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Smart glasses evaluation during the COVID-19 pandemic: First-use on Neurointerventional procedures

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ABSTRACT

The COVID-19 pandemic is rapidly transforming the healthcare system, with telemedicine, or virtual health, being one of the key drivers of the change. Smart glasses have recently been introduced to the public and have generated interest with healthcare professionals as demonstrated by their early adoption in clinics and hospitals. Observing procedures is essential for young interventionalist-in-training, but sometimes it is difficult for them to be able to get the volume of exposure to procedures that they need. Here, we report the first experience using smart glasses for Neurointerventional procedures, highlighting potential benefits and limitations during different scenarios including invitro and life cases. This field is novel, innovative, and may have potential to improve both patient care and patient safety in other health care settings.

1. Introduction

In the last years there has been a rapid advancement in robotics, sensors, artificial intelligence, genomics, data analytics/informatics, nanotechnology, and virtual reality for delivering precision medicine [1, 2].

The COVID-19 pandemic is rapidly transforming the healthcare system, with telemedicine, or virtual health, being one of the key drivers of the change [3–5]. Although medical education has also adopted the concept of e-learning, there are still some surgical specialties where life procedural observations are mandatory for training.

Smart glasses have been adopted by logistics and manufacturing companies with the aim of remote viewing, teleconferencing, documentation, and quality control in complex processes [6–12]. This field is novel, innovative, and has been found to have potential to improve both patient care and patient safety in other health care settings.

According to our literature search, few reviews have been published about smart glasses in surgical and nonsurgical settings [6–12]. The aim of this study was, therefore, to highlight potential benefits and limitations with the Neurointerventional use of smart glasses in different scenarios, including in vitro and real-life procedures.

2. Material and methods

The Rods & Cones (Apollolaan, Amsterdam) application establishes a video connection between the remote expert and the operator wearing smart glasses with cameras. Once connected, the remote expert controls the connection, and the operator does not need to touch the smart glasses (Fig. 1). Through a firewall, the connection is made with the application running on the Azure cloud. The platform is currently available on Iristick Hardware (Fig. 1).

The glasses have an integrated speaker and microphone connector for earpiece, a display screen, a central camera, a zoom camera and a flash light (Fig. 1). The smart glasses are controlled by a smartphone that

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is connected to the hospital network via Wi-Fi. The remote expert connects through the application using its own computer (Fig. 1).

Requirements for the Wi-Fi provided in the room where the smart glasses are an upload bandwidth of at least 3 Mbit/sec and preferably 10 Mbit/sec, and a download speed of at least 0.8 Mbit/sec.

As the video of the smart glass requires high download bandwidth, 4 levels of video quality, were defined which can be switched by the remote expert: high definition (720 p on 2 cameras): up to 15 Mbit/s, standard definition (540 p on 2 cameras): 7.5 Mbit/s, low definition (360 p on 2 cameras): up to 3 Mbit/s and a very low definition (360 p only central camera): 0.8 Mbit/s.

In the current study, 5 Neurointerventionalists performed invitro and clinical procedures on streaming.

In vitro testing were performed using a full vascular silicone model (United biologics Inc, USA) (Fig. 2).

The aim of this study was to highlight potential benefits and limitations during different scenarios from low to high complexity: mechanical thrombectomy, carotid stenting, stent assisted-coiling and flow diversion. The image quality correlation between operator and remote physicians (vessel/device definition and stability of retransmission), their audio interaction (audio delay and stability) and the operator comfort wearing the glasses were assessed.

This video is only transmitted to a certified remote assistant in a 1-to-1 mode. Videos and images are not stored during or after transmission. The study was approved by the institutional review board.

3. Results

8 procedures were performed and transmitted on streaming, 2 invitro and 6 real-life cases (Table 1). One mechanical thrombectomy, 2 carotid stenting, 1 stent assisted coiling and 4 flow diversion cases were tested (Figs. 2 and 3).

Although during the invitro testing the users felt unfamiliar with smart glasses and noted that there was a learning curve, the clinical cases were performed with a high level of satisfaction. No objective or subjective nervousness or anxiety were found.

Smart glasses were found to be comfortable to wear, but some users who wore prescription glasses found it difficult to combine these with smart glasses while others did not have this issue.

The quality of imaging was positively evaluated by the remote expert when the operator worked on a magnified field. The image quality of the low-definition (360 p on 2 cameras, up to 3 Mbit/s) and very low-definition (360 p only central camera, 0.8 Mbit/s) modes were insufficient to achieve enough resolution. Although standard definition (540 p on 2 cameras,7.5 Mbit/s) showed enough resolution for hands-on evaluation from the remote expert, only the high definition mode (720 p on 2 cameras, up to 15 Mbit/s) allowed a correct evaluation of the angiographic images. Invitro and flowdiverter cases achieved the best visualization rating (Table 1).

Patient's unpredictable movements were negatively rated, showing a better correlation during the procedures performed under general anesthesia.

The treating physician sometimes had to come closer to the monitor than they preferred. Although the quality of the zoom was positive reported, it required more attention and effort from operator to maintain head stable.

Wi-Fi and/or Bluetooth were used for data transmission. Smart glasses were able to connect to Wi-Fi and Bluetooth without problems. but issues with Wi-Fi coverage were noted.

During data transmission, stuttering, cutoffs, and delays occurred (Table 1).

Platform interface was intuitive, and no issues were reported from the remote expert.

4. Discussion

In recent years, telemedicine's growth has been incremental, and used by only 8% of Americans in 2019 [3–5]. During the COVID pandemic the massive conversion to telemedicine demonstrate its utility as an effective tool for the so-called social distancing in clinical or other

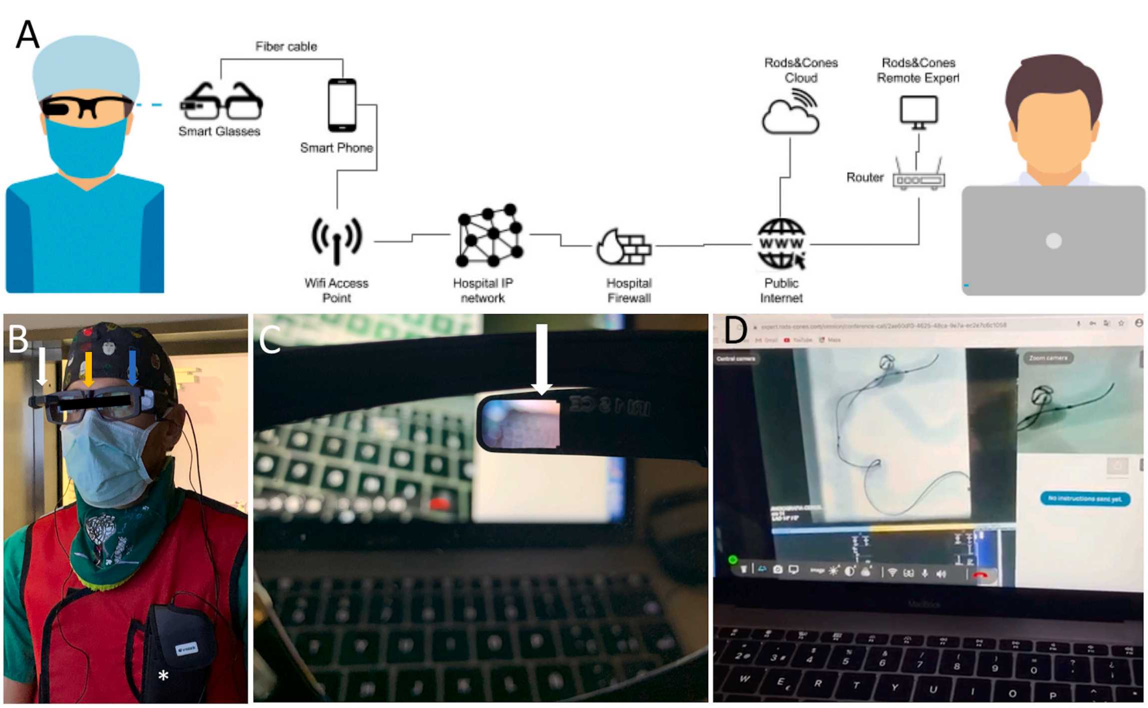

Fig. 1. Smart glass system. (A) The Rods & Cones application establishes a video connection between the remote expert and the operator wearing smart glasses with cameras. (B) A right lens integrated small screen (white arrow), central camera (yellow arrow) and left zoom camera (blue arrow). The smart glasses are controlled by a smartphone that is connected to the hospital network via Wifi (*) (C, D) Right eye operator view showing the small screen which replicates the remote view (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article).

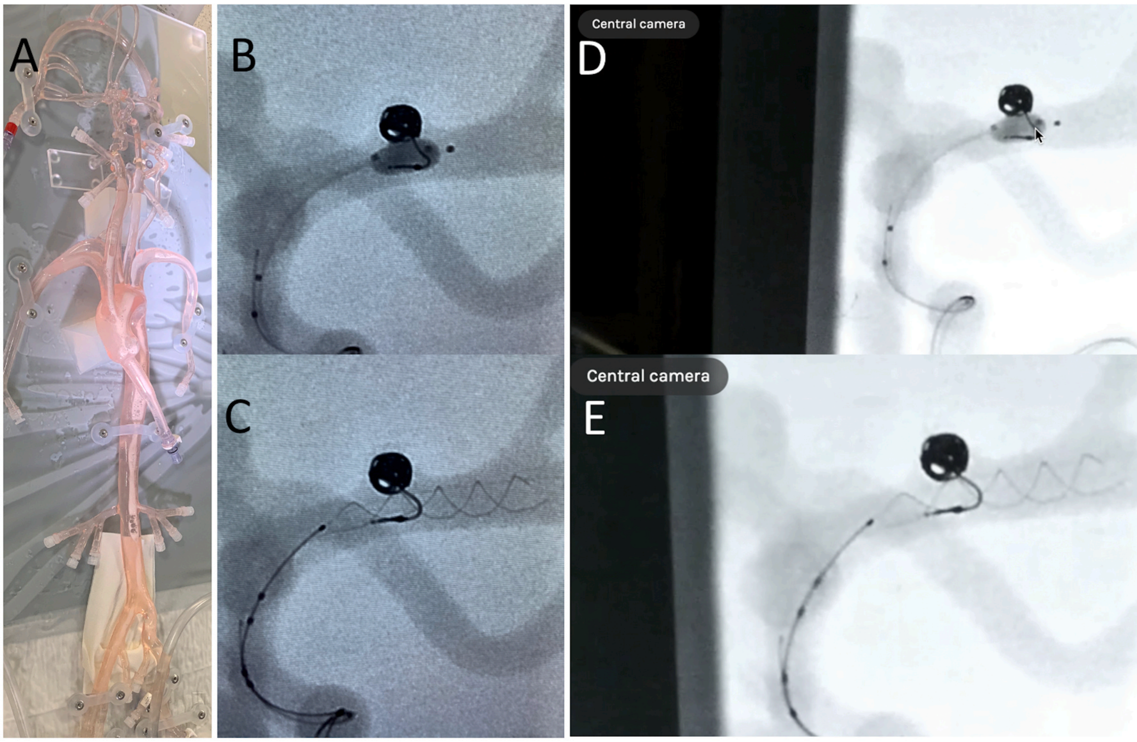

Fig. 2. In-vitro evaluation under fluoroscopy. (A) Full vascular Silicone model (B,C) real life operator's view (D, E) remote view. A good correlation between both views is demonstrated. A baby Leo stent was deployed through a Eclipse 6 × 9 2 L balloon for Stent assisted coiling.

Table 1
Cases performed in Streaming using the smart glasses.

Case	Disease	Experience	Technique	Location	Anesthesia	Audio	Image*	Device
1	Stroke	Human	Mechanical thrombectomy	Right M2	Sedation	Good interaction	Medium-poor	Cacth V35**
2	Carotid Stenosis	Human	CAS	ICA	Sedation	Good interaction	Good	Roadsaver Stent***
3	Carotid Stenosis	Human	CAS	ICA	Sedation	Cutoff/delay	Good	Roadsaver Stent***
4	Aneurysm	In-vitro	Stent-assisted coiling	M1	Na	Cutoff/delay	Excellent	Optima coils**. Eclipse 2L 6 × 7 SN**. Baby leo 2.5 × 18**
5	Aneurysm	In-vitro	Flow diverter	AcoA	Na	Cutoff/delay	Excellent	SVB** 3.25 × 25. 2.75 × 10
6	Aneurysm	Human	Flowdiverter	Paraclinoid	GA	Good interaction	Excellent	Silk Vista**
7	Aneurysm	Human	Flowdiverter	Cavernous	GA	Good interaction	Good-medium	Leo/Silk+**
8	Aneurysm	Human	Flowdiverter	Paraclinoid	GA	Good interaction	Excellent	Silk Vista**

*Image quality (high definition mode), fully device visualization: excellent, good, medium, poor.
Balt extrusion, Montmorency, France. * Terumo Corp, Tokyo, Japan.

settings [3–5].

Smart glasses have recently been introduced to the public and have generated interest with healthcare professionals as demonstrated by their early adoption in clinics and hospitals [6–12].

Smart glasses are small computers, which comprise a head-mounted monitor that can display various information and a video camera that records what the wearer is seeing. This is quite suitable for medical purposes and especially for surgery. The applications in medical education have been demonstrated in the surgery, urology, and cardiology training programs [6–12].

Observing procedures is essential for young interventionalist-in-training, but sometimes it is difficult for them to be able to get the volume of exposure to procedures that they need, especially with limited numbers of cases at some institutions.

As an alternative to smart glasses, another telemedicine options have been recently described for the Neurointerventional field. The Tegus system [13,14] (Tegus medical GmbH, Hamburg, Germany), is a recent telestream system designed with a similar purpose, but without the use of glasses. The operator and remote doctor use headsets to communicate with each other while imaging is based on a 360 degrees camera placed into a tripod controlled by the proctor (remote physician). As an advantage, the Tegus system is more comfortable for the operator and connection more stable considering the use of LAN (local area network) instead of Wi-Fi. The view angle and zoom are controlled by the remote proctor to guarantee the best possible visualization and to avoid unnecessary distractions for the trainee.

The smart glasses are controlled by a smartphone that is connected to the hospital network via Wi-fi.

In our experience, the most frequent limitation of smart glasses was the Wi-Fi bandwidth which was related to unstable connection.

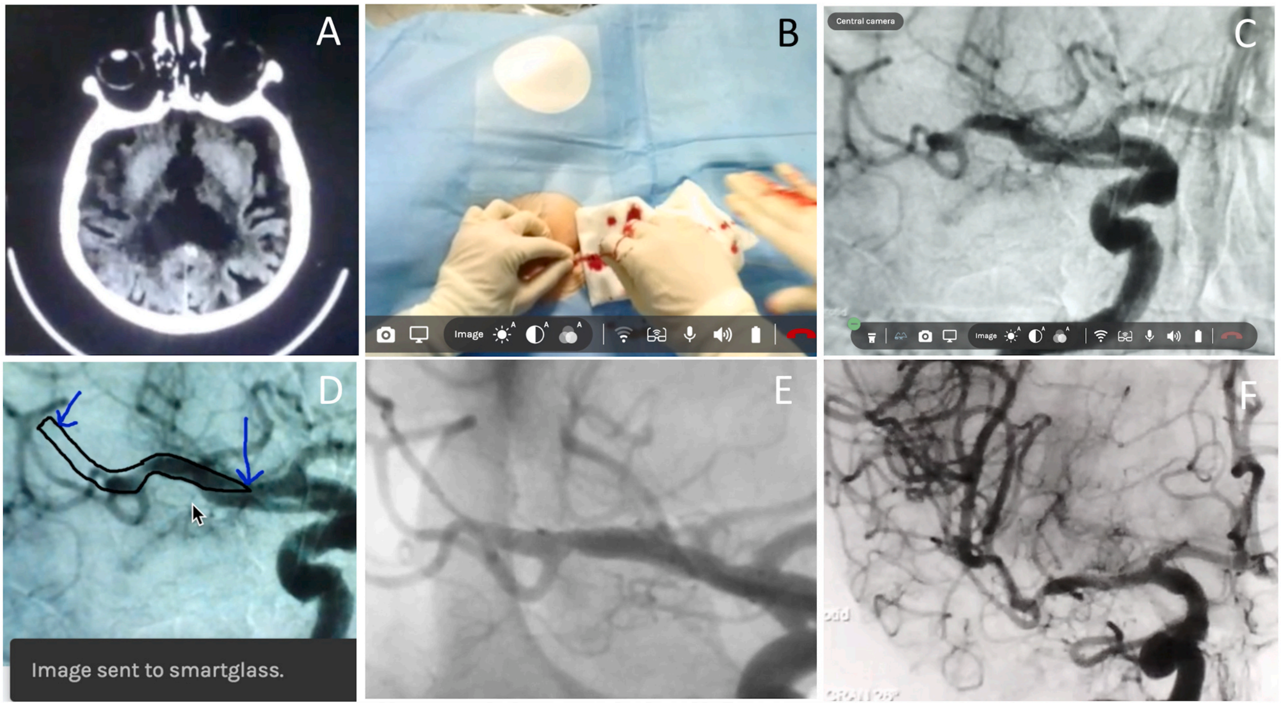

Fig. 3. Life-case, right M2 occlusion. Remote expert view: (A) Radiology monitor visualization for discussion and decision making based on CT findings. (B) Hands-on interaction during the access phase. (C) Remote view of the angiographic run showing the M2 occlusion. (D) Life drawing performed from the remote physician that was direct sent to the glasses and visualized into the integrated operator glass-screen. (E,F) Stentriever placement and final reperfusion.

Infrastructure, such as Wi-Fi and streaming, is a prerequisite for clinical use of most new technology, including smart glasses, and has been found to be a limitation in both surgical and nonsurgical settings.

From the 4 levels of video quality of the system, in our experience only the “high definition mode” (720 p on 2 cameras) was appropriated for guarantee a device/image remote correlation. Battery life is another limitation for long procedures, as AVM or DAVF embolizations.

The potential advantages of the smart glasses is that the visual field of the operation site is not disturbed by the operator’s head or another external elements. Also, the operator can verify the video images during the retransmission by looking at the monitor.

In our experience, the glasses were comfortable to wear except in some cases where operator wore prescription glasses. Whilst in our cases there were no major complaints, in theoretical longer procedures, as AVM embolizations, could be more cumbersome for the operator.

Another advantage of the smart glasses is that they don’t need a complex installation, so they are more accessible and replicable.

Once connected, the remote expert controls the connection, and the surgeon or instrument nurse does not need to touch the smart glasses. Remote doctor has the capability to draw a specific image that can be integrated into operator glass-screen, enhancing the interaction.

Also, the peer-to-peer interaction is not limited to the angiosuite, since any visualization including radiology monitors may be discussed meaning that smart glassed could help for a patient selection in case of emergent pathologies like Stroke or even for patient monitoring (Fig. 3).

A coordination with the operator is mandatory considering that remote doctor does not have the independence to select the visual field, fully dependent on operator head movement. Unfortunately, without the ability to adjust the camera angle, it can be difficult to conform the operating space to the fixed view of the camera. Comparing to the conventional live transmission systems using steady cameras, the smart glasses drawback for the remote viewer are in those circumstances requiring the operator to be looking back and forth continuously from the monitor to the table for instrumentation.

The results further highlight that there was a learning curve associated with the use of smart glasses. In our experience, invitro test were previously performed for that purpose prior the life cases. This indicates that user training is crucial when introducing smart glasses into complex care environments in order to maintain high-quality care and patient safety.

Several head-mounted video cameras are already available [6–10]. Rods & Cones platform is conceived to work on any type of smart glass. All web connections are encrypted and application environments used Azure Security Center. No recording was allowed and all data protection were ensured following standards.

Smart glasses have potential to reshape healthcare, however several adjustments are needed before the device can be used to its fullest potential. In order to gain acceptance by medical professionals, smart glasses need to be constantly updated and developed to fit the needs of their specific users.

In our opinion, the combination of both modalities (smart glasses and steady cameras) may be ideal for enhancing the interaction between operator and viewer.

The health care community is faced with an unprecedented opportunity to learn from the current experience to draw lessons for the future. Further clinical studies will need to be conducted to qualitatively assess the benefits of telemedicine systems, as an adjunct or replacement to current health information technology infrastructure.

5. Conclusion

Smart glasses may be a helpful tool on the Neurointerventional field for educational and clinical purposes. The value of telehealth for interventional procedures need to be evaluated in large studies and real-life environments.

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Ethics approval

Institutional Review Board, CEim, Hospital Clínico Univeristario de Valladolid. PI 20-2079.

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CRediT authorship contribution statement

MMG, VK: Study concept, literature review, acquisition of data, draft and review of the manuscript. All authors have contributed to the authorship, and final review of the manuscript.

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Competing interests

MMG is consultant of Balt, Medtronic and Stryker.

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