computed tomography scan and operating theatre was increased in those suspected of COVID-19.[1] All of our patients deserve the best care feasible. The case fatality rate for COVID-19 infection is 3.1%.[2] For major trauma patients, fatality rate is 10.4%, even without COVID.[3] This pandemic is far from over, and for this and any future pandemic response, health services need to keep mindful that although trauma admissions may decrease, and the mechanisms of injury may alter, they will not go away. The same could be predicted for other emergent surgical conditions. I would echo other clinicians'[4] call to keep the trauma and surgical emergency response strong during these times lest these patients become an indirect victim of this or future pandemics.

Author Contributions

David J. Read: Conceptualization; writing-original draft; writing-review & editing.

References

1. Saxon L, Faizo T, Gumm K, Tong S, Read DJ. Quality of care during the COVID-19 pandemic at a level-1 trauma centre. *ANZ J. Surg.* 2021.
2. COVID-19 National Incident Room Surveillance Team. COVID-19: epidemiology report 34. *Commun. Dis. Intell. (2018)* 2021; **45**: 11. https://doi.org/10.33321/cdi.2021.45.8.
3. Australian Trauma Quality Improvement Collaboration. Australia New Zealand Trauma Registry, Management of the Severely Injured, 1 July 2017 to 30 June 2018. 2019.
4. Way T, Tarrant S, Balogh Z. Social restrictions during COVID-19 and major trauma volume at a level 1 trauma centre. *Med. J. Aust.* 2021; **214**: 38–9.

David J. Read,*† CSC, MBBS, FRACS
**Trauma Service, Royal Melbourne Hospital, Melbourne, Victoria, Australia and †Department of Surgery, The University of Melbourne Medical School, Melbourne, Victoria, Australia*

doi: 10.1111/ans.16905

Live-streaming surgery during COVID-19 using a 3D printed camera

The COVID-19 pandemic provided an unprecedented challenge to communities and health systems throughout the world. In order to protect patients, health workers and students, many hospitals imposed restrictions that resulted in excluding medical students. Experience in the operating theatre is an important part of medical student education, where precious time allocated to surgical education may be as short as 10 weeks. During the COVID-19 pandemic, there was still urgent surgery being performed which potentially provided valuable and unique learning opportunities. The challenge for educators was how to bring these opportunities to the students in a safe and effective way.

During the 2020 COVID-19 pandemic, 39 Deakin School of Medicine students based at the University Hospital Geelong clinical school, Victoria, Australia, were scheduled to rotate through general surgery but had restricted access to operating rooms due to government-imposed state-wide restrictions. These students were invited to participate in a pilot program where a surgeon conducted teaching associated with real-time video streaming of the operative procedure. A 3D printed camera with audio and visual capability was custom designed and developed by Deakin University engineers to fit the headpiece of the surgeon (Fig. 1). Students were based offsite with access to the live educational session using readily available electronic devices (laptops, smartphones or tablet devices).

An interactive tutorial was given by the surgeon to describe the clinical scenario and background information relevant to the operative case. Questions between the educators and medical students were encouraged throughout the operation. Approval for this teaching modality was gained from the clinical school director prior to commencement. Patients all gave verbal consent prior to their operation and videoing was only of the surgical field with no identifying patient details to protect privacy. Students were educated on respecting patient privacy and asked to ensure no viewings outside the tutorial group.

Following these tutorials, all 39 students were invited to participate in an electronic survey to assess their experience of engaging in live-streaming tutorials. The survey utilized a 5-point scale, with the option of additional comments. All responses were de-identified to the researchers. Ethics approval was gained from the Deakin University Faculty of Health Human Ethics Advisory Group.

Twenty-five students of 39 completed the survey, achieving a response rate of 64%. A variety of open and laparoscopic general surgery procedures were observed by survey responders, where the

Fig. 1. 3D printed camera mounted to surgeon's headpiece.

majority of students were satisfied or very satisfied with the learning content of each surgery (Table 1).

Only 3 (12%) reported that COVID-19 had not significantly impacted their surgical learning, whilst one respondent commented that 'almost all aspects [were affected] including theatre experience, ward exposure, clinic exposure'. With regard to participating in live-streamed operations, 20 respondents (80%) found it at least somewhat useful (Fig. 2).

Furthermore, 25 respondents (100%) found the introductory teaching at least somewhat beneficial in aiding surgical learning. Eighteen students (72%) indicated that increasing the frequency of live streaming would be at least somewhat beneficial in aiding surgical learning. Twenty-three (92%) students found narration and teaching during the procedure beneficial.

Students found the quality of the video and audio variable with 22 (88%) responding that the quality impacted their learning. Furthermore, 19 (76%) reported that live-streaming did not compensate for in-person theatre time. Fourteen (56%) reported they see a role for this teaching modality when there are no COVID-19 restrictions on their attendance.

During COVID-19 medical schools around the world adopted a wide variety of strategies. In Italy, almost 10 000 medical students were fast-tracked into the workforce without sitting their concluding exams.[1] Iran developed a virtual and e-learning program to allow continuation of studies.[2] Singapore, having learnt from the SARS outbreak, instituted a university COVID-19 response team that restructured teaching using multiple strategies.[3] As evidenced by the SARS epidemic, some of these changes to teaching are expected to remain in place for many years.[4] It is essential we capture the medical education ingenuities emerging from the COVID-19 pandemic.[5]

Table 1 Experience of survey respondents with different types of surgeries

Type of surgery	Number of observing students	Proportion or respondents satisfied or very satisfied with learning content
Abdominoperineal resection	10	9/10 (90%)
Laparoscopic fundoplication	12	9/12 (75%)
Open right hemicolectomy	14	12/14 (86%)
Laparoscopic cholecystectomy	16	13/16 (81%)
Open ultra-low anterior resection	11	7/11 (64%)
Laparoscopic inguinal hernia repair	8	7/8 (88%)
Open Hartmann's procedure	9	6/9 (67%)

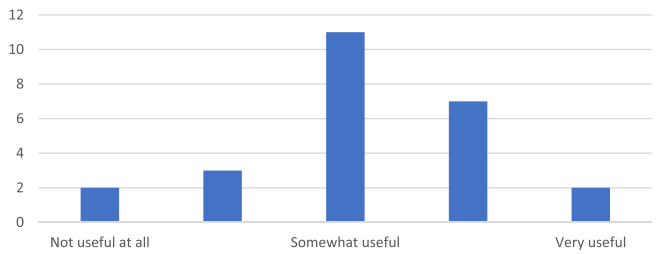

Fig. 2. Number of respondents who found live-streamed surgeries useful in aiding surgical learning.

Live-streaming operations could be one of those strategies with several studies reported from the COVID-19 period, however to the best of our knowledge this is the first study using a 3D printed camera. The University of Kansas live-streamed neurosurgery to medical students from multiple cameras including a GoPro worn by the surgeon,[6] while The University of Pennsylvania also described the development of a virtual Otolaryngology – Head and Neck Surgery Rotation for medical students where surgeries were also live-streamed using a GoPro.[7] Interestingly, it has been found that live-streaming is more beneficial to student learning than watching a play-back of the video at a later date due to improved perception of learning in the theatre environment.[8]

This study uniquely utilized 3D printing technology which is showing increasing presence in the medical field.[9] In our experience, commercially available camera mounts are cumbersome to use in combination with headlights, masks and face shields. Deakin University has world leaders in 3D printing, which facilitated the creation of a high-definition camera that was easier and more comfortable to use than commercially available products. The camera and mount system which was purpose-built for surgery and integrated into the headlight equipment normally in use while operating, allowed excellent vision with minimal impact to the surgeon.[10] However, students had contrasting experiences with the quality of video and audio. One student commented 'technical issues did limit the benefit provided', while another commented, 'having the head mount allows open operations to be seen better than in person'. Possibly, the variable limiting technical factor was speed and bandwidth of the hospital's wireless internet necessitating investigation prior to further utilization of this teaching modality. Further evaluation comparing the surgeon and student perspectives of a 3D custom printed camera compared to GoPro is needed.

Live streaming could reduce variability in student surgical experiences. In our study, one student commented 'sharing the experience of complex cases throughout the group rather than just a luck of the draw style game of chance was beneficial'. This is also reflected in the literature where students being matched to theatre sessions improve access and exposure to high-quality surgical teaching and makes pursuit of a surgical career more likely.[11]

Variability in student responses may reflect differences between tutors, as occurs in any tutorial setting. However, this study demonstrates unique technology enabling continuing education from a remote location despite restrictions experienced during COVID and potentially in the future. Live-streaming could provide access to a highly educational resource for students or surgical trainees in the rural sector. Another role would be to support/advise rural and remote-based surgeons during procedures and to provide intra-operative advice whilst recognizing the limitations of not being present.

A key limitation of our survey is that given COVID-19, students were unable to attend any in-person operations. This is reflected in responses such as 'I was grateful to have this supplemental learning opportunity, however, as a student interested in a surgical career it does not sufficiently compensate for in-person experience'. We agree with survey responses and previous authors that live-streaming would be an adjunct to current surgical teaching.[12] Outside COVID-19 restrictions, attending the operating theatre is required for practical skill acquisition and exposure to the theatre environment. Future studies could compare live-streaming using the 3D printed camera headpiece combined with in-person theatre experiences to in-person alone.

Acknowledgements

The authors wish to acknowledge the Geelong surgical COVID-19 response team members: Dr Will Anderson, Dr Tess Asgill, Dr Pia Bernardi, Dr Elliot Bowden, Dr Jessie Cole, Mr Simon Crowley, Dr Henry Drysdale, Professor Glenn Guest, Dr Steve Lau, Dr Yit Leang, Dr Ellen McMahon, Dr Eileen Mary Moore, Mr Sonal Nagra, Dr Sally Ooi, Dr Bushra Othman, Dr Sam Pellegrino, Dr Matthew Shears, Associate Professor Douglas Stupart, Dr Kirk Underwood, Professor David Watters, Dr Jordyn Dangen. The authors also wish to acknowledge Associate Professor of Defence Robotics James Mullins, and the engineering department of Deakin University Geelong for their development of the 3D printed head-mounted camera.

Author Contributions

Jordyn Dangen: Conceptualization; formal analysis; writing-original draft; writing-review and editing. **Yung-Hsin Hsueh Sylvia:** Data curation; investigation; methodology; project administration. **Steve Lau:** Investigation; supervision; validation; writing-review and editing. **Sonal Nagra:** Conceptualization; formal analysis; project administration; supervision; validation; writing-review and editing. **David Watters:** Conceptualization; data curation; investigation; methodology; supervision; validation; writing-review and editing. **Glenn Guest:** Conceptualization; formal analysis; investigation; methodology; project administration; resources; supervision; validation; writing-review and editing.

References

1. Lapolla P, Mingoli A. COVID-19 changes medical education in Italy: will other countries follow? *Postgrad. Med. J.* 2020; **96**: 375–6.
2. Aghakhani K, Shalbafan M. What COVID-19 outbreak in Iran teaches us about virtual medical education. *Med. Educ. Online* 2020; **25**: 1770567.
3. Ashokka B, Ong SY, Tay KH, Loh NHW, Gee CF, Samarasekera DD. Coordinated responses of academic medical centres to pandemics: sustaining medical education during COVID-19. *Med. Teach.* 2020; **42**: 762–71.
4. Patil NG, Chan Y, Yan H. SARS and its effect on medical education in Hong Kong. *Med. Educ.* 2003; **37**: 1127–8.
5. Ahmed H, Allaf M, Elghazaly H. COVID-19 and medical education. *Lancet Infect. Dis.* 2020; **20**: 777–8.
6. Jack MM, Gattozzi DA, Camarata PJ, Shah KJ. Live-streaming surgery for medical students education – educational solutions in neurosurgery during the COVID-19 pandemic. *J. Surg. Educ.* 2021; **78**: 99–103.
7. Chao TN, Frost AS, Brody RM *et al*. Creation of an interactive virtual surgical rotation for undergraduate medical education during the COVID-19 pandemic. *J. Surg. Educ.* 2021; **78**: 346–50.
8. Park A, Schwartz RW, Witzke DB *et al*. A pilot study of new approaches to teaching anatomy and pathology. *Surg. Endosc.* 2001; **15**: 245–50.
9. Tack P, Victor J, Gemmel P, Annemans L. 3D-printing techniques in a medical setting: a systematic literature review. *Biomed. Eng. Online* 2016; **15**: 115.
10. Whiteley C. International acclaim for 3D printing pioneer Deakin Research 2017. Deakin Research. 2017 [Cited 4 June 2020]. Available from URL: https://www.deakin.edu.au/research/research-news/articles/international-acclaim-for-3d-printing-pioneer
11. Bartlett RD, Momin SM, Azam S, Rotimi O, Quick TJ. Development of a "surgical shadowing scheme" to improve undergraduate experiences of surgery. *Adv. Med. Educ. Pract.* 2019; **10**: 619–26.
12. O'Brien J, Natarajan M, Aryal K. Live streaming of laparoscopic general surgery is a useful teaching tool. *Bull. R. Coll. Surg. Engl.* 2018; **100**: 144–8.

Jordyn Dangen,*† BMBS
Yung-Hsin (Sylvia) Hsueh,‡ BBiomed
Steve Yee Chiang Lau,*† MBBS, FRACS
Sonal Nagra,*†‡ MBBS, FRACS
David Watters,*†‡ ChM, FRACS
Glenn Douglas Guest,*†‡ MBBS, FRACS
**Department of Surgery, Barwon Health, Geelong, Victoria, Australia, †Department of Surgery, University Hospital Geelong, Geelong, Victoria, Australia and ‡School of Medicine, Deakin University, Geelong, Victoria, Australia*

doi: 10.1111/ans.16797