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Feasibility of the use of a *S*tereoscopic *C*amera *I*n the *F*inal *I*nclusion (SCI-FI) of Donor Organ Assessment Using Virtual Reality Technology

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Abstract

Objective: Donor organ assessment is challenging, particularly when physicians and surgeons have to make decisions remotely. To improve communication and preparation for the transplant process, we proposed that a versatile, secure, and transportable video presence would enable a detailed assessment of donor organs.

Methods: A virtual reality camera with a 360-degree visualization range was used with a smartphone receiver to enable integral assessment of the donor's heart in the operating room, with visualization of the organs in real time. Prospective, observational data was collected in two cases in this proof-of-concept study. An assessment physician evaluated the donor heart remotely, and the assessment physician's conclusions were compared to the transplanting surgeon.

Results: The assessment physician was able to adjust the view, angle, contrast, and zoom of the images independently and deemed the organs suitable for transplant, which correlated in a blinded fashion with the procurement surgeon's independent assessment.

Discussion: Usage of 360-degree high definition cameras and real-time, three-dimensional mobile receivers may be a feasible approach to apply to organ procurement, allowing physicians located remotely from the procurement center to participate and assist in the final intraoperative assessment for organ acceptance.

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Introduction

Telemedicine facilities are becoming increasingly popular for the provision of remote health care.[1] Most impressively, transcontinental robotic cholecystectomy has been performed in which the surgeon was in the USA and the patient was in France.[2] However, telemedicine approaches are not currently used in the organ transplantation setting, which commonly incur substantial distances and travel time between the donor and implanting teams.[3] The distance often poses a clinical assessment challenge because the on-site procurement surgeon is often the only individual with direct knowledge of real-time donor data. Currently, cell phones are often used to communicate between the procurement surgeon and the transplanting team; however, these methods are often not encrypted and cannot provide real-time images. Further, the procurement surgeon faces a challenge of operating and trying to send images at the same time.

Currently, there is a significant organ shortage; thus, the utilization of donor organs must be optimized and efficient. To improve the organ assessment process, we proposed a proof-of-concept study that uses of a 360º high definition camera that can be easily set up in the procurement operating room (OR) and can be operated remotely by the transplant team. The receivers are smartphones that utilize a secure and encrypted connection and can independently adjust view angle, contrast, and zoom capability.

Methods

Patients

Internal review board approval was attained for this investigation from the institution's Committee for the Protection of Human Subjects (HSC-MS-16-0748). Video images were received but not stored, and no patient's identifiers were used or recorded to protect privacy.

Patient screening involved identifying those who were confirmed as an organ donor and were admitted to a large, central hospital in an urban setting. Of those eligible, patients whose hearts would be transplanted at a facility within 1000 meters of the central hospital were selected for recruitment. The next of kin for the organ donor was approached to obtain written, informed consent for the project.

Equipment, Connection, and Mobile Applications

A 360fly® virtual reality camera (360fly, Inc., New York, New York) was used (Figure 1A); it is a 61mm spherical camera that weighs 138 grams. The camera requires a full charging time of 2.5 hours and features a battery life of 2 hours; thus, a power connection is not necessary for the OR. We used the 4K bike mount, also made by 360fly, Inc. This mount allows the camera to be affixed to an IV pole at the head of the operating table, where it remains for the duration of procurement (Figure 1B). The lens has eight-element glass ultra-fisheye lenses, each with 360-degree field of view. The focal length of the camera is 0.8 mm, and minimal focus distance is 30cm; the video resolution is 1504x1504 at 30fps. The camera is supported by mobile technology, including iOS 9+ and Android 4.4+.

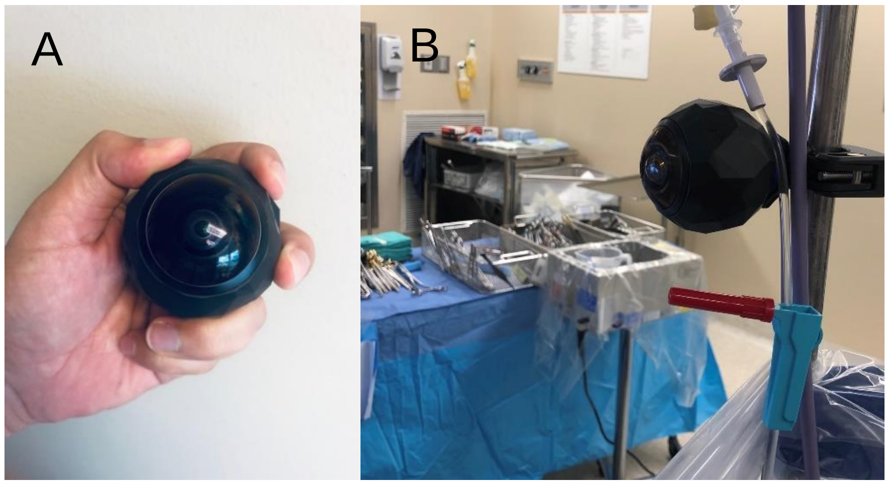

Figure 1A: *Image of the 360fly® virtual reality camera (360fly, Inc., New York, New York).* ***Figure 1B:*** *The camera can be attached to an IV pole in the operating room as depicted.*

The receiver is a smart phone that utilizes an app. The camera connection between the procurement team and the implantation center is through Livit Now, a secured and encrypted broadcast application. Access only can be granted from the mobile device located at the retrieval center next to the camera.

The camera allows the receiver to experience the scene in every direction with tracking ability, which in turn permits the user to capture the images in the OR. The receiver user can use the viewfinder to independently attain real-time images that can visualize any direction in the camera's 360 degrees view; they can zoom in and out and adjust contrast as needed.

Procedure for Equipment Set Up

The ORs where procurement and implantation were done were in two different buildings. The procurement process occurred in an OR within 1000 meters and four floors apart from the OR for the recipient heart transplantation.

Data Collection

All participating physicians received training on how to use the camera and receivers and how to handle the tracking system. After confirmation of donor organ availability was made, the next of kin of the donor patient was approached by the procurement surgeon to attain consent for collection and transmission of audiovisual material. Before the surgery, the OR staff for the organ procurement consented to the transmission of audiovisual material that could include them. Patient identifiers were masked while the donor OR was prepared. The procurement surgeon set up the 360fly camera on the IV pole (Figure 1B). An assessment physician with experience in cardiothoracic surgery established and confirmed a secure connection that enabled live streaming and visual direction control. Once the chest of the donor was opened, the assessment physician was able to visually assess the donor heart and hemodynamics displayed on the anesthesia monitor. Assessments included a visual inspection to ensure the donor heart contained no visible abnormalities or ventricular dilation and retained normal contractility. The data collected by the assessment physician was not used by the procurement or the transplanting surgeons. Of note, all images were live streamed, and video was not recorded to protect patient information. The transplanting surgeon did not have access to the video feed but did communicate with the procurement surgeon per standard of care.

At the end of the procurement process, the assessment physician was asked to complete a survey regarding image quality, system use convenience, and technical questions using a Likert scale. In addition, two other questions were asked: 1) Whether the assessment physician was able to assess the video feed, and 2) Whether the organ donor was suitable for transplantation. The assessment was compared to the transplanting physician's opinion to donor organ suitability.

Results

Patients and Surgery

During a period of 24 months, there were three patients screened for this proof-of-concept study. In one case, the organ donor's family declined to participate in the research study. The other two families agreed, and the next of kin provided informed consent. The same assessment physician remotely accessed the video feed during the procurement process.

In both cases, the assessment physician was able to assess the donor's heart and, based upon those observations, decided that the heart was indeed suitable for transplant. The transplanting surgeon did deem the organs viable, and both were transplanted.

Outcomes and Follow-up

The assessment physician's survey results were consistent for both cases. They strongly agreed that the receiver has a friendly interface, displays a good video quality, maintains an adequate connection, and is convenient for remote organ assessment. The assessment physician declared that the video feed was adequate to assess the donor's heart and that using this tool, they would deem the heart suitable for transplantation. The correlating transplanting surgeon deemed that both hearts were suitable.

Discussion

Donor organ assessment is currently reliant on a single individual—the procurement surgeon. Although discussions with other institutional team members may be undertaken, these physicians and surgeons do not have access to real-time data. This is in stark contrast to the recipient situation, where both pre-operatively and intraoperatively all available physicians and surgeons can directly access and treat the recipient.

The system that was used in this proof-of-concept study optionally displays binocular images that can be visualized by either a cellphone or tablet device or used to set up a headset that can leverage virtual reality technology. This option may prove to be of further benefit and allow for even more detailed images for both assessment and educational purposes. While the video feed and detail were deemed acceptable in these two cases, it must be noted that the specifications could be done to optimize the camera for the specific task of organ assessment. More specifically, ORs have particular lighting challenges. A dynamic range of filters on the lens could enable optimal lighting and image quality. One of the ideal elements is the independent Viewfinder option. The durability and size of the camera are pivotal for transportation and use in an OR setting. The Viewfinder allows the assessment physician to independently use the receiver to scan the room without having the procurements surgeon or staff adjust the camera. Likewise, the assessment physician can zoom in and out and adjust their view on the receiver using the 360-degree visibility available. Receiving teams would benefit as they would have real-time updates as to the progress of the procedure as well as images of the heart itself. Increased communication improves almost all surgical procedures.

This deficiency in donor organ assessment is not well addressed. Some organ procurement organizations/states have developed recovery centers, where donors may be transported to sites at least somewhat closer to recipient hospitals.[4] However, some distance between donor-recipient sites may be present, thus precluding multi-practitioner assessment of the donor organ. Consequently, the use of a telemedicine approach to assess donor cardiac function represents a highly feasible approach that could improve communication between teams and thereby improve patient care. The system that we chose permits the remote physician to independently assess the entire OR environment, without requiring extra work or logistics from the procurement surgeon. This is a proof-of-concept result with two normal donors. We recognize that these data are limited; however, they are promising.

It is clear that technology is available to enable remote evaluation; however, the advancements have not been broadly or specifically applied to the cardiothoracic surgery field. Partnering with industry will be necessary to harness the power of the technology and enable its optimal use in the OR. Further and larger prospective studies will be required to better define the utility of telemedicine approaches to donor organ assessment. Recording of these assessments would also enable retrospective review that would allow for both quality improvement, training, and outcome analysis.

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