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Establishing a Virtual Corneal Clinic: A Real-Time Teleophthalmology Approach

Sharita Rosalyne Siregar, MD, Lily Silva Ardiani, MD,* Anna Chua, DN,† Berlisa Yong Qin Chong, BSc Optom,† and Donald Tiang Hwee Tan, FRCSE, FRCSG, FRCOphth, FAMS*†*

Purpose: Keratoplasty patients require regular and timely follow-ups. During this COVID-19 pandemic which restricted global travel, we developed a novel real-time, hybrid teleophthalmology approach to comanage international keratoplasty patients between Singapore and Indonesia.

Methods: A retrospective consecutive observational study of 72 corneal patients (63 were postkeratoplasty) who attended a virtual corneal clinic (VCC) between June 2020 and April 2021 at JEC Eye Hospitals (JEC) in Jakarta, Indonesia. ZOOM Meeting software (Zoom Video Communication Inc, San Jose, CA) was used to simultaneously connect the Singapore corneal specialist at Eye & Cornea Surgeons (ECS), Singapore, using a real-time approach. Clinical examinations included full panels of video-linked corneal, glaucoma, and retinal imaging and investigations performed before real-time video-linked slit-lamp examination, with immediate clinical decision making between corneal specialists and patients.

Results: VCC enabled effective real-time clinical evaluation and collaborative clinical decisions, with full patient interaction, with the aim of maintenance of graft clarity, visual function, and management of comorbidities—a) topical and systemic medications were adjusted in 79.2% of patients; b) further referrals to glaucoma, retinal, and oculoplastic subspecialists were made in 16.6% of cases; c) additional adjunctive surgical procedures were performed at JEC in 6.9% cases; and d) government permission was obtained for 4 patients (5.6%) to fly to Singapore for urgent corneal surgery.

Conclusions: The virtual corneal clinic is a novel real-time hybrid teleophthalmology approach which is effective in the comanagement of international keratoplasty patients and represents the advances in ophthalmic telemedicine.

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From the *JEC Eye Hospitals and Clinics, Jakarta, Indonesia; and †Eye & Cornea Surgeons, Eye & Retina Surgeons, Camden Medical Centre, Singapore.

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Correspondence: Donald Tiang Hwee Tan, FRCSE, FRCSG, FRCOphth, FAMS, Eye & Retina Surgeons, One Orchard Boulevard #13-03, Camden Medical Centre, S248649 Singapore, Singapore (e-mail: dt@ers.clinic).

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Corneal transplantation is the most frequently performed transplant procedure worldwide, but due to a wide variety of social barriers and variable limited access to corneal tissue, patients in many countries still have highly limited access to this procedure that can overcome corneal blindness, the fourth leading cause of blindness worldwide, after unaddressed refractive error, cataract, and glaucoma.[1,2] In addition to the challenges of access to corneal transplantation, patients who have received corneal transplants also generally require lifelong follow-up due to long-term complications such as allograft rejection and glaucoma.[3,4]

In South-East Asia, with a wide mix of developed and developing countries and rural versus urban settings, corneal transplantation rates vary significantly between different countries. Indonesia, the largest country in South-East Asia, and the largest archipelago in the world, consisting of 5 major islands and total number of 17,508 islands, has a vast geographical landscape, which poses significant challenges to accessibility for health care. In 2018, the Vision Loss Expert Group of the Global Burden of Disease Study data concluded that corneal opacification was the third major cause of blindness in Indonesia.[1] With a population of 46 million, the West Java region maintains a prevalence of corneal blindness of 5.4%.[5] Although corneal transplantation is clearly a treatment option for corneal blindness, logistical and human resource issues, coupled with challenges to procure adequate numbers of local donor corneas, severely limit corneal transplantation in Indonesia, and as a result, some corneal patients travel to Singapore where there are less challenges in procuring corneal tissue. Data from the Singapore Corneal Transplant Study (SCTS) confirm that over 20% of all keratoplasties performed at the Singapore National Eye Centre were for overseas patients who flew in for surgery and who come from neighboring South-East Asian nations such as Malaysia, Indonesia, Vietnam, and Myanmar.[6]

In December 2019, a new form of coronavirus infection was first reported in Wuhan, China, and with rapid global spread, the World Health Organization (WHO) declared the subsequently termed COVID-19 disease to be a global

pandemic in June 2020, which is still very much active, especially in Asia. In South-East Asia, COVID-19 emerged in early 2020—in Singapore, the first case was reported on January 23rd, and in Indonesia, in February 2020. Indonesia overtook India as the new epicenter of the pandemic in Asia in July 2021 with 2.83 million infections and over 54,000 new cases reported daily by the WHO.[7] As of December 2021, the newest variant named Omicron was detected and it is now predominant in most countries due to its enhanced risk of transmission.[8,9] In addition, in early February 2022, the Indonesia Ministry of Health just announced a third wave of the pandemic due to the Omicron surge.

Travel restrictions have been imposed globally due to COVID-19, and the Singaporean COVID-19 travel restrictions since March 2020 prevented foreign keratoplasty patients from receiving follow-up care in Singapore. Eye & Cornea Surgeons (ECS) is a private medical group with the largest private sector corneal transplant program in Singapore, and in March 2020, foreign keratoplasty patients, predominantly from Indonesia, began calling for assistance regarding their follow-ups. In response, ECS initiated a telemedicine program and contacted JEC Eye Hospitals and Clinics (JEC), Jakarta, Indonesia, to develop a novel, collaborative, real-time teleophthalmology virtual corneal clinic (VCC). ECS Indonesian keratoplasty patients who requested assistance, or whose clinical follow-up schedules were due, were contacted and informed about VCC, and on consent, traveled from their hometown or city to JEC in Jakarta to attend the VCC. Here, dedicated corneal specialists and other subspecialists from JEC examined patients with a real-time video consultation with their primary surgeon from ECS (DTHT). The intention of this approach is to mimic an in-person corneal examination by the primary surgeon and the referring ophthalmologist. Advantages, disadvantages and potential impacts, and far-reaching implications on teleophthalmology, patient access, and monitoring in this COVID-19 pandemic and post-COVID-19 global environment will be evaluated in this study.

MATERIALS AND METHODS

This retrospective study was conducted on 72 consecutive patients (84 eyes) who attended VCC sessions, which involved coming to a JEC hospital to meet the appointed doctor and undergoing prespecified preliminary investigations. Then followed by clinical examination by the attending JEC subspecialists, with simultaneous real-time video consultation with the primary corneal surgeon from ECS (DTHT), Singapore, using ZOOM Meeting software (Zoom Video Communication Inc, San Jose, CA). The process involved a real-time video from slit-lamp examinations and reviewing of clinical case notes and investigations using video-linked EMR systems. Synchronous bidirectional communication was achieved through a ubiquitous video communication with appropriate audiovisual technologies. The study inclusion criterion was ECS Indonesian corneal patients with a history of keratoplasty and keratoprosthesis surgery who were unable to come to Singapore for their scheduled clinical appointments due to COVID-19 travel restrictions. Sessions included in this study were performed over a 10-month period between June 2020 and April 2021 and were recorded with patient consent. The study was approved by the Medical and Health Research Ethics Committee of Faculty of Medicine, Public Health and Nursing of Universitas Gadjah Mada–Dr. Sardjito General Hospital (Ref. No: KE/FK/0690/EC/2021) and adhered to the tenets of the Declaration of Helsinki. VCC data included patient demographics, a concise but detailed summary of previous corneal and keratoplasty history from the referring Singapore corneal specialist, all VCC examination and investigations performed, and clinical decisions made at each VCC appointment.

Virtual Corneal Clinic Protocol

Appointment Scheduling, Medical Summaries, and Pretesting Requirements

ECS Indonesian corneal patients with a history of PKP, DMEK, DSAEK, DALK, and keratoprosthesis surgery performed who were unable to come to Singapore for their scheduled clinical appointments due to COVID-19 travel restrictions were contacted by ECS through emails to ascertain whether they were keen to physically attend clinic visits at JEC locations in Jakarta, involving their Singapore corneal specialist participating on a teleophthalmology consultation, along with collaborating Indonesian ophthalmologists. Patients received detailed information regarding the VCC process, including confidentiality issues and financial counseling, and on full informed consent, ECS emailed relevant patient details to JEC. Patients were made aware at the outset that they would have the privilege of 2 simultaneous clinical/specialist consultations but would also have to pay consultation charges for both clinics, which generally mirrored the normal clinical consultation charges of the respective clinics involved (the cost-savings of avoiding air travel far outweighed clinical charges). VCC appointments were then coordinated and scheduled between ECS, JEC, and patients—in both ECS and JEC, these sessions were booked and dovetailed into the specialists' respective corneal clinics which coincided. Detailed medical summaries and preexamination investigation requests from ECS were sent to JEC before the appointments to enable receiving JEC ophthalmologists to review the patient's medical history and for JEC clinic staff to plan for relevant preexamination test (PET) requests from the Singapore corneal specialist (Fig. 1).

Preexamination Investigations

Where necessary, preexamination investigations were requested by the Singapore corneal specialist, as part of the original continuation of care of the particular corneal patient, and these tests were booked at JEC, with patients requested to come earlier at specific time points just before the VCC. Examples of PET are provided in Table 1. The results of these investigations were then reviewed by the doctors simultaneously during the VCC. For pediatric patients who would be not compliant with slit-lamp examination, the VCC surgeons discussed sedation or examination under anesthesia findings, with the parents also present so that they were informed of the

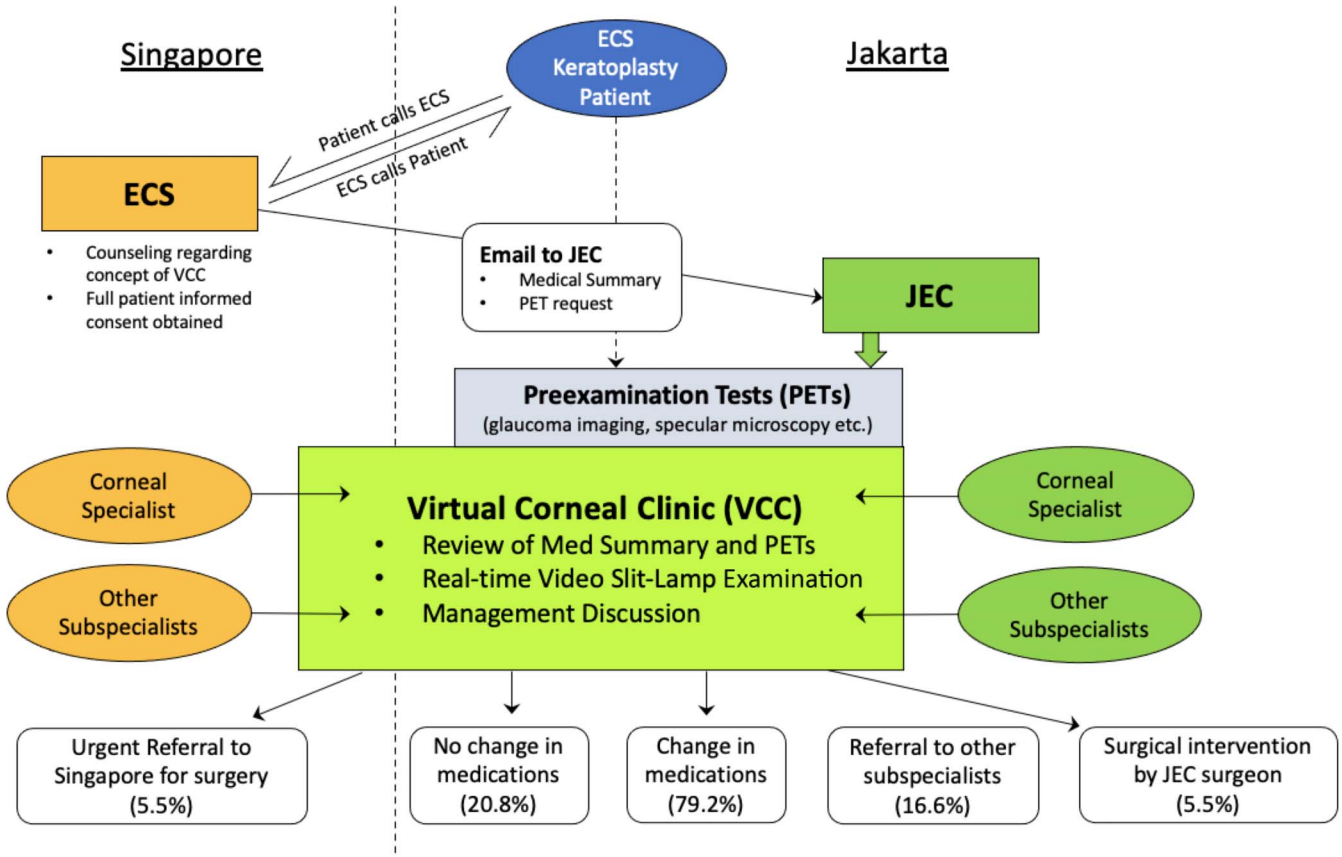

FIGURE 1. Virtual corneal clinic (VCC) protocol. (The full color version of this figure is available at www.corneajrnl.com.)

child's progress. Where possible, prior sedations or general anesthetic examinations were requested and preplanned before the VCC session.

Electronic Hardware and Software Required to Establish a VCC

The establishment of a VCC between ECS and JEC was facilitated by the fact that both sites had fully computerized clinics with full internet access and large screen monitors in the clinics, and well-established electronic medical record (EMR) support and remote desktop software, with the list of electronic hardware and software listed in Table 2. Good internet access was important, and dedicated omnidirectional microphones were used to reduce ambient noise levels. ZOOM Meeting software (Zoom Video Communication Inc., San Jose, CA) was used with remote desktop software to synchronize the teleophthalmology consults, with images received from the slit-lamp biomicroscope saved into the patients' EMR.

Each institution used its own electronic records to document VCC sessions. As the patients were seen at JEC, JEC's electronic records were usually viewed by ECS live and online, but on occasion, where needed, previous ECS medical records were also shared with JEC doctors by screen-sharing. Where clinical judgments were made, to subjectively grade or evaluate the severity or extent of clinical findings, these issues were subjectively described and deliberated on (usually until a consensus was reached) and subsequently recorded as such in both sets of medical records by the individual doctors. We used internet bandwidths with a minimum download speed of 20 Mbps and a minimum upload speed of 3 Mbps. Two thousand one hundred pixels were presented on the desktop monitor with a resolution of 1920 pixels by 1080 pixels. We did not specify monitor screen sizes but simply used the available 17-inch desktop computer screens with a standard resolution, present in the clinics.

Teleophthalmology Informed Consent and Patient Confidentiality

All patients agreed to have their ECS medical records shared with the JEC VCC staff and were required to sign a teleophthalmology consent form which enabled full

TABLE 1. Preexamination Tests and VCC Examinations

VCC	PET
Refraction, IOP, and slit-lamp examination	**Cornea:** Endothelial specular microscopy, anterior segment optical coherence tomography (AS-OCT).
—	**Glaucoma:** Visual field automated perimetry and optic nerve head OCT
—	**Retina:** Macula OCT.

IOP; intraocular pressure, OCT; optical coherence tomography, PET; preexamination test, VCC; virtual corneal clinic.

TABLE 2. Hardware and Software to Conduct a VCC

Hardware	
Screen monitor	To access patients' EMR and performance of face-to-face video consultation
Video-linked slit-lamp biomicroscopy	Real-time video imaging of the patients' eye
Omnidirectional microphone	To reduce ambient noise levels in JEC clinic
Internet access	Fast and stable connection required
Software	
Remote desktop	Synchronization with image-saving capabilities directly to the EMR
ZOOM video conference	Platform that provides a simultaneous video consultation between 2 or more parties, with recording facilities

EMR; electronic medical record, JEC; JEC Eye Hospitals and Clinics, VCC; virtual corneal clinic.

disclosure of patient demographics and identifiers, contact details, and full medical details. In addition, consent for video recording of the teleconsultations was available as an option for patients. Care was taken to ensure that patient confidentiality was respected and fully conformed to the Singapore data protection laws, including the Personal Data Protection Act (PDPA) Law No. 26 of 2012, and also complied with the Singapore Ministry of Health National Telemedicine Guidelines (2015) and Indonesian medical records and data protection laws Peraturan Menteri Kesehatan No. 269 tahun 2018 tentang Rekam Medis and Peraturan Menteri Komunikasi dan Informatika No. 20 tahun 2016 tentang Perlindungan Data Pribadi dalam Sistem Elektronik. To ensure full privacy and security, only authorized parties were provided with the Zoom user ID and password, and once parties were admitted to the session, the meeting room was "closed" to ensure no additional logons were permitted. In addition, VCC session recordings were stored on JEC's internal servers, not on Zoom, and all clinical and administrative staff (including IT staff) of both JEC and ECS are bound by medical confidentiality.

Post-VCC

At the conclusion of the VCC, a short medical summary was sent to the patient, detailing the various changes to treatment. In addition, any medications which were required and not available in Indonesia were then couriered to the patient from Singapore. VCC processes are shown in Fig. 2.

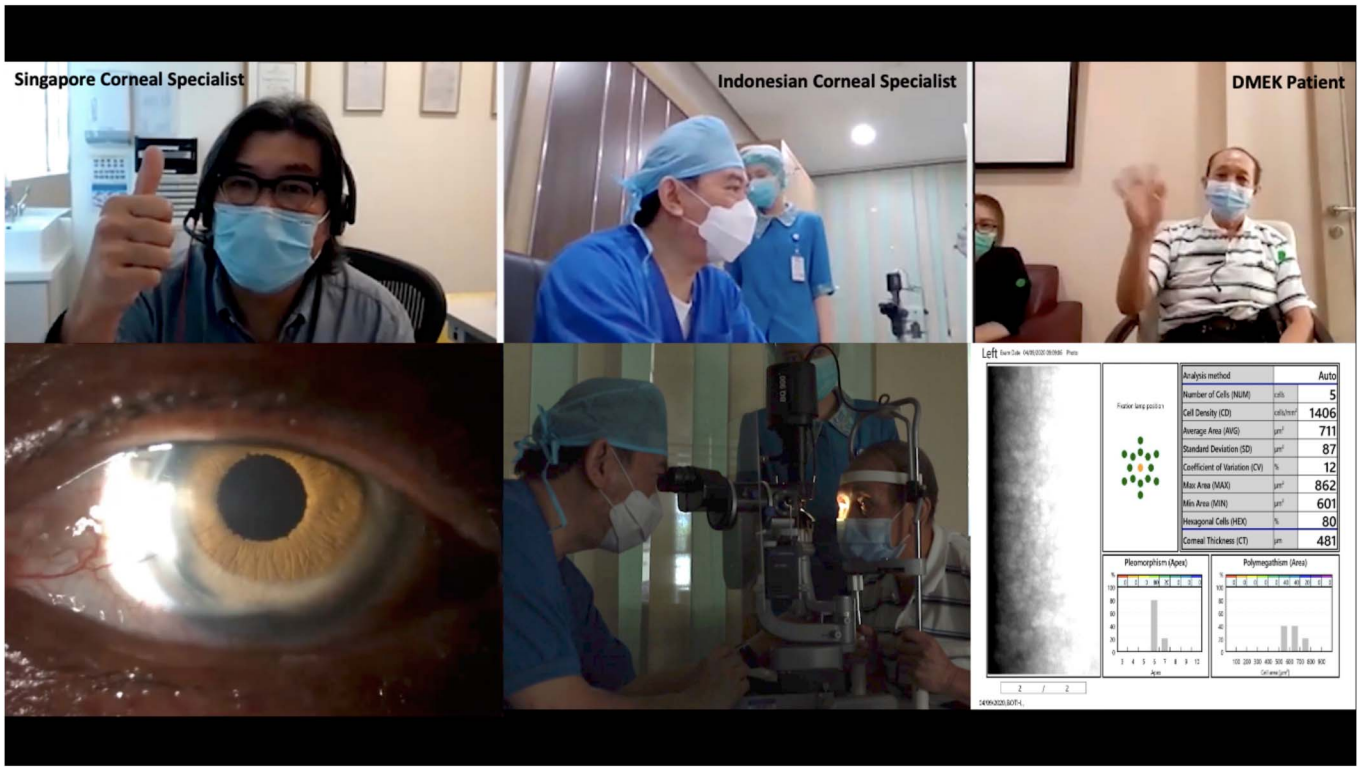

FIGURE 2. Composite images obtained during a virtual corneal clinic (VCC) session—the patient is a one-eyed man with end-stage glaucoma with bullous keratopathy and 360 degrees of peripheral anterior synechiae, who underwent DMEK combined with phacoemulsification, IOL insertion, and HumanOptics CustomFlex Artificial Iris inserted into the capsular bag. Slit-lamp image shows a clear DMEK graft with the artificial iris clearly visible within the anterior lens capsule. This patient ultimately required an Ahmed valve implant to control his glaucoma which was performed by JEC glaucoma surgeons. Consent for tube surgery was obtained in the presence of the patient's son who attended the VCC Zoom session while in the United States. (The full color version of this figure is available at www.corneajrnl.com.)

RESULTS

Eighty-two patients involved in this teleophthalmology program were documented during the period June 2020-April 2021. Of these, 10 patients were excluded from this study analysis because they were not corneal patients but were patients with other ophthalmic morbidities including retinal and glaucoma cases. Of the 72 corneal patients (84 eyes) who met the inclusion criteria, 44 (61%) were women and 28 (39%) were men. The mean age of the patients was 55.4 ± 18.6 years, ranging from 1 to 88 years. The purpose of VCC was that of postkeratoplasty follow-up in 63 patients (87.5%) under the care of the primary corneal specialist (DTHT), whereas 9 patients (12.5%) were first consulted who either requested for consultation with the Singapore corneal specialist or were referred by the Indonesian specialists. In addition to DTHT as the primary ECS corneal specialist, 4 other Singapore ECS subspecialists (in glaucoma, oculoplastics, medical, and surgical retina) were also co-opted into the VCC sessions where required. On the JEC side, a total of 3 corneal specialists and 4 additional doctors from other subspecialties were also co-opted to participate.

Thirty-six patients (50.0%) originated from within Jakarta city, whereas the other half were from wide-ranging cities dispersed throughout the Indonesian archipelago including other cities such as Surabaya (5 patients (6.9%)), Bandung (4 patients (5.6%)), and Bekasi (4 patients (5.6%)). Patients often used internal domestic flights to fly to Jakarta for their VCC appointment because the various cities were located far apart across Indonesian islands—the furthest distance between these cities was approximately 5245 km between east and west, a distance exceeding that between Los Angeles and New York (4489 km).

All forms of keratoplasty, including keratoprosthesis, were represented in this patient group—Descemet membrane endothelial keratoplasty (DMEK, 37 eyes, 44.0%) was the most common form of keratoplasty, followed by Descemet stripping automated endothelial keratoplasty (DSAEK, 14 eyes, 16.7%), penetrating keratoplasty (PKP, 11 eyes, 13.1%), deep anterior lamellar keratoplasty (DALK, 4 eyes, 4.8%), Boston keratoprosthesis type 1 (4 eyes, 4.8%), and osteo-odonto-keratoprosthesis (OOKP, 1 eye, 1.2%). Details are provided in Table 3.

TABLE 3. Diagnosis

Diagnosis	Total N = 84 Eyes (%)
DMEK	37 (44.0)
DSAEK	14 (16.7)
Medical corneal cases	13 (15.5)
Penetrating keratoplasty	11 (13.1)
Boston K keratoplasty type 1	4 (4.8)
DALK	4 (4.8)
OOKP	1 (1.2)

DALK; deep anterior lamellar keratoplasty, DMEK; Descemet membrane endothelial keratoplasty, DSAEK; Descemet stripping automated endothelial keratoplasty, OOKP; osteo-odonto-keratoprosthesis.

Video real-time slit-lamp biomicroscopic examination (SLE) was the most important clinical procedure during VCC which provided the maximum benefit of teleophthalmology because the corneal specialist in Jakarta performed SLE real-time, which was viewed in Singapore by the referring corneal specialist. Communication between surgeons during SLE enabled detailed discussion around examination of specific areas of the grafted cornea, with the ability of the viewing Singapore surgeon to request higher magnification of specific areas of the graft, specify closer examination of areas such as the corneal state adjacent to a glaucoma tube and the scleral or conjunctival state around the tube plate or trabeculectomy bleb, or request for the removal of bandage contact lenses or for corneal staining. Overall, the video-linked resolution was clearly sufficient to detect minor corneal changes such as faint stromal nebulae; very mild, localized areas of stromal edema; or superficial epitheliopathy without surface staining, which was generally adequate to determine the overall graft status, be it DMEK, DSEK, or DALK. However, with the resolution of the video image clearly not as ideal as actual SLE, examination for the presence of very fine keratic precipitates (KPs), or anterior chamber cellular activity, was generally not easily seen, although larger, more obvious pigmented and unpigmented KPs were easily spotted, and in many instances, the Singapore surgeon requested the Indonesian examiner to specifically look for the presence of fine KPs or intraocular inflammation and depended on the findings of the examiner as slit-lamp video-resolution clearly was insufficient to see fine KPs or AC activity. A particular advantage of VCC, however, was that surgeons were able to discuss the current findings and state of the graft collectively so as to enable an integrated clinical response or management, which was also heard by and noted by the patient or attending relative, as part of an integrated examination and patient management decision. This was especially significant in the cases where the JEC specialist had referred the patient in the original instance to the Singapore specialist for a medical opinion and further treatment.

The ability to review the preexamination tests (PETs) which had just been performed before the VCC, which classifies as an additional hybrid telemedicine approach, also greatly facilitated and expedited the patient management process. For example, the ability to review the most current corneal endothelial cell count after SLE (and also see the digital specular microscopy image) and compare this to previous cell counts which had been performed in Singapore greatly facilitated the spatial trajectory of the surviving graft, while reviewing (and comparing previous) high-resolution AS-OCT and pachymetric data, both quantitative and qualitative, was also very informative. Similarly, the evaluation of adjunctive tests, such as automated perimetry, and posterior segment investigations, such as ultrasound B-scans, and OCTs also was invaluable in the holistic management of patients, especially as many were complex cases with secondary glaucoma and previous glaucoma surgery.

Where needed, preplanned, simultaneous involvement of additional specialists (glaucoma, retina, oculoplastic, and pediatric) was a significant additional advantage to expedite efficient clinical care, with these additional specialists joining

in the VCC from their respective clinic rooms or hospital locations, something which patients also greatly appreciated because ordinarily, they would have to be shunted sequentially to corneal, glaucoma, or retinal clinics during 1 visit or at other specific visits. This was however not always possible, depending on the clinic timings or the various specialists. One further advantage to patients was the ability to involve additional family members not colocated with the patient, as and when needed—1 specific VCC involved important decision making in the management of a one-eyed patient with end-stage corneal and glaucoma disease, whereby the son, a senior decision maker of the family, joined the VCC from the United States.

We evaluated the overall clinical impact of VCC by determining the clinical management changes to the treatment regimen of the VCC patients within the study period. Of the 72 patients, 57 patients (79.2%) had their topical and/or systemic medications altered in some form or other after VCC, mainly pertaining to tapering (or increasing) of topical steroid dosing regimens and variation of glaucoma medication combinations. Twelve patients (16.6%) required additional follow-up referrals to other specialties (glaucoma: 6 (8.3%), retina: 5 (6.9%), and oculoplastic 1 (1.4%))—these comprised patients with de novo comorbidities diagnosed during VCC or cases in which the particular subspecialist was not able to attend the VCC. In all instances, the results/opinions of the subsequent subspecialty referral were subsequently conveyed to the VCC team by group email, leading to email discussions between managing surgeons and specific changes to the clinical management detailed in the VCC clinical records of the patient. Finally, VCC also affected on a small, but clinically significant group of patients who required subsequent surgical intervention after VCC. Four patients (5.5%) had additional therapeutic interventions which were performed at JEC, which included glaucoma tube surgery, blepharoplasty, suture removal, and Nd:YAG laser capsulotomy. An additional 4 patients (5.5%) required surgery which was subsequently performed in Singapore—in 3 cases, this was following specific urgent medical requests to the Singapore Ministry of Health for them to fly to Singapore and perform their quarantine before surgery. These included a pediatric 6-year-old patient with congenital glaucoma and mesodermal dysgenesis and multiple failed grafts, who had artificial iris implantation in Singapore, followed by PK; an advanced Fuchs endothelial corneal dystrophy patient with painful bullous keratopathy, who then had DMEK performed in Singapore; and a Boston keratoprosthesis (type 1) patient who required vitrectomy and membrane peeling in Singapore for myopic retinoschisis in an only eye. All patients had successful outcomes up to the present time. One final patient fortuitously came to Singapore on a work visit pass and had Nd:YAG laser capsulotomy.

Some operational limitations of the VCC program were experienced on occasion, mostly pertaining to issues with transient transmission difficulties, presumably related to high network usage on either side, but these were relatively rare occurrences, and no clinical sessions had to be canceled or postponed because of transmission difficulties.

DISCUSSION

Countries in the South-East Asia are currently at the epicenter of the resurgence of new waves of COVID-19 linked to the Delta and Omicron variants of COVID-19, with the worst affected country in the region being Indonesia. As of September 2021, the Singapore Ministry of Health has not rescinded the directive prohibiting foreign medical patients to travel to Singapore, and recently in early February 2022, the Minister of Health of Indonesia has announced a third wave of the pandemic in Indonesia due to the Omicron surge. The challenge for patients from high-risk COVID-19 countries to seek medical care overseas will thus continue, at least until the pandemic is controlled globally. Postkeratoplasty patients are at particular risk, partly because timely follow-up clinic visits are essential to long-term graft survival, and many corneal patients seek corneal transplants in neighboring countries and would routinely travel overseas for postoperative follow-up care, which has now been disrupted by COVID-19 and imposed travel restrictions.

Our approach to mitigate the severe consequences of graft failure among our keratoplasty patients has been to develop a specific form of physician-to-physician teleophthalmology which best mimics or enables surrogate clinical evaluation by the corneal surgeon. The VCC program involves the development of a real-time video conferencing approach enabling synchronous bidirectional communication between physicians, patients, and even patients' relatives, with the real-time synchronous slit-lamp examination, between the patient's originating surgeon and the receiving specialist in the patient's host country, using audiovisual technology. In addition, the VCC concept also integrates a preceding asynchronous hybrid component, in which specific investigations are preordered and performed immediately before VCC video-consultation or performed after that visit in preparation for evaluation at the next VCC session.[10,11] One example of this approach is our ability to temporally track corneal endothelial cell status after DMEK, DSAEK, or PK which provides a significant prognostic value to physicians and patients. The additional hybrid component allows patients to be seen and managed by multiple subspecialties simultaneously applied in VCC which greatly enhances concurrent comorbidity management within a comprehensive subspecialist team approach. The concept of the VCC program also works for retinal examinations using the retinal lens and the slitlamp, or even using an indirect ophthalmoscope if it can be video linked. Video real-time simultaneous consultation from each individual subspecialty clinics, from either Singapore or Jakarta, also represents a significant time-saving advantage over conventional interreferrals, where patients necessarily have to attend different specialty clinics on the same day or on different days. This approach, although requiring significant planning and coordination, has the effect of greatly expediting clinical decision making, coupled with the value of real-time holistic conferencing of all subspecialists concerned with the patient's care.

Studies on teleophthalmology tend to focus on telemedicine initiatives involving physician–patient interactions for patients without access to local ophthalmologists or, in

this COVID-19 era, to avoid patients traveling to attend medical clinic appointments, and as such, there seem to be few examples in the literature of this form of real-time synchronous teleophthalmology for the anterior segment because most home-based clinical examinations would be highly limiting.[10–12] By contrast, our approach involves a physician-to-physician or clinic-to-clinic coconsultation for postsurgical management and long-term follow-up of keratoplasty patients. Although this teleophthalmology program was derived out of necessity in this current COVID-19 pandemic which restricted air travel between countries, our VCC concept essentially enables a teleophthalmology approach for close collaboration between non–co-located ophthalmology subspecialists, which could still be relevant beyond this COVID-19 crisis, and may even constitute part of the "new-norm" of clinical medicine. In the instance of corneal disease, many ophthalmologists refer corneal patients to corneal specialists who may be located in another state or region for consultation or surgery—if keratoplasty is performed, then the patient needs to either travel regularly for his postoperative follow-up care or rely on his general ophthalmologist who may be less familiar with managing keratoplasty patients. In this instance, repeat VCC management will enable such patients to continue to be followed up by their local ophthalmologist, but simultaneously enjoy coconsultation with their distant corneal surgeon. In our series, most of these postkeratoplasty patients were extremely complex, and hence the advantage of several corneal and other subspeciality surgeons discussing together to come to a joint management plan. Similar scenarios could be envisaged in the case of other complex or subspecialty conditions, where highly specialized subspecialist expertise would be desired.

To cater to the relatively higher demands of a physician–physician teleophthalmology setup, where detailed subspecialist examination and investigations would be needed, it is clear that VCC transmission of real-time slit-lamp video examination, coupled with the ability to review EMR-based imaging investigations, and a synchronous or asynchronous prior hybrid adjunctive approach would be essential.[12] The recent familiarity of current audiovisual telecommunication technologies, such as Zoom, the common cloud-based communications application, coupled with EMR-based ophthalmology clinic software and clinic equipment essentially transforms what would have been a 1 ophthalmologist clinic visit into a multispecialist real-time consultation also known as a hybrid approach.[11] One obvious limitation of VCC, therefore, is the ability of both clinic locations to have the same relatively high level of cloud access and clinical technologies, which is probably available in most developed countries.

The limitations of VCC include the need for good telecommunication links, good transmission capabilities of the transmitting clinic, and the reliance on a stable network as well as the potential for cybersecurity risks imposed by data transfer of medical information across networks.[10,12] However, we consider these limitations to be far outweighed by the much improved and time-sensitive patient care afforded to our keratoplasty patients, to say nothing of the significant reduction in travel costs to patients, and the benefit of multiphysician assessments. As it is, although Singapore is undergoing even more stringent local restrictions and quarantine orders due to the increasing number of Delta and Omicron variant COVID-19 cases, ECS has currently adopted a similar VCC concept as part of its contingency plans in case 1 or more of our physicians become COVID-19-positive and are forced to undergo home quarantine—using VCC will still enable our patients to be managed from home by our quarantined physician, with the assistance of his or her colleagues in the clinic. Finally, it is highly likely that our institutions will continue with VCC after this current COVID-19 pandemic abates as a new collaborative clinical approach to patient management.

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REFERENCES

1. Gain P, Jullienne R, He Z, et al. Global survey of corneal transplantation and eye banking. *JAMA Ophthalmol.* 2016;134:167–173.
2. WHO. Blindness and vision impairment. Available at: https://www.who.int/news-room/fact-sheets/detail/blindness-and-visual-impairment. Accessed January 16, 2022 Updated October 14, 2021.
3. Di Zazzo A, Lee SM, Sung J, et al. Variable responses to corneal grafts: insights from immunology and systems biology. *J Clin Med.* 2020;9:586.
4. Azevedo Magalhaes O, Shalaby Bardan A, Zarei-Ghanavati M, Liu C. Literature review and suggested protocol for prevention and treatment of corneal graft rejection. *Eye*. 2020;34:442–450.
5. Das T. Blindness and visual impairment profile and rapid assessment of avoidable blindness in South East Asia: analysis of new data. 2017 APAO holmes Lecture. Asia-Pacific journal of ophthalmology (Philadelphia, Pa.), 2017 APAO Holmes Lecture. *Asia Pac J Ophthalmol.* 2018;7(5):312–315.
6. Tan DT, Janardhanan P, Zhou H, et al. Penetrating keratoplasty in asian eyes: the Singapore corneal transplant study. *Ophthalmology*. 2008;115:975–982.
7. WHO. Rolling updates on coronavirus disease (COVID-19). Updated July 31 2020. Available at: https://www.who.int/emergencies/diseases/novel-coronavirus-2019/events-as-they-happen. Accessed April 19, 2021.
8. WHO. Update on Omicron. Updated November 28, 2021. Available at: https://www.who.int/news/item/28-11-2021-update-on-omicron. Accessed January 16, 2022.
9. CDC. Omicron variant: what You need to know. Updated December 20, 2021. Available at: https://www.cdc.gov/coronavirus/2019-ncov/variants/omicron-variant.html. Accessed January 16, 2022.
10. Sharma M, Jain N, Ranganathan S, et al. Tele-ophthalmology: need of the hour. *Indian J Ophthalmol.* 2020;68:1328–1338.
11. Kalavar M, Hua H-U, Sridhar J. Teleophthalmology: an essential tool in the era of the novel coronavirus 2019. 7/23/pubmed8/15/medline7/23/entrez. *Curr Opin Ophthalmol.* 2020;31:366–373.
12. Saleem SM, Pasquale LR, Sidoti PA, Tsai JC. Virtual ophthalmology: telemedicine in a COVID-19 era. *Am J Ophthalmol.* 2020;216:237–242.