Title
Evaluation of augmented reality technology in global urologic surgery.

Journal
The American Journal of Surgery, 226(4)

Authors
Dominique, Georgina
Kunitsky, Kevin
Natchagande, Gilles
et al.

Publication Date
2023-10-01

DOI
10.1016/j.amjsurg.2023.05.014

Peer reviewed

The American Journal of Surgery xxx (xxxx) xxx

Contents lists available at ScienceDirect

The American Journal of Surgery

journal homepage: www.americanjournalofsurgery.com

Original Research Article

Evaluation of augmented reality technology in global urologic surgery

Georgina Dominique [a, b], Kevin Kunitsky [c], Gilles Natchagande [d], Mohamed Jalloh [e], Abeselom Lemma Gebreamlak [f], Isiaka Lawal [g], Michel Michaël Agounkpe [d], Fred D. Hodonou [d], Dodji Magloire Ines Yevi [d], Josué D.G. Avakoudjo [d], Kurt McCammon [h], Graham Watson [i], Kymora B. Scotland [b, *]

[a] *Charles R. Drew University of Medicine and Science, Los Angeles, CA, USA*
[b] *David Geffen School of Medicine at University of California, Los Angeles, CA, USA*
[c] *Kansas City University of Medicine and Bioscience, Kansas City, MO, USA*
[d] *Universitaire Centre National Hospitalier Universitaire Hubert K. Maga de Cotonou, Benin*
[e] *Hôpital Général Idrissa Pouye, Dakar, Senegal*
[f] *Tikur Anbessa Hospital, Addis Ababa, Ethiopia*
[g] *National Hospital, Abuja, Nigeria*
[h] *Eastern Virginia Medical School, Norfolk, VA, USA*
[i] *East Sussex Healthcare NHS Trust, East Sussex, United Kingdom*

A R T I C L E I N F O

Article history:
Received 14 March 2023
Received in revised form
8 May 2023
Accepted 10 May 2023

Keywords:
global surgery
Surgical training
Augmented reality
global surgical partnerships
Surgical technology

A B S T R A C T

Background: The COVID-19 pandemic drastically reduced opportunities for surgical skill sharing between high-income and low to middle-income countries. Augmented reality (AR) technology allows mentors in one country to virtually train a mentee in another country during surgical cases without international travel. We hypothesize that AR technology is an effective live surgical training and mentorship modality.
Methods: Three senior urologic surgeons in the US and UK worked with four urologic surgeon trainees across the continent of Africa using AR systems. Trainers and trainees individually completed post-operative questionnaires evaluating their experience.
Results: Trainees rated the quality of virtual training as equivalent to in-person training in 83% of cases (N = 5 of 6 responses). Trainers reported the technology's visual quality as “acceptable” in 67% of cases (N = 12 of 18 responses). The audiovisual capabilities of the technology had a “high” impact in the majority of the cases.
Conclusion: AR technology can effectively facilitate surgical training when in-person training is limited or unavailable.

1. Introduction

Global surgical partnerships allow for the transfer of surgical skills, knowledge, and resources between high and low to middle-income countries to the benefit of both the health professionals involved and the patients. The COVID-19 pandemic halted global surgery mission trips. The loss of opportunity for surgical skill sharing between surgeons from different countries highlighted the need for a surgical teaching modality that can be implemented when in-person training is not feasible or is unavailable.

Augmented reality (AR) technology may provide a welcome supplement to the standard in-person surgical training model. AR technology allows mentors in one country to virtually train and skill-share with a mentee in another country during surgical cases. The audiovisual capabilities of AR technology allow trainers to not only see the surgical field and associated imaging but also provide verbal and visual feedback to the trainee in real-time. Commercially-available augmented reality technology is already being investigated for use across surgical specialties for both surgical planning and execution in the United States (US).[1–3] In Urology specifically, augmented reality and virtual technology have been introduced into procedures such as robotic assisted radical prostatectomy, robotic assisted partial nephrectomy, as well as renal and prostate biopsy.[4–8] The introduction of AR technology into

* Corresponding author. University of California Los Angeles, 200 Medical Plaza Driveway, Suite 140, Los Angeles, CA, 90095, USA.
E-mail address: kscotland@mednet.ucla.edu (K.B. Scotland).

https://doi.org/10.1016/j.amjsurg.2023.05.014
0002-9610/© 2023 Published by Elsevier Inc.

global surgical partnerships allows for the continuation of collaboration, mentorship, and learning between international teams without the necessity of international travel.[9] We aim to explore the utility of augmented reality technology as a surgical training modality.

2. Methods and materials

Three experienced Urologic surgeon trainers with sub-specialization and expertise in general urology, endourology, and reconstructive surgery in the US and the United Kingdom worked with four urologic surgeon trainees in Benin, Ethiopia, Nigeria, and Senegal. All trainees are trained urologic surgeons who completed their training abroad but have not completed sub-specialty training. Trainer-trainee pairs were based on previous mentorship relationships. Trainer-trainee pairs completed surgical procedures together using either the Proximie™ or Vuzix™ augmented reality technology systems (Fig. 1). The market price of the Proximie™ system is ~$17,000/year while the Vuzix™ smart glasses range from $1300–2500. Both technologies, however, were donated in-kind to Medi Tech Trust UK Charity.

The Proximie™ system utilizes a standing console which transmits audio and visual feedback between the trainee in the operating room and the trainer in any location, in real time. The console's camera is positioned over the operating table, transmitting a live visualization of the procedure being performed and facilitating telepresence. The fluoroscope can also be connected into the console system. The mentor can then verbally provide feedback or annotate on the live view of the surgical field or imaging which is then seen by the mentee on the Proximie screen. Similarly, the Vuzix™ augmented reality glasses allow the trainer to see the trainee's point-of-view in the operating room and provide audiovisual feedback through the glasses. Through both technologies, the trainer is able to use virtual indicators to draw and provide feedback on the OR field or imaging (Fig. 4) while simultaneously providing verbal feedback through the audio capabilities of the technology.

After each surgical case using one of the technologies, trainers and trainees completed online questionnaires individually assessing the training experience and the utility of the technology during the surgical procedure.

3. Results

A total of 14 surgical cases were performed with augmented reality technology and evaluated using the online questionnaires. Surgical cases included percutaneous nephrolithotomy (PCNL) and urethral reconstruction (Fig. 4). The questionnaires for both trainers and trainees can be found in the supplemental data (Supplemental Data 1 and Supplemental Data 2). All of the trainers and trainees completed online questionnaires (Table 1, Table 2, Fig. 2, and Fig. 3).

3.1. Technology set-up and use

Trainees used the Proximie™ system in 50% of cases reported and the Vuzix AR system in 50% of cases (Fig. 2). Trainees experienced some technical problems while using the AR technology in 83% of the cases (N = 5 of 6 responses). Trainees reported that the virtual/augmented reality technology was easy to set up and use in 100% of cases (N = 5 of 6 responses) while trainers found the technology easy to set up in 72% of cases (N = 13 of 18 responses) and not easy to set-up and use in 11% of cases (N = 2 of 18 responses). Trainers reported technical problems in 11% of cases (N = 2 of 18 responses) and "no" technical problems in 89% of cases (N = 16 of 18 responses)(Fig. 2). The technical problems experienced included difficulty connecting the C-Arm of the fluoroscope and the videostack directly into the Proximie™ system, smart glasses battery draining during the procedure, poor image quality of the trainer on the mentee's side, and the occasional loss of the mentor's camera during drops in connectivity.

3.2. Virtual connection

These questions queried internet connectivity throughout each case. Trainees reported "rarely" having difficulty staying connected with the trainer in 91% of cases (N = 11 of 12 responses). Trainers reported "rarely" having difficulty with maintaining connection in 39% of cases (N = 7 of 18 responses) and "never" having difficulty connecting in 50% of cases (N = 9 of 18 responses). Trainees reported "often" having difficulty maintaining connection in 9% of cases (N = 1 of 11 responses) and trainers reported "often" having difficulty in 11% of cases (N = 2 of 18 responses) of cases. Trainees "rarely" experienced delay or time lag in 100% of cases (N = 12 of 12 responses) while trainers "never" experienced delay or time lag in 56% of cases (N = 10 of 18 responses) and "rarely" in 11% of cases (N = 2 of 18 responses) but "often" in 33% of cases (N = 6 of 18 responses). Trainers reported that time lag was problematic in 11% of cases (N = 1 of 9 responses).

3.3. Audiovisual capabilities

Trainers reported that the visual quality while using the technology was "acceptable" in 67% of cases (N = 12 of 18 responses) and "looks like I'm there" in 33% of cases (N = 6 of 18 responses). Trainers rated the impact of visual input/ability to draw on the screen for trainees as "high" in 83% of cases (N = 15 of 18 responses), "neutral" in 11% of cases (N = 2 of 18 responses), and "low" in 6% of cases (N = 1 of 18 responses). Trainees rated the

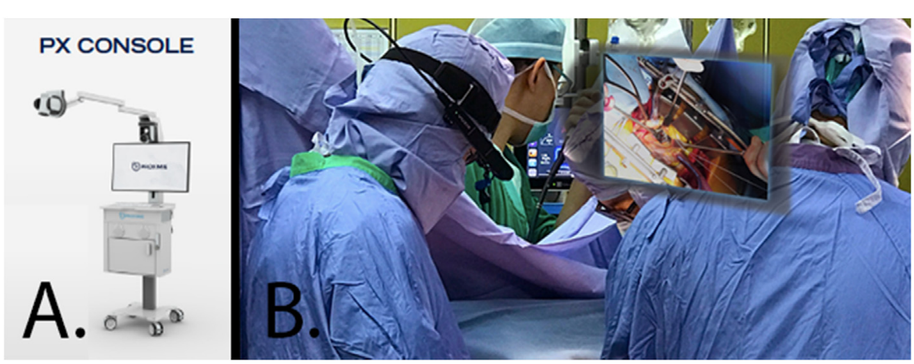

Fig. 1. A) Proximie™ Augmented Reality System. Photo courtesy of Proximie™. B) Vuzix™ Augmented Reality Smart Glasses in use during surgery. Photo courtesy of Vuzix™.

Table 1
Trainee demographics.

Where do you work?	What is your designation?	For how long have you practiced urology?	What does your practice entail?	If you chose “other” for your practice, please explain …	Does your Urology department collaborate with or host urologists from High Income Countries?	If your Urology department does collaborate or host urologist from High Income Countries, how many times per year?	What is the average duration spent by visiting surgeon at your site at a given time?
Cotonou, Benin	General Urologist	5–10 years	Minimally invasive surgery	open surgery and endourology	Yes	2-5 times	1–2 weeks
Dakar, Senegal	General Urologist	>10 years	Other	RECONSTRUCTION + MINIMALLY INVASIVE + OPEN SURGERY	Yes	2-5 times	1–2 weeks
Abuja, Nigeria	General Urologist	>10 years	Other	Open Surgery and Minimally Invasive surgery	Yes	Once	<1 week
Addis Ababa, Ethiopia	General Urologist	<5 years	Open surgery		Yes	Once	<1 week

Table 2
Trainer demographics.

Where do you work?	What is your designation?	For how long have you practiced urology since finishing training?	What does your practice entail?	If you chose “other” for your practice, please explain …	Does your Urology department collaborate with or host urologists from Low Income Countries?	If your Urology department does collaborate or host urologist from Low Income Countries, how many times per year?	What is the average duration spent by visiting surgeon at your site at a given time?
East Sussex, United Kingdom	Endourologist	>10 years	Minimally invasive surgery		Yes	Once	>4 weeks
Norfolk, Virginia	Reconstructive urologist	>10 years	Open surgery		Yes	Once	1–2 weeks
Los Angeles, California	Endourologist	<5 years	Minimally invasive surgery		No		

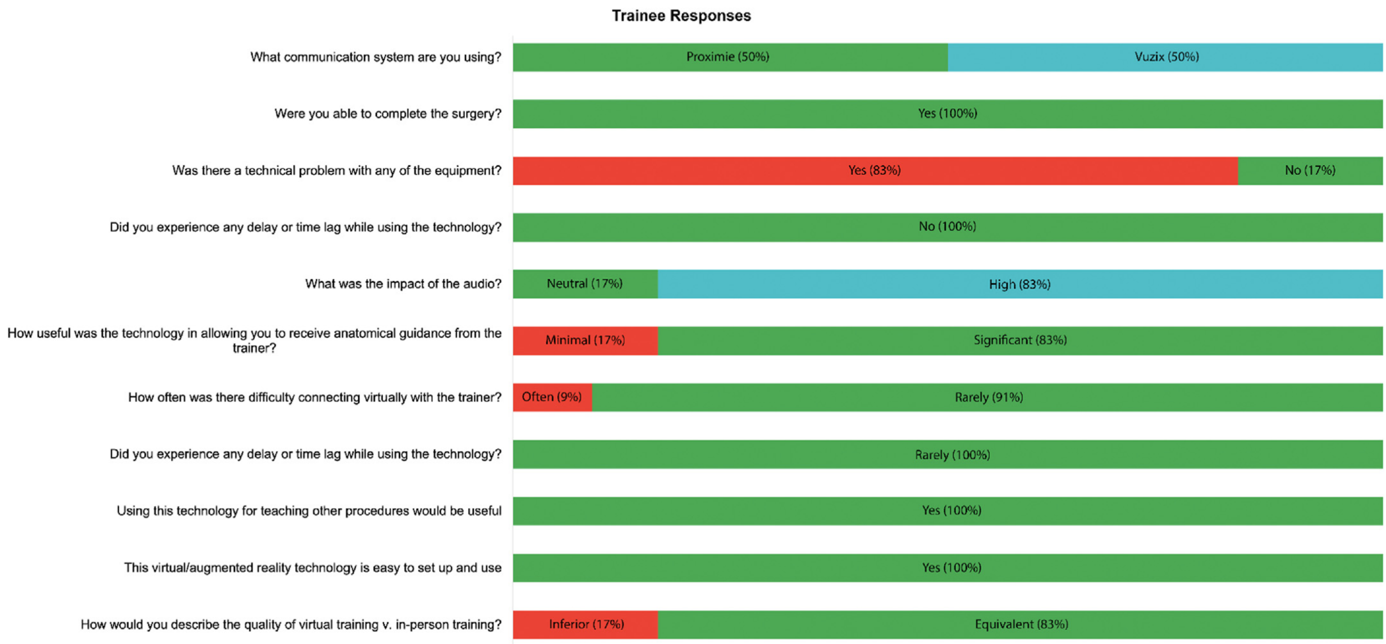

Fig. 2. A composite of online questionnaire responses completed by trainees.

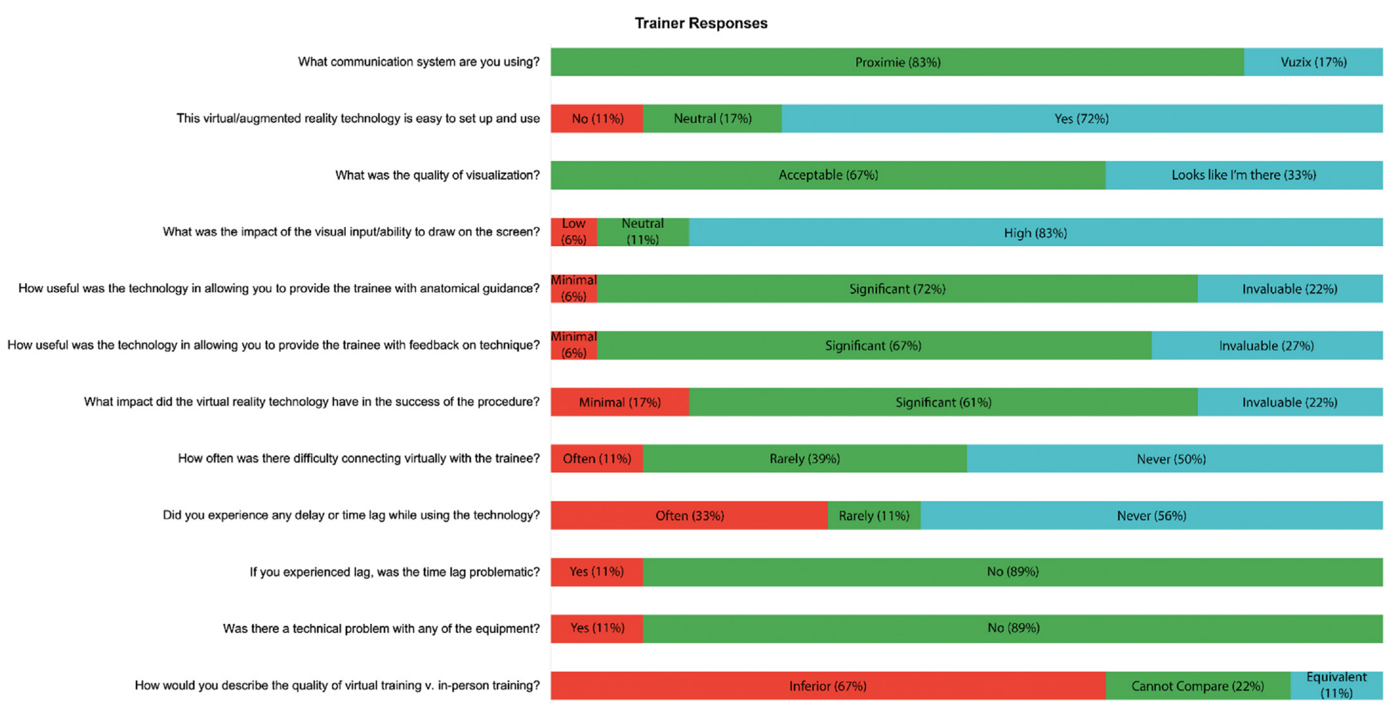

Fig. 3. A composite of online questionnaire responses completed by trainers.

impact of the audio as "high" in 83% of cases (N = 5 of 6 responses). Trainees rated the usefulness of the anatomic guidance from the trainer through the technology as "significant" in 83% of cases (N = 5 of 6 responses). Trainers rated the usefulness of being able to provide anatomical guidance as "significant" in 72% of cases (N = 13 of 18 responses) and "invaluable" in 22% of cases (N = 4 of 18 responses). For trainers, the ability to provide anatomical guidance had "minimal" utility in 6% of cases (N = 1 of 18 responses). The utility of the technology in allowing trainers to provide feedback on technique to trainees was "significant" in 67% of cases (N = 12 of 18 responses), "invaluable" in 27% of cases (N = 5 of 18 responses), and "minimal" in 6% of cases (N = 1 of 18 responses).

3.4. *Surgical training utility*

On their initial questionnaire response, all trainees reported having trained face-to-face 1 to 5 times with the trainer before the procedure. In 100% of the cases (N = 6 of 6 responses), trainees

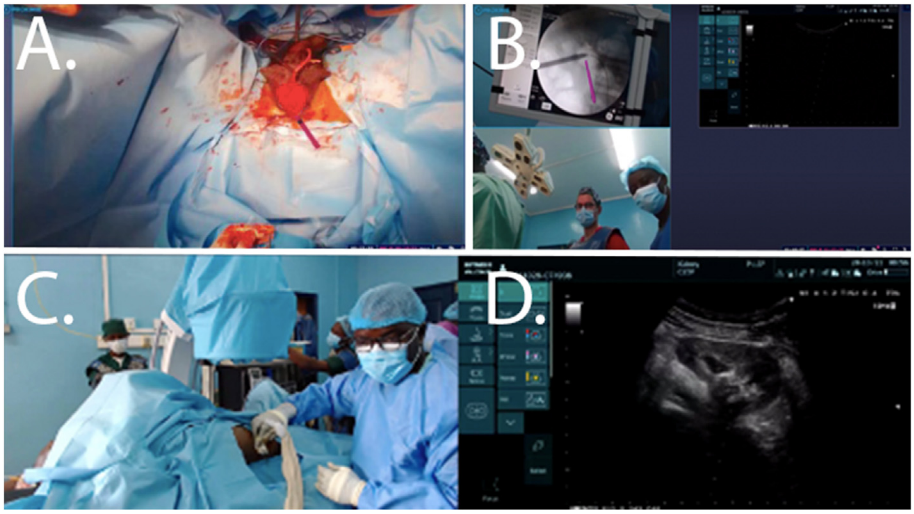

Fig. 4. A) A purple crayon indicator being used by the trainer to guide dissection during urethral reconstruction. B) A purple scalpel indicator being used by the trainer to guide wire placement during a percutaneous nephrolithotomy (PCNL) procedure. C) A trainee performing an ultrasound for a PCNL procedure with the AR technology, D) allowing the trainer to see the imaging in real time. (For interpretation of the references to colour in this figure legend, the reader is referred to the Web version of this article.)

were able to complete the procedure they were being trained on. Trainees rated the quality of virtual training as “equivalent” to in-person training in 83% of cases (N = 5 of 6 responses) and “inferior” in 17% of cases(N = 1 of 6 responses). Trainees responded in 100% of cases (N = 6 of 6 responses) that using this technology for teaching other procedures would be useful. Trainers rated the quality of virtual training as “inferior” to in-person training in 67% of cases (N = 12 of 18 responses), “cannot compare” in 22% of cases (N = 4 of 18 responses), and “equivalent” in 11% of cases (N = 2 of 18 responses).

4. Discussion

In this study, augmented reality technology proved a useful surgical training modality when in-person teaching was restricted due to the global pandemic. Trainees and trainers both reported easy set-up and use of the technology in the majority of cases with little issue connecting virtually. When delay and time lag did occur, which we have now come to expect with any virtual meeting, it was only problematic in a small minority of cases. In fact, though trainees experienced technical problems during a majority of the cases, they were able to complete every case and did not have to forgo the intended procedure. Bandwidth was not measured in this study, and we are unable to infer the magnitude of its contribution to delay or time lag. The visual quality was acceptable or “looks like I'm there” in all cases. The impact of the audio and visual input/ability to draw on the screen was high in the majority of cases. The usefulness of the ability to provide anatomical guidance through the AR technology was “significant” in the majority of cases for both the trainer and trainees. Trainees felt that there was equivalence to in-person training in the majority of the cases and that using the technology for teaching other procedures would be useful. Trainers, however, rated virtual training as inferior to in-person training in the majority of cases and equivalent only in a small percentage of cases. We believe that this disconnect may be attributed to the seniority and training experience of the trainers. The trainers involved in this study have combined 15+ years of in-person global partnership training experience while the trainees are more junior and have less global surgical partnership training experience to compare the virtual training sessions to. While it certainly cannot replace in-person surgical training, augmented reality technology can be explored as a supplemental teaching modality when in-person teaching is unavailable or restricted.

There are several limitations to our study that can be improved upon for further exploration of the utility of augmented reality technology in surgical training. This study utilized a small trainer/trainee cohort consisting largely of pairs connected by previous global surgical partnership trips before the pandemic travel restrictions. Thus, the small sample size may not allow the findings to be generalizable. We did not control for the experience level of trainees or trainers which may have had an influence on the training experience and comfort level during cases. Though all cases in this study were completed even with problems in connection, it is important to emphasize that our study consisted of mentees that are trained urologists and had previously performed the procedure they were receiving training on. The trainees and their teams are equipped to handle complications with or without mentorship. The surgical experience of the mentee is important to take into consideration when deciding to use AR technology for surgical training as the mentee and their surgical team will have the sole physical ability to operate if complications arise during the training. It may be unethical to attempt this type of training without confidence that the mentee and their team are capable of handling surgical complications. By the same token, surgical training via AR technology is not meant to replace in-person training but rather complement and strengthen global partnerships by facilitating more interactions without the logistics or cost of travel between countries. In fact, the technologies continue to be used between mentor and mentee pairs who participated in this study. We understand that the sticker price of the AR technologies may present a deterrent in replicating this study in other global partnerships, however, both companies are eager to work with individuals and institutions in order to further integrate their technologies into the healthcare field. Future studies should utilize a larger cohort of trainer-trainee pairs for comparison and consider stratification of responses by trainer seniority and/or trainee surgical experience. Research on the utility of augmented reality technology for use in surgical training would also benefit from a more formal comparison of the different types of commercially available technologies (e.g. standing augmented reality console v. eyewear). Nonetheless, our study showed benefit to the addition of augmented reality technology to the surgical training landscape.

Funding

This work was supported by The Medi Tech Trust UK charity.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.amjsurg.2023.05.014.

References

1. Bernard F, Haemmerli J, Zegarek G, Kiss-Bodolay D, Schaller K, Bijlenga P. Augmented reality-assisted roadmaps during periventricular brain surgery. *Neurosurg Focus*. 2021;51(2):1–11. https://doi.org/10.3171/2021.5.FOCUS21220.
2. Rad AA, Vardanyan R, Lopuszko A, et al. Virtual and augmented reality in cardiac surgery. *Braz J Cardiovasc Surg*. 2022;37(1):123–127. https://doi.org/10.21470/1678-9741-2020-0511.
3. Gouveia PF, Costa J, Morgado P, et al. Breast cancer surgery with augmented reality. *Breast*. 2021;56:14–17. https://doi.org/10.1016/J.BREAST.2021.01.004.
4. Hamacher A, Kim SJ, Cho ST, et al. Application of virtual, augmented, and mixed reality to urology. *Int Neurourol J*. 2016 Sep;20(3):172–181. https://doi.org/10.5213/inj.1632714.357. Epub 2016 Sep 23. Erratum in: Int Neurourol J. 2016 Dec;20(4):375. PMID: 27706017; PMCID: PMC5083835.
5. Roberts S, Desai A, Checcucci E, et al. "Augmented reality" applications in urology: a systematic review. *Minerva Urol Nephrol*. 2022 Oct;74(5):528–537. https://doi.org/10.23736/S2724-6051.22.04726-7. Epub 2022 Apr 6. PMID: 35383432.
6. Pfefferle M, Shahub S, Shahedi M, et al. Renal biopsy under augmented reality guidance. *Proc SPIE-Int Soc Opt Eng*. 2020 Feb;11315, 113152W. https://doi.org/10.1117/12.2550593. Epub 2020 Mar 16. PMID: 32476704; PMCID: PMC7261605.
7. Porpiglia F, Fiori C, Checcucci E, Amparore D, Bertolo R. Augmented reality robot-assisted radical prostatectomy: preliminary experience. *Urology*. 2018 May;115: 184. https://doi.org/10.1016/j.urology.2018.01.028. Epub 2018 Mar 13. PMID: 29548868.
8. Sparwasser P, Haack M, Epple S, et al. Smartglass augmented reality-assisted targeted prostate biopsy using cognitive point-of-care fusion technology. *Int J Med Robot*. 2022 Jun;18(3), e2366. https://doi.org/10.1002/rcs.2366. Epub 2022 Jan 25. PMID: 35034415.
9. Watson G, Payne SR, Kunitsky K, Natchagande G, Mabedi C, Scotland KB. Stone disease in low- and middle-income countries: could augmented reality have a role in its management? *BJU Int*. 2022. https://doi.org/10.1111/BJU.15877.