HoloLens in Plastic Surgery: What is the Future?

Augmented Reality in Plastic Surgery

J Luck[1], R Miller[1], A Gargan[1], S O'Sullivan[1], A Scarborough[1], G Masterson[1], N Gosling[2], S Saour[1]
Department of Plastic and Reconstructive Surgery[1]; Simulation Laboratory[2] St George's Hospital, London.

Background

HoloLens is a mixed reality technology within a head-mounted device. With augmented reality (AR) capabilities, it allows the user to add information and proctor images onto a real-time visual field. This has vast potential within a plastic surgery setting. Here, we share our experience of developing its use in two key areas: surgical education and perforator-based free flap reconstruction.

Autologous breast reconstruction using the deep inferior epigastric perforator flap has been established as the standard for perforator-based free-flap breast reconstruction [1,2]. This technique relies on the surgeon's ability to identify the patient's relevant abdominal vasculature to facilitate accurate dissection, optimise surgical outcomes, and minimise morbidity [1-3].

Encouraged by the use of AR telesurgery technologies in COVID-19 patients, we developed a series of AR-enhanced virtual ward rounds using the HoloLens. In addition, we describe how this technology can facilitate real-time surgical planning, increasing the value and tangibility of pre-operative CT angiogram (CTA) imaging in deep-inferior epigastric artery perforator (DIEP) breast reconstruction [3,4].

Methodology

Firstly, we developed a series of remotely-delivered simulated ward rounds. The HoloLens headset allowed the consultant educator to move freely between ward, theatre and hand trauma clinic environments. In total, 60 penultimate-year medical students participated in a virtual plastic surgery session, with a further suturing techniques workshop provided separately.

In addition, we piloted the use of HoloLens in two patients undergoing DIEP breast reconstruction. Contrast-enhanced CTA scans were performed pre-operatively and exported to a software package which allowed subsurface structures of interest, including the rectus muscle and perforating vessels, to be mapped and converted into a real-time 3-dimensional (3D) image linked to the HoloLens device (fig 1) [5].

This composite on-lay image (fig 2) was then accessed intra-operatively by the surgeon as well as remote trainee observers. It takes ≈15 minutes to build the 3D image on the HoloLens from the computed tomographic data. However, this was done preoperatively, so no intraoperative time was added.

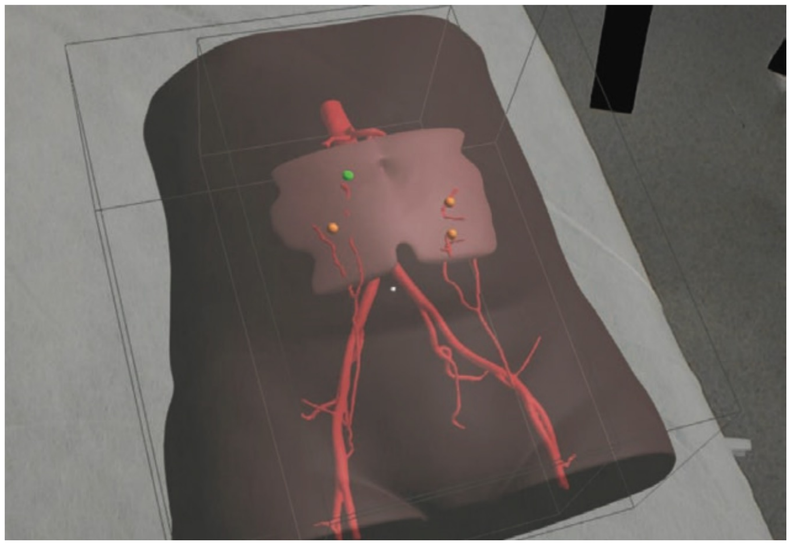

Fig 1: Image from the HoloLens demonstrating the three-dimensional model of the patient's abdominal vasculature.

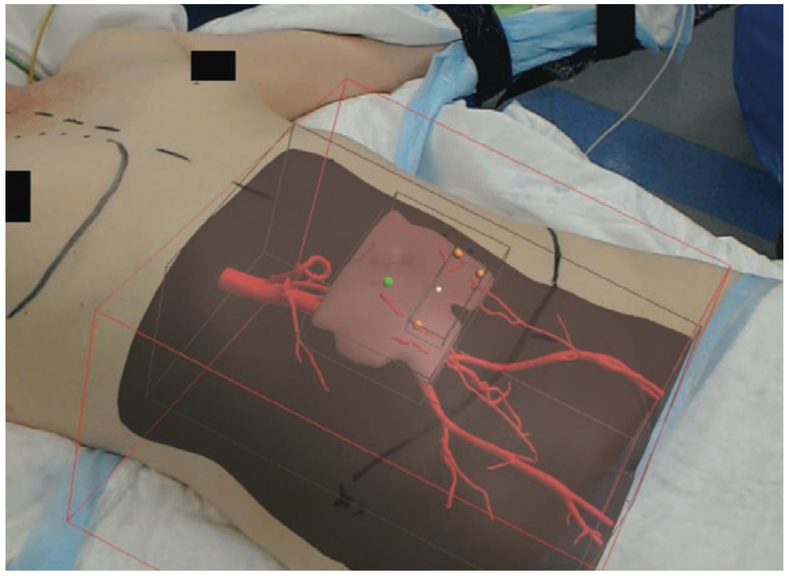

Fig 2: Image from figure 1 superimposed onto the patient, on the operating table, in real-time.

Results

Students attending the AR-enhanced virtual round were asked to complete an online Likert scale questionnaire. Responses were collated from 47 participants (response rate 78.3%). The percentage of students who 'Agreed' or 'Strongly Agreed' with the following statements are provided below:

- I was unable to achieve my full learning potential due to COVID-19: **78.7%**
- I enjoyed the HoloLens AR workshop: **89.3%**
- I would recommend HoloLens AR workshops to my fellow students: **85.1%**
- I would like to see HoloLens AR workshops continuing post-COVID-19: **82.9%**
- AR could improve surgical training: **91.4%**

With respect to the DIEP surgery pilot, the 3D software construct was superimposed directly onto the patient in the operating theatre. Using hand gestures, the rectus muscle on the 3D model could be manipulated to visualise the perforators (deep to and through the muscle), improving pre-op planning and marking, as well as real-time procedure visualisation. Correlation of the perforators displayed on AR image to the vessels identified intra-operatively demonstrated that these were mapped with high fidelity.

Conclusion

We demonstrate the increasing capabilities of HoloLens-enabled AR technologies within plastic surgery. Given the overwhelmingly positive learner feedback we demonstrate the effectiveness of the HoloLens system in improving medical education, for both undergraduates and surgeons in training.

For perforator-based free flap reconstructions, our experience offers proof-of-concept, supported by evidence of its accuracy and ease of use. HoloLens has the potential to increase ease of identification for dissection, efficiency and speed of operation, these factors may improve surgical outcomes and reduce potential complications. To our knowledge, HoloLens has not been previously used in either of these settings.

References

1. *Serletti J, Fosnot J, Nelson J, Disa J, Bucky L. Breast reconstruction after breast cancer. Plast Reconstr Surg. 2011;127:124e–135e.*
2. *Man L, Selber J, Serletti J. Abdominal wall following free TRAM or DIEP flap reconstruction: a meta-analysis and criti- cal review. Plast Reconstr Surg. 2009;124:752–764.*
3. *Teunis T, van Voss M, Kon M, van Maurik J. CT-angiography prior to DIEP flap breast reconstruction: a systematic review and meta-analysis. Microsurgery 2013;33:496–502.*
4. *Tepper O, Rudy H, Lefkowitz A, et al. Mixed reality with HoloLens. Plast Reconstr Surg. 2017;140:1066.*
5. *Yushkevich PA, Piven J, Hazlett HC, et al. User-guided 3D active contour segmentation of anatomical structures: sig- nificantly improved efficiency and reliability. Neuroimage 2006;31:1116.*

NHS
St George's University Hospitals
NHS Foundation Trust