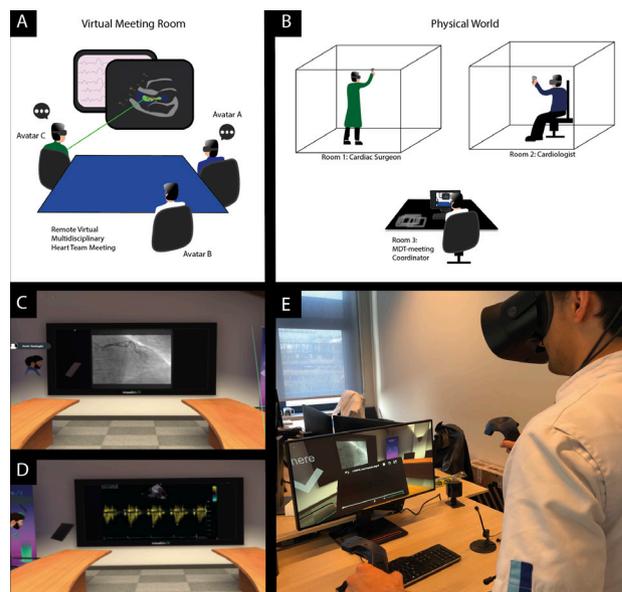


Figure 1 Immersive virtual reality based coronary revascularisation heart team meetings. (A, B) Illustrative depiction of the experimental setup for remote multidisciplinary heart team meetings. Participants in remote areas of the hospital (right panel) joined a virtual meeting room as an avatar (left panel) and discussed a clinical case of a patient with coronary artery disease that was presented by an MDT (multidisciplinary team meeting)-coordinator. (C, D) Several screenshots that have been acquired during a multidisciplinary remote and virtual reality-based heart team meeting. (E) In addition, photos present the hardware setup that enable remote virtual reality meetings.

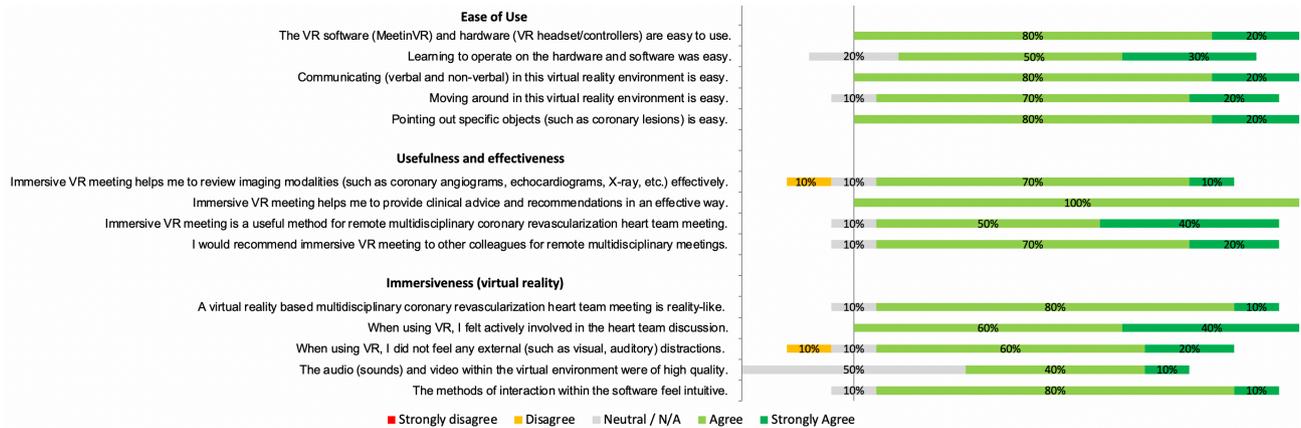


Figure 2 Questionnaire results on ease of use, usefulness and effectiveness, and immersiveness of virtual reality (VR) software and hardware for remote heart team meetings.

visualised and assessed in VR (figure 1). In all meetings, the team suggested coronary artery bypass grafting as the most suitable therapy. This corresponded with the clinical recommendation. The duration of the meetings was comparable to regular physical meetings with a maximum of 10 min (excluding 5 min of briefing).

Ease-of-use, immersiveness, usefulness, and effectiveness

An overview on the results of the questionnaires is presented in figure 2. In general, VR-based meetings were rated as an easy-to-use, useful and effective method for remote heart team meetings. The participants were also asked to fill out advantages and disadvantages of VR-based meetings. These results are presented in online supplemental file S2. Some of the most common advantages were user-friendliness, safety, engagement, (especially during social distancing) and pointing out specific lesions in VR by all participants. Important (potential) disadvantages were the dependency on IT-infrastructure, the quality of the images and the dependency and comfort of wearing VR-hardware.

Alternative methods and future use

Ease-of-use, usefulness and effectiveness were rated to be better than tele/video conferencing by 90% of the users. Interestingly, when compared with physical meetings, 50% of the users rated VR-meetings to be similar and 20% rated VR-meetings to be much better. In addition, immersiveness was rated better than tele/video conferencing by 90% of the users. Refer to online supplemental figure 1 for a detailed overview of these results.

Ninety per cent of the participants rated VR meetings to be a good method for future remote meetings and would like to work with this technology in the future and 80% of the users thought that in the future, they would even prefer working with this technology rather than tele/video conferencing. However, when compared with physical meetings, 50% did not prefer

VR. See online supplemental figure 2 for a detailed overview.

DISCUSSION

In this study we present the first examination of VR-based remote multidisciplinary heart team meetings to overcome social distancing challenges due to COVID-19. Remote meetings were organised in immersive VR using HMD and controllers and by providing a clinical case of a patient with coronary disease. We found that in general, the user experience was rated positive and that there was a positive attitude towards the use of VR as an alternative method for remote conferencing. An appreciated feature was found to be the possibility interact and to point out lesions directly with a virtual laser-pointer. This seemed to be an important shortcoming of 2D tele/video conferencing methods, where only one user can point out lesions (with a mouse arrow) when he/she is actually sharing his/her screen. Another advantage that was mentioned frequently was the engagement in the meeting. Due to all immersive features, the participants felt actively involved in the meetings and did not experience visual or auditory distractions from their surroundings. In addition, communication was mentioned to be intuitive and as good as a physical meeting, which underlines the advantages of immersive VR even more. Based on the questionnaire results and the experiences, it seems of the utmost importance that a VR device should be easy to use, light in weight, applicable to different types of software and preferably unwired. In addition, it should be possible to wear the headset when wearing glasses. For future clinical implementation, it is important to design a highly secured platform which is connected to the electronic health record, so a large set of patient data can be uploaded without any delay or inefficient anonymisation procedures. Moreover, a platform is needed that offers high security and compliance standards. For regular clinical implementation during a pandemic,

hygienic measures should be taken into account as well. Even though most participants were excited using this novel VR technology, also some shortcomings and disadvantages were mentioned. For example, there seemed to be quite some room for improvement in terms of image quality. In some cases, the pixels on the shared monitor in the virtual meeting room were visible and thus the angiography images seemed to be a little less clear. However, most participants (80%) did not feel that this resulted in a less effective assessment of imaging modalities (figure 2).

With regard to the future, an interesting application of immersive technology and televirtuality would be the possibility of a real-time and remote evaluation of a patient through holographic telepresence and mixed reality technology.¹⁴ Finance is another important factor in considering structural clinical implementation and therefore a cost-effectiveness study would be desirable. A recent review on the use of telemedicine for multidisciplinary meetings demonstrated that some of the important advantages that telemedicine has to offer are decreased burdens of travel, a reduction of travel expenses and a reduction of overtime.¹⁵ Lack of acceptance associated costs of technology and suboptimal availability of an IT-infrastructure were identified as possible challenges and barriers for implementation of telemedicine for multidisciplinary meetings.

Besides enabling remote multidisciplinary meetings, VR technology has the potential to result in further advances in medicine and could be beneficial for both patients and physicians. Specifically, during these challenging times, alternative simulation and communication methods can be beneficial for physicians to cope with the current restriction rules due to COVID-19 but might also be a valid option for the future.^{16 17} More development, research and validation in technology could hopefully pave the way for a fully remote and immersive experience for the future of clinical medicine. Finally, we believe that future studies, comprising several cases and larger datasets that directly compare VR-based methods to other alternatives (eg, tele/video conferencing) are needed to draw conclusions.

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Contributors AHS, ARW, AD, EAFM and AJJCB designed the study. AHS and HT designed the questionnaires. AHS, ARW and AD conducted the coordination of the meetings, did the participant recruitment, acquired the questionnaires and performed the analysis of data. AHS, ARW and AD wrote the first draft of the manuscript, which was reviewed and edited by RPJB, WT, JWR-H, HT, YJHJT, EAFM and AJJCB. AHS submitted the manuscript and created the figures.

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Patient consent for publication Not required.

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Supplementary file S1

Immersive virtual reality coronary revascularization heart team meeting questionnaire

How often do you participate in coronary revascularization heart team meetings?

1. I never participate in coronary revascularization heart team meetings
2. I participate incidentally (less than once per month) in coronary revascularization heart team meetings
3. I participate sometimes (1-2 times / month) in coronary revascularization heart team meetings
4. I participate often (every week) in coronary revascularization heart team meetings

How many years of experience do you have in participating in coronary revascularization heart team meetings?

1. I have 0-1 years of experience in participating in coronary revascularization heart team meetings
2. I have 1-3 years of experience in participating in coronary revascularization heart team meetings.
3. I have 3-5 years of experience in participating in coronary revascularization heart team meetings.
4. I have >5 years of experience in participating in coronary revascularization heart team meetings.

How often do you use Virtual Reality hardware/software (e.g. virtual reality gaming, virtual reality simulations, virtual reality consoles, etc.)?

1. I have no experience (I never had VR experience until today)
2. I have basic experience (I have had some incidental VR experiences before, e.g. gaming, entertainment, etc.)
3. I am experienced (I use VR consoles and applications on a regular basis).
4. I am an expert (I have a VR console and applications myself).

Do you have any experience in immersive (virtual reality-based) remote meetings?

1. Yes
2. No

Ease of Use

1. The VR software (MeetinVR) and hardware (VR headset/controllers) are easy to use.

5 Strongly Agree	4 Agree	3 Neither Or N/A	2 Disagree	1 Strongly Disagree
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2. Learning to operate on the hardware and software was easy.

5 Strongly Agree	4 Agree	3 Neither Or N/A	2 Disagree	1 Strongly Disagree
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3. Communicating (verbal and non-verbal) in this virtual reality environment is easy.

5 Strongly Agree	4 Agree	3 Neither Or N/A	2 Disagree	1 Strongly Disagree
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4. Moving around in this virtual reality environment is easy.

5 Strongly Agree	4 Agree	3 Neither Or N/A	2 Disagree	1 Strongly Disagree
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5. Pointing out specific objects (such as coronary lesions) is easy.

5 Strongly Agree	4 Agree	3 Neither Or N/A	2 Disagree	1 Strongly Disagree
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Usefulness and effectiveness

1. Immersive VR meeting helps me to review imaging modalities (such as coronary angiograms, echocardiograms, X-ray, etc.) effectively.

5 Strongly Agree	4 Agree	3 Neither Or N/A	2 Disagree	1 Strongly Disagree
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2. Immersive VR meeting helps me to provide clinical advice and recommendations in an effective way.

5 Strongly Agree	4 Agree	3 Neither Or N/A	2 Disagree	1 Strongly Disagree
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3. Immersive VR meeting is a useful method for remote multidisciplinary coronary revascularization heart team meeting.

5 Strongly Agree	4 Agree	3 Neither Or N/A	2 Disagree	1 Strongly Disagree
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4. I would recommend immersive VR meeting to other colleagues for remote multidisciplinary meetings.

5 Strongly Agree	4 Agree	3 Neither Or N/A	2 Disagree	1 Strongly Disagree
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Immersiveness (virtual reality)

1. A virtual reality based multidisciplinary coronary revascularization heart team meeting is reality-like.

5 Strongly Agree	4 Agree	3 Neither Or N/A	2 Disagree	1 Strongly Disagree
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2. When using VR, I felt actively involved in the heart team discussion.

5 Strongly Agree	4 Agree	3 Neither Or N/A	2 Disagree	1 Strongly Disagree
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3. When using VR, I did not feel any external (such as visual, auditory) distractions.

5 Strongly Agree	4 Agree	3 Neither Or N/A	2 Disagree	1 Strongly Disagree
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4. The audio (sounds) and video within the virtual environment were of high quality.

5 Strongly Agree	4 Agree	3 Neither Or N/A	2 Disagree	1
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				Strongly Disagree
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5. The methods of interaction within the software feel intuitive.

5 Strongly Agree	4 Agree	3 Neither Or N/A	2 Disagree	1 Strongly Disagree
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Alternative meeting methods

1. Regarding ease-of-use, **virtual reality** conferencing is a..... way for organizing remote heart team meetings when compared to **tele/video** conferencing.

5 Much Better	4 Somewhat better	3 Similar	2 Somewhat worse	1 Much Worse
------------------	----------------------	--------------	---------------------	-----------------

2. Regarding usefulness and effectiveness, **virtual reality** conferencing is a..... way for organizing remote multidisciplinary heart team meetings when compared to **tele/video** conferencing.

5 Much Better	4 Somewhat better	3 Similar	2 Somewhat worse	1 Much Worse
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3. Regarding usefulness and effectiveness, **virtual reality** conferencing is a..... way for organizing remote multidisciplinary heart team meetings when compared to **physical meetings**.

5	4	3	2	1
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Much Better	Somewhat better	Similar	Somewhat worse	Much Worse
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4. Regarding immersiveness (engagement in virtual environment), **virtual reality** conferencing is a..... way for organizing remote multidisciplinary heart team meetings when compared to **tele/video** conferencing.

5 Much Better	4 Somewhat better	3 Similar	2 Somewhat worse	1 Much Worse
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Attitude towards (future) use

1. VR meetings are a good method for future remote coronary revascularization heart team meetings.

5 Strongly Agree	4 Agree	3 Neither Or N/A	2 Disagree	1 Strongly Disagree
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2. I would like to work with this technology in the future.

5 Strongly Agree	4 Agree	3 Neither Or N/A	2 Disagree	1 Strongly Disagree
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3. I enjoyed using VR for remote multidisciplinary meetings.

5 Strongly Agree	4 Agree	3 Neither Or N/A	2 Disagree	1 Strongly Disagree
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4. In the future, I prefer using virtual reality conferencing methods over **tele/video** conferencing methods.

5 Strongly Agree	4 Agree	3 Neither Or N/A	2 Disagree	1 Strongly Disagree
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5. In the future, I prefer using virtual reality conferencing methods over **physical** conferencing methods.

5 Strongly Agree	4 Agree	3 Neither Or N/A	2 Disagree	1 Strongly Disagree
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Please provide advantages and disadvantages of immersive VR technology for organizing multidisciplinary meetings (please rank in order of importance (*start with the most important (dis)advantages*))

Advantages:

1.
2.
3.

Disadvantages:

1.
2.
3.

Did you feel that there were missing features in this virtual reality environment?

.....

Thank you for your participation

Supplementary file S2

Participant's opinion on advantages and disadvantages of remote multidisciplinary coronary revascularization heart team meetings in virtual reality.

Participant 1

Advantages:

1. Avoidance of distraction from surroundings.
2. Clear audiovisual content.
3. Attractive virtual meeting room.

Disadvantages:

1. Wearing glasses.
2. Sharpening the images for participants.
3. Costs?

Participant 2

Advantages:

1. No need to travel.
2. Decrease the risk of infection during COVID-19 pandemic.

Disadvantages:

1. Quality of the videos.

Participant 3

Advantages: none.

Disadvantages: none.

Participant 4

Advantages:

1. Could be of great help to organize "physical-like" meetings to meet colleagues in other/remote hospitals.

Disadvantages:

1. None.

Participant 5

Advantages:

1. Ease of use.
2. Good visualization of angiography/chest X-ray of patient.
3. Good communication.

Disadvantages:

1. Dependent upon internet.

Participant 6

Advantages:

1. Great method to engage in the heart team discussions (or other meetings) requiring participants interaction with the data showed (in this case angio and echo). This is not quite possible with video/teleconferences.
2. Best option for remote meetings during these pandemic times.
3. Good sound and user friendly.

Disadvantages:

1. It requires to be in possession of a VR equipment (somehow expensive?).

2. As an alternative to physical meetings during the pandemic it might mandate specific protocols for use in order to keep the risk of virus transference between users low.
3. Some people might not tolerate the virtual reality environment and might feel nausea or dizziness.

Participant 7

Advantages:

1. Distance is not a burden anymore.
2. Integration of images, also 3D/VR is possible.
3. It was OK when more people speak together.

Disadvantages:

1. Wearing VR glasses is awful compared to watch a screen!
2. Even more dependent on IT infrastructures and stability of networks.

Participant 8

Advantages:

1. Intuitive way of communication.
2. Pointing out lesions is doable in VR, but not in zoom/teams (video conferencing).
3. Fully immersive, less distraction from surroundings.

Disadvantages:

1. Quality of images (pixels can be seen).
2. Somewhat time-intensive to set up everything (in this proof of concept setup at least).
3. Delay in connection sometimes.

Participant 9

Advantages:

1. Direct contact with meeting participants.
2. Viewing images together with the possibility to interact.

Disadvantages:

1. The above may not necessarily require VR; online communication and sharing images can also be done with other methods.
2. Image quality of coronary angiogram was suboptimal.
3. We would need methods to view images in original quality. In fact, this is more important than the way of communication.

Participant 10

Advantages:

1. No travel time.
2. As good as physical meeting.
3. Use of pointer by all the participants.

Disadvantages:

1. No sharp images
2. Learning curve to handle tool.

Alternative meeting methods

Regarding ease-of-use, virtual reality conferencing is a..... way for organizing remote heart team meetings when compared to tele/video conferencing.



Regarding usefulness and effectiveness, virtual reality conferencing is a..... way for organizing remote multidisciplinary heart team meetings when compared to tele/video conferencing.



Regarding usefulness and effectiveness, virtual reality conferencing is a..... way for organizing remote multidisciplinary heart team meetings when compared to physical meetings.



Regarding immersiveness (engagement in virtual environment), virtual reality conferencing is a..... way for organizing remote multidisciplinary heart team meetings when compared to tele/video conferencing.



■ Much worse ■ Somewhat worse ■ Similar ■ Somewhat better ■ Much better

Attitude towards (future) use