

A Feasibility Trial of HoloLens 2™; Using Mixed Reality Headsets to Deliver Remote Bedside Teaching During COVID-19

Arun Sivananthan (✉ arun.sivananthan@nhs.net)

Imperial College London

Aurelien Guerout

Imperial College Healthcare NHS Trust

Geiske Zijlstra

Imperial College London

Guy Martin

Imperial College London

Aravindhan Baheerathan

Imperial College Healthcare NHS Trust

Philip Pratt

Medical iSight Corporation

Ara Darzi

Imperial College London

Nisha Patel

Imperial College London

James Kinross

Imperial College London

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Abstract

Background COVID-19 has had a catastrophic impact measured in human lives. Medical education has also been impacted: appropriately stringent infection control policies have precluded medical trainees from attending clinical teaching. Lecture-based education has been easily transferred to a digital platform, but bedside teaching has not transitioned so well. The aim of this study was to assess the feasibility of using a mixed reality (MR) headset to deliver remote bedside teaching to trainee doctors during the COVID-19 pandemic.

Methods Two MR sessions were led by senior specialty registrars (the clinical trainers) wearing the HoloLens™ headset. The trainers selected patients admitted with pathology requiring their specialist input; thus, the educational sessions were opportunistic. The headset allowed bi-directional video and audio communication between the trainer and trainee doctors during the consultation.

Trainee doctor conceptions of bedside teaching, impact of COVID-19 on bedside teaching and technical success of the session was evaluated using pre- and post-round questionnaires using 1 ('strongly disagree' or 'never') to 7 ('strongly agree' or 'always') Likert scales and white space questions. Feedback on acceptability of the round was collected verbally from patients after each encounter. Data related to clinician exposure to at risk patients and use of PPE were also collected.

Results Pre-questionnaire respondents (n=24) strongly agreed that bedside teaching is key to educating clinicians (7, IQR 6-7). It was also apparent that bedside teaching had become a rarity during COVID-19 (2, IQR 2-4).

Session 1 feedback (n=6) was adversely affected by a loose microphone connection. With the issue rectified for session 2 (n=4), most respondents strongly agreed that they felt like they were physically present for the session (7, IQR 6.75-7). Mixed-reality versus in-person teaching led to a 79.5% reduction in cumulative clinician exposure time and 83.3% reduction in PPE use.

Conclusions This study is proof of principle that HoloLens™ can be used effectively to deliver high-quality clinical bedside teaching. This novel format confers significant advantages in terms of: minimising exposure of trainees to COVID-19; saving PPE; enabling larger attendance; and convenient accessible real-time clinical training.

Introduction

The initial outbreak of the Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) in Wuhan in December 2019 has developed into a global pandemic with unavoidable collateral impact in postgraduate medical education. As of 15th November 2020, almost 54 million confirmed cases of Coronavirus Disease 2019 (COVID-19) and over 1.3 million deaths have been reported in 191 countries (1). Further to this catastrophic impact measured in human lives, the pandemic has engendered major organisational change in healthcare systems and significant economic recession (2).

Bedside teaching plays an important role in medical education with evidence of benefit to trainees, patients and clinicians(3). Despite increasingly sophisticated and capable diagnostic investigations, good history taking, and clinical examination remains a core part of the diagnostic process.

Stringent infection control policies have been introduced in hospital settings with the aim of preventing nosocomial spread of infection and protecting healthcare workers. These involve use of personal protective equipment, minimising clinician contact and social distancing. These necessary precautions have had an impact on traditional forms of medical education. Social distancing has precluded students and junior trainees from gathering for teaching and clinical rotations have been cancelled.

The clinical environment in which students would usually acquire practical skills and form their professional identity was severely restricted by infection control policies during COVID-19 (5). In a survey of 152 junior doctors in May 2020 at a UK teaching hospital, only 21.1 % of participants felt that their educational needs were being met during the COVID-19 period. Learning opportunities have become fewer as operations have been cancelled and clinics transitioned to tele-medical modalities. Despite this, bed side teaching has not undergone the same degree of digital transformation. However, novel tele-medicine technologies may provide a solution to this challenge.

Augmented reality (AR) merges the virtual world and real world where the “display of an otherwise real environment is augmented by means of virtual (computer graphic) objects” (6). Mixed Reality (MR) is a subtype of AR where these digital objects can be manipulated and interacted with in real time as if part of the real world.

HoloLens™ is an MR head-mounted device developed and marketed by Microsoft Corporation (Redmond, WA, USA). The headset combines several types of sensors to provide a true ‘heads-up display’ with the ability to place virtual, ‘hologram’ objects within the user’s visual field. It also permits live bidirectional communication via video, mixed reality composites and voice with multiple remote users. In a clinical setting this allows the wearer of the device to share their clinical interaction remotely with multiple connected users as well as display and manipulate ‘holographic’ images (within the real environment) which can also be collaboratively interacted with by the remote users.

In simple terms this allows the patient interaction to be observed remotely by multiple trainees as well as display and collaboratively interact with a multitude of clinically relevant ‘holograms’ such as blood results, radiological images or educational figures (7) (Fig. 1). This remote yet intra-situational learning confers specific benefits in the context of COVID-19 in terms of reducing risk of contagion and economising Personal Protective Equipment (PPE) (especially for ‘non-essential’ tasks).

The use of HoloLens™ and similar MR devices have already been trialled in medical education specifically for teaching anatomy (8, 9). A recent pilot study at this centre demonstrated the use of HoloLens™ during the COVID-19 pandemic for direct clinical care reduced time exposure of staff caring for COVID-19 patients by 51.5% with an 83.1% reduction in PPE use (10).

The aim of this study was to assess the feasibility of using a HoloLens™ device and the mixed reality environment to deliver remote bedside teaching to trainee doctors to support the delivery of higher quality care during the COVID-19 pandemic.

Methods

Gagné's principles of instruction (11), Ker et al.'s six questions for planning teaching ward rounds (12) and Abdool and Bradley's work on improving medical teaching rounds (13) were used to design the format for the 'HoloLens™ teaching ward round.

The AR sessions were led by senior specialty registrars (the clinical trainers) who selected patients admitted with pathology requiring their specialist input. Social distancing precluded junior doctors from observing these educational consultations. HoloLens™ was therefore used opportunistically. Trainers received instruction and time to practise using the HoloLens™ device. The HoloLens™ headset, in collaboration with the local infection prevention and control team, was incorporated as personal protective eye protection (Fig. 2). with a decontamination protocol (10). The device and protocols were registered at our local institution with data governance agreed upon. The project was undertaken as a quality improvement (QI) technology project under supervision of the institutional QI team and no additional ethical approval was required. No patient identifying images are provided with authors used to simulate images and their consent for publication given.

Informed consent was received from the patients by the clinical trainer prior to the remote session. 4–6 trainee doctors via a secure, two-factor authentication video link system (Microsoft Teams), connected to the session on a trust computer with webcam enabled. Prior to entering the patient's room aims for the session were established by the group. On entering the patient's room the trainer placed a fixed 'hologram' of the trainee doctors 'attending' adjacent to the patient allowing bi-directional video and audio communication between the trainer and trainee doctors during the consultation. This was also supported by a chat function beside the 'hologram' where the trainee doctors could type questions and responses. The trainee doctors were also able to select radiological images and educational figures to superimpose on the real view at the trainers' request.

Two sessions were carried out, one with a gastroenterology case of a flare of ulcerative colitis and the other with a neurology case of a third nerve palsy by two different trainers who were due to clinically review the patient. Thus these reviewers were used opportunistically for teaching so as not to increase exposure risk.

A history and clinical examination was taken with participants encouraged to ask questions verbally or written using Teams' chat function. Discussion of the case was aided by superimposition of relevant images as additional 'holograms' such as endoscopy images demonstrating the patient's inflamed mucosa and diagrams showing the anatomy of the colon. Key learning points were discussed and documented collaboratively using the chat function.

Trainee doctor conceptions of bedside teaching, impact of COVID-19 on bedside teaching and technical success of the session was evaluated using pre- and post-round questionnaires (Appendix 1 and 2) using 1–7 Likert scales and white space questions. Verbal consent was gained before the round from all patients included. Feedback on acceptability of the round was collected verbally from patients after each encounter.

Data related to clinician exposure to at risk patients and use of PPE were collected.

Results

24 participants answered the pre-session questionnaire. 19 were junior doctors and 4 were specialist trainees. Table 1 summarises their responses. Participants strongly agreed that bedside teaching is key to educating clinicians (7, IQR 6–7). It was also apparent that bedside teaching had been severely affected by the COVID-19 pandemic, becoming a rarity (2, IQR 2–4).

Table 1

Respondents' scores to the pre-session questionnaire. Presented as medians (IQR). *denotes Likert scale scores ranging from 1= 'never' to 7= 'every day'. §denotes Likert scale scores ranging from 1= 'strongly disagree' to 7= 'strongly agree'.

| Pre-questionnaire questions | Respondents' scores [n = 24] |
|--|------------------------------|
| In my past experience, teaching occurs on ward rounds | 4 (3–4)* |
| In my recent experience, during the COVID-19 period, teaching occurs on ward rounds | 3 (2-3.25)* |
| Over my career (including medical school) teaching on ward rounds has been helpful to my learning | 5 (4–6)§ |
| Bedside teaching is key to educating clinicians | 7 (6–7)§ |
| I have had bedside teaching during the COVID-19 period | 2 (2–4)* |
| I have been at the patients' bedside on ward rounds during the COVID-19 period | 4 (2–6)* |
| I have been able to observe the senior clinician-patient interaction on ward rounds during the COVID-19 period | 5 (2.75-6)* |
| I enjoy most ward rounds as they are an excellent opportunity for learning | 4 (4–5)§ |
| I find most senior clinicians who lead ward rounds engaging as teachers | 4 (3–5)§ |
| I feel able to ask the senior clinician educational questions during ward rounds | 4.5 (3-5.25)§ |

Session 1 and 2 had 6 and 4 participants respectively, all of whom had answered the pre-questionnaire. There were 3 interim foundation doctors, 5 foundation year 1 doctors and one registrar. Table 2 summarises their responses to the post-teaching questionnaire. The 1st session was affected by a loose

microphone connection and this was reflected by participants strongly disagreeing (2.5, IQR 1.25-3) that they were able to see and hear the patient-clinician interaction, as if they had been present in person. In the second session with the issue rectified, the quality of video and audio allowed respondents to appreciate subtle clinical signs and most strongly agreed that they felt like they were physically present (7, IQR 6.75-7). Feedback regarding session engagement, usefulness and quality was positive across both sessions. The patients facilitating the sessions found them acceptable and had no particular concerns.

Table 2

Respondents' scores to the post-session questionnaire. Presented as medians (IQR). All answers presented as Likert scale scores ranging from 1= 'strongly disagree' to 7= 'strongly agree'.

| Post-questionnaire questions | Respondents' scores | | |
|--|---------------------|---------------------|-----------------|
| | 1st session [n = 6] | 2nd session [n = 4] | Pooled [n = 10] |
| I was able to see and hear the patient-clinician interaction, like I was in the room | 2.5 (1.25-3) | 7 (6.75-7) | 4.5 (2.25-6.75) |
| The teaching was relevant to me | 6.5 (6-7) | 6.5 (5.75-7) | 6.5 (6-7) |
| I found the clinician leading the ward round engaging as a teacher | 7 (6.25-7) | 7 (7-7) | 7 (7-7) |
| I felt able to ask the clinician leading the ward round educational questions | 7 (6.25-7) | 6.5 (5.75-7) | 7 (6-7) |
| I felt like my questions were answered | 7 (6.25-7) | 6.5 (6-7) | 7 (6-7) |
| The session was helpful to my learning | 5.5 (3.5-6.75) | 6.5 (6-7) | 6 (5.25-7) |
| In my opinion the use of HoloLens in this context is worthwhile | 5.5 (3.5-6.75) | 6.5 (6-7) | 6 (5.25-7) |

Both teaching sessions were undertaken with at risk COVID-19 patients in side rooms. Session 1 and 2 lasted 26 and 33 minutes respectively. Cumulative clinician exposure to at-risk-patients was 59 minutes versus 288 minutes had bedside teaching occurred in person. This was equivalent to a 79.5% reduction in exposure (Fig. 3). 10 pieces of disposable PPE (gown, apron, gloves and mask) alongside the HoloLens™ were used to facilitate teaching versus 60 pieces of disposable PPE had bedside teaching occurred in person. This was equivalent to a 83.3% reduction in PPE use (Fig. 3).

Discussion

This study is proof of principle that mixed reality headsets can be used effectively to deliver high-quality clinical bedside teaching. This novel format confers significant advantages in terms of: minimising exposure of trainees and medical students to SARS-CoV2; saving PPE; enabling much larger attendance than possible at traditional bedside teaching; creating an environment that is less intimidating for the

patient; and real-time application of learning to a clinical context, by augmenting the headset view with educational figures for example.

Several key lessons were also learned, namely that the effectiveness of the session is dependent on the technology functioning as intended and operator competence. This was apparent early on and performing equipment checks before the sessions and allowing trainers to practise with the headset aimed to minimise issues. A steep learning curve was observed, with trainers able to use the headset confidently after one or two practices. The technology is clearly good enough for educators to deliver high-quality clinical bedside teaching as demonstrated in the 2nd session's participants' feedback. Specifically, resolution was good enough to appreciate the trainer demonstrating a rapid afferent pupillary defect.

A potential limitation of remote bedside teaching is the inability of the trainee to clinically examine the patient or appreciate signs themselves. The pandemic has necessitated such an approach as remote teaching was the best available surrogate to in person teaching. It is unclear however what the difference in educational impact is, of mixed reality remote versus in person bedside teaching. Similarly, the clinical cases chosen had signs that were appreciable remotely but some clinical signs require tactile feedback for example: examining limb tone during neurological examination, or auscultation for cardiac murmurs. On this latter point, note that digital stethoscopes that would allow sharing of auscultation findings and these are potentially compatible with a HoloLens™.

This study itself was purely a feasibility trial and therefore it is difficult to comment on much beyond the technical feasibility to deliver a remote mixed reality bedside teaching session. Further research would be useful to ascertain the education effectiveness of such an intervention using measures beyond subjective feedback. It is important to note that telemedicine is available in simpler and more accessible formats and the additional potential of the mixed reality component, specifically to share educational figures and radiological images at the bedside, needs to be further investigated.

The ability to create a virtual classroom at the bedside where learners can remotely attend a bedside clinical teaching session and relevant results images can be shared, interacted with and discussed is a novel evolution of the traditional bedside teaching format. Its benefits in a pandemic situation are clear but its applicability outside of this context has potential and will need further investigation.

Conclusions

Mixed reality bedside teaching is technologically feasible and acceptable using the HoloLens™ platform. This confers significant benefit allowing bedside teaching to continue whilst complying with the stringent and necessary infection prevention strategies during the COVID-19 pandemic. Beyond the pandemic there may indeed be additional benefits including the convenience of remote attendance and the introduction of educational 'holograms' to the bedside. Further research is warranted into this exciting educational platform.

List Of Abbreviations

AR - Augmented reality

MR - Mixed Reality

PPE - Personal Protective Equipment

Declarations

Ethics approval and consent to participate

No ethical approval was required. HoloLens™ was approved as part of normal Personal Protective Equipment and for use as part of service provision in the trust.

Consent for publication

No patient data has been published here. Staff were used to simulate images.

Availability of data and materials

AS, AG and GZ have access to the data and take responsibility for integrity of the data and analysis.

Competing interests:

All authors declare no relevant competing interests

Funding:

No funding was received. Equipment was loaned by Microsoft(Redmond, WA, USA) but no influence was borne on the study.

Authors' contributions

All authors contributed to the project with AS and AG designing the project. AG and GZ collected data. GZ, AS, AG, AB, GM, PP, and JK helped deploy the devices. AD, NN, GM, PP, JK reviewed the manuscript. JK and GM had ultimate oversight over the mixed reality working group.

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Figures

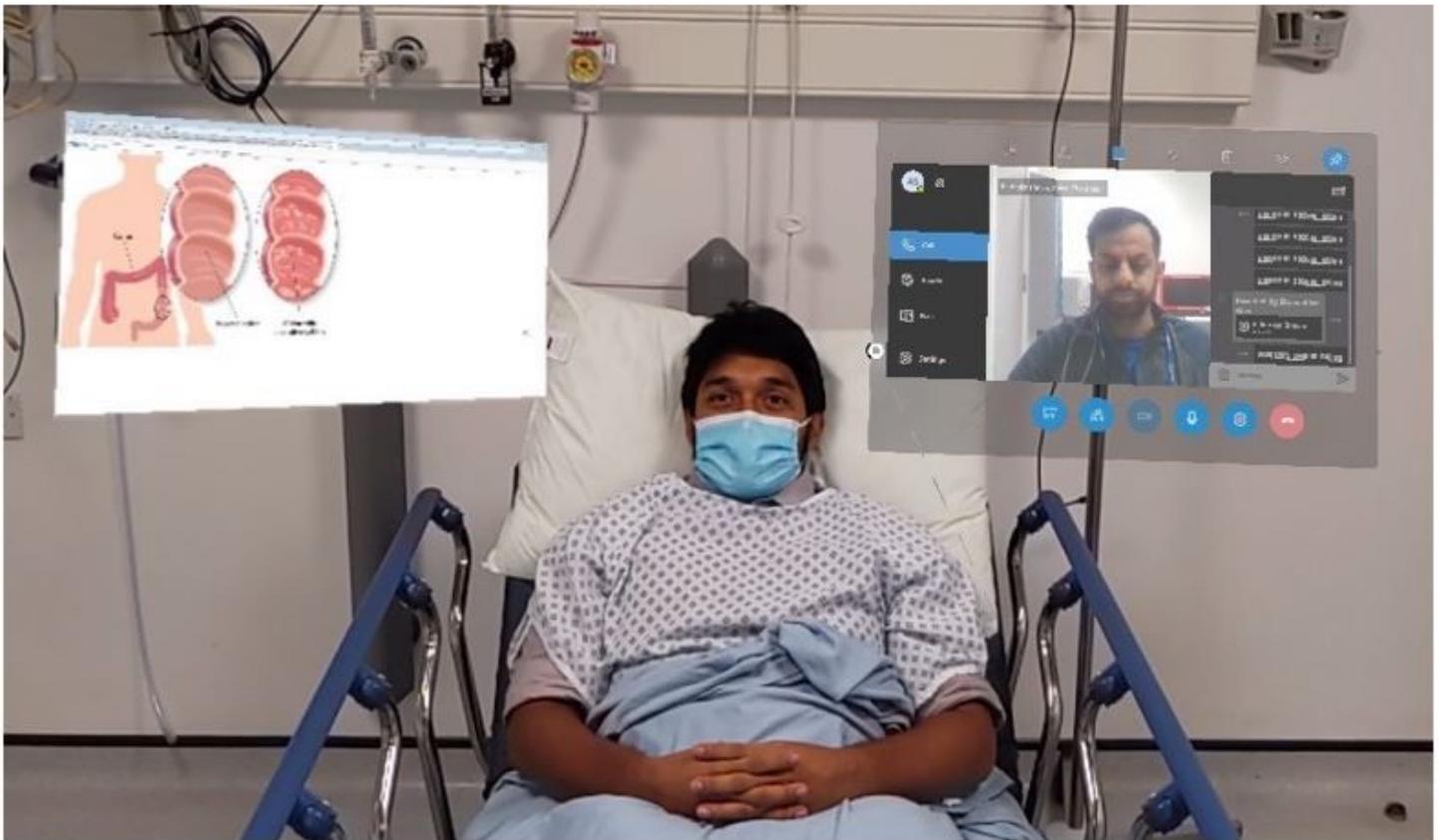


Figure 1

First person view from trainer wearing HoloLens™ and same view seen by remote attendee. Video and audio bidirectional communication with trainees through the right screen. Relevant clinical image shared on left screen. Both 'holograms' can be manipulated by hand gestures. (Simulated using staff for patient confidentiality, presented with consent by authors AS, AG and Jabed Ahmed)



Figure 2

HoloLens™ used as part of personal protective equipment. (Simulated using staff for patient confidentiality, presented with consent by authors AS, AG and Javed Ahmed)

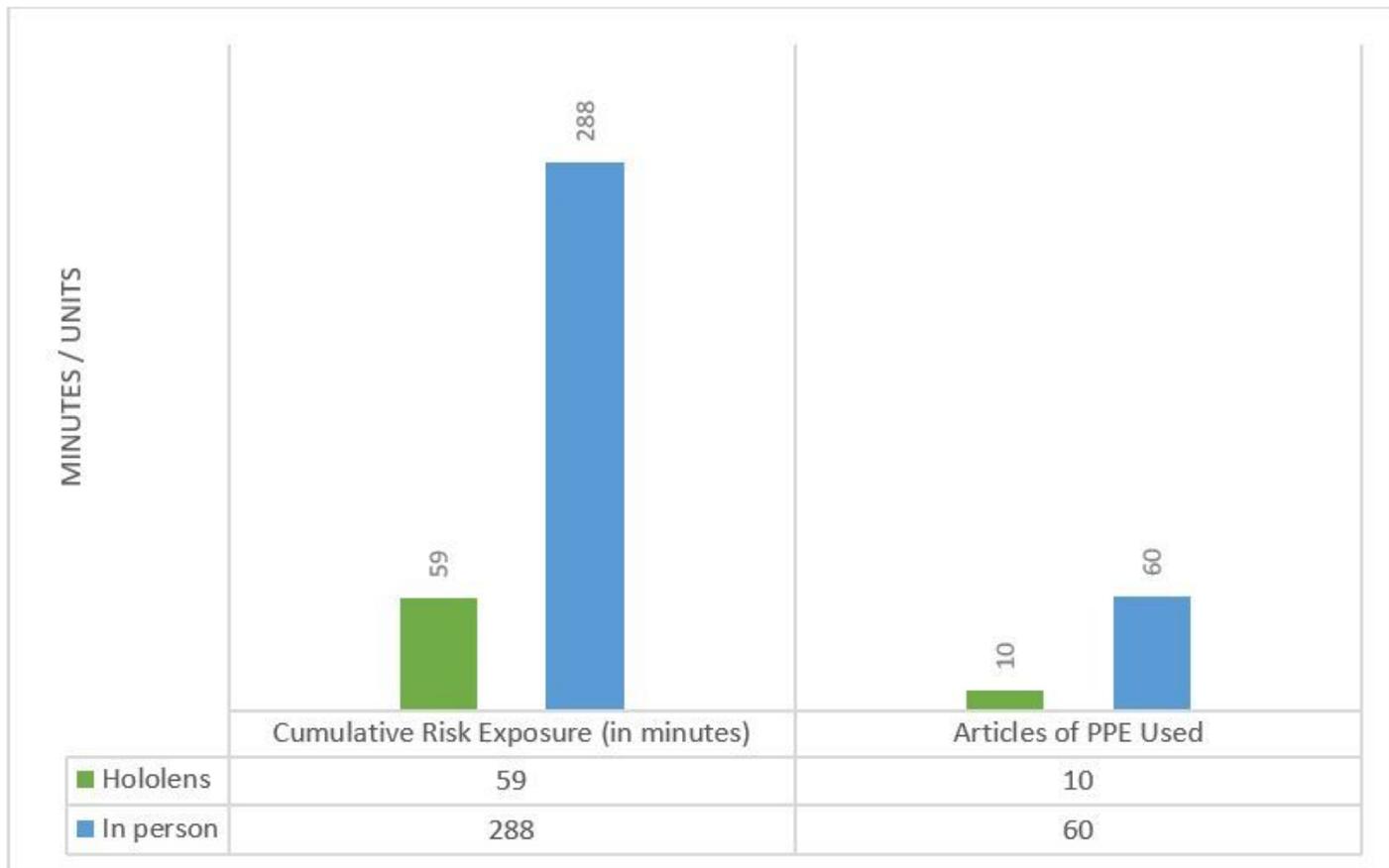


Figure 3

Cumulative exposure in minutes to risk at patients and article of PPE used in HoloLens™ mixed reality teaching versus in person teaching (projected)

Supplementary Files

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