Virtual Interactive Presence in Global Surgical Education: International Collaboration Through Augmented Reality

Matthew Christopher Davis[1], Dang D. Can[2], Jonathan Pindrik[1], Brandon G. Rocque[1], James M. Johnston[1]

■ BACKGROUND: **Technology allowing a remote, experienced surgeon to provide real-time guidance to local surgeons has great potential for training and capacity building in medical centers worldwide. Virtual interactive presence and augmented reality (VIPAR), an iPad-based tool, allows surgeons to provide long-distance, virtual assistance wherever a wireless internet connection is available. Local and remote surgeons view a composite image of video feeds at each station, allowing for intraoperative telecollaboration in real time.**

■ METHODS: **Local and remote stations were established in Ho Chi Minh City, Vietnam, and Birmingham, Alabama, as part of ongoing neurosurgical collaboration. Endoscopic third ventriculostomy with choroid plexus coagulation with VIPAR was used for subjective and objective evaluation of system performance.**

■ RESULTS: **VIPAR allowed both surgeons to engage in complex visual and verbal communication during the procedure. Analysis of 5 video clips revealed video delay of 237 milliseconds (range, 93—391 milliseconds) relative to the audio signal. Excellent image resolution allowed the remote neurosurgeon to visualize all critical anatomy. The remote neurosurgeon could gesture to structures with no detectable difference in accuracy between stations, allowing for submillimeter precision. Fifteen endoscopic third ventriculostomy with choroid plexus coagulation procedures have been performed with the use of VIPAR between Vietnam and the United States, with no significant complications. 80% of these patients remain shunt-free.**

■ CONCLUSION: **Evolving technologies that allow long-distance, intraoperative guidance, and knowledge transfer hold great potential for highly efficient international neurosurgical education. VIPAR is one example of an inexpensive, scalable platform for increasing global neurosurgical capacity. Efforts to create a network of Vietnamese neurosurgeons who use VIPAR for collaboration are underway.**

INTRODUCTION

In much of the world, subspecialty surgical care is not available readily.[1-9] The absence of local subspecialty care has a demonstrable impact on morbidity and mortality,[10,11] and time to surgical intervention is critical in many conditions.[10,12,13] Hands-on training of local surgeons in their home country is the optimal method for increasing global surgical capacity, and technology allowing a remote, experienced surgeon to provide real-time guidance to local surgeons has great potential for training and capacity building.[14-16]

Telesurgery, the use of robotic actuators that allow a geographically remote surgeon to perform a procedure, has attracted growing interest during the past 2 decades,[14,17-38] and robotic tools have been used in multiple subspecialties and across long distances.[14-16,22,26,28,30,31,36,39-42] However, the adaptation of telesurgical systems to developing countries is hampered by issues of cost,[14,29,43,44] connectivity,[33,35,45] and the continued need for skilled operators at the surgical site. Additionally, most neurosurgical procedures are not amenable to existing robotic technology, and the cost of complex systems has limited the role of robotic tools in neurosurgery.[46,47]

Telepresence involves nonrobotic tools to support interactive video and audio telecollaboration in which a remote surgeon

Key words
- Global Health
- Neurosurgery
- Pediatrics
- Telecommunications

Abbreviations and Acronyms
ETV/CPC: Endoscopic third ventriculostomy and choroid plexus coagulation
VIPAR: Virtual interactive presence and augmented reality

[1]University of Alabama at Birmingham, Birmingham, Alabama and [2]Neurosurgical Department, Children's Hospital #2, Ho Chi Minh City, Vietnam

To whom correspondence should be addressed: Matthew Christopher Davis, M.D. [E-mail: matthewdavis08@gmail.com]

Supplementary digital content available online.

Citation: World Neurosurg. (2016) 86:103-111.
http://dx.doi.org/10.1016/j.wneu.2015.08.053

Journal homepage: www.WORLDNEUROSURGERY.org

Available online: www.sciencedirect.com

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provides guidance and training without directly performing the procedure. Telepresence systems have grown in popularity alongside telesurgical tools,[38] but previous systems were limited to providing assistance through verbal exchange or use of a pointer tool.[48,49]

Virtual interactive presence and augmented reality (VIPAR) is a recently developed tool that allows surgeons to provide real-time virtual assistance and training wherever a standard internet connection is available.[50,51] The technology provides a hybrid perspective of local and remote video feeds, allowing a remote surgeon to digitally "reach into the surgical field," to highlight anatomic structures and providing a visual demonstration of complex operative techniques.

VIPAR can be rapidly deployed under sterile conditions,[52] and has been used in orthopedic surgery for training of resident surgeons with an attending surgeon immediately available in an adjoining room.[53] VIPAR has been shown to be feasible for long-distance telecollaboration in neurosurgical studies on cadaveric specimens,[51] but the use of long-distance VIPAR has never been reported in neurosurgical patients or for international collaboration.

Here we describe the performance, utility, and feasibility of implementing VIPAR as a tool for global surgical education and telecollaboration between neurosurgeons in the United States and Vietnam.

MATERIALS AND METHODS

Overview

Neurosurgeons from the Children's of Alabama Hospital in Birmingham, Alabama, traveled to Children's Hospital #2 in Ho Chi Minh City, Vietnam, to provide lectures, in-clinic instruction, and intraoperative training to local neurosurgeons on advanced techniques in pediatric neurosurgery. The VIPAR system was implemented and trialed in neuroendoscopy and cases that required the use of the operative microscope and used for international telecollaboration and continuing education after the return of the visiting team to Children's of Alabama. Institutional Review Board approval was obtained from both the University of Alabama at Birmingham as well as the Ethical Review Committee at Children's Hospital #2.

VIPAR

The VIPAR system consists of a local station and a remote station connected over a local wireless or 3G mobile connection, providing worldwide point-to-point connectivity. Local and remote stations were established at Children's Hospital #2 and Children's of Alabama Hospital, respectively.

Both local and remote surgeons view a composite image of video feeds at each station, allowing for visual demonstration and telecollaboration. The proprietary software performs real-time calibrations to spatially match the local and remote visual feeds and uses a merging feature to overlay the 2 images. The distant station image appears as a semitransparent overlay on the local station image,[50] and a single hybrid image is displayed to both parties. Whereas early iterations required complex video capture and display systems,[50,51] newer versions run on iPad (Apple, Cupertino, California, USA) devices, and use a commercially available app, Lime (Lime Apps, Recoleta, Buenos Aires, Argentina), downloaded onto the device. The forward-facing camera on each iPad provides video and audio capture, whereas the iPad screen provides video display. An iPad Air 2 was used at both local and remote stations to provide 1080p HD video recording (30 frames per second). A schematic of the VIPAR system is presented in Figure 1.

VIPAR runs on iOS6.0 or later. Information is transmitted between users using AES 128 encryption. Servers record the instance of the communication, including the start and end times of the connection. No data about content of the communication are known or recorded by the vendor servers, and neither video nor audio may be directly recorded using the VIPAR software, allowing for secure data transfer.

Local Station at Children's Hospital #2

The local station was constructed in the neurosurgery operating room at Children's Hospital #2 in Ho Chi Minh City, Vietnam, with the use of an iPad Air 2 and locally available internet connection. The local device was fixated to either the endoscopy tower or the operative microscope using a commercially available flexible support arm (Hoverbar 3; Twelve South, LLC, Mount Pleasant, South Carolina, USA). Positioning of the device entails directing the camera toward the endoscopic or microscope video projection, while the iPad screen is left visible to the operating surgeon, and located outside of the surgical field. The local station setup is shown in Figure 2, *left*.

Distant Station at Children's of Alabama Hospital

The distant station was set up in a conference room at Children's of Alabama Hospital in Birmingham, Alabama, with the use of a separate iPad Air 2 and local wireless internet connection. A pediatric neurosurgeon directed the forward-facing iPad camera at a white background and placed his or her hands and instruments into the camera capture field. The distant station also carries a telestration feature on the iPad screen that allows the expert surgeon to freeze the screen or draw on the image using a 2-dimensional pen tool. The distant station setup is shown in Figure 2, *right*.

Connectivity

Although early VIPAR models required high-speed fiber-based local connectivity, the latest iteration allows the system to function with upload and download speeds within the throughput capacity of wireless network and 3G mobile internet connectivity. Connection between stations uses commercial codecs (vsx 7000; Polycom, San Jose, California, USA; and Tandberg, Cisco Systems, San Jose, California, USA).

Both local area wireless network and 3G mobile internet connectivity at the local station were evaluated. A Linksys WRT54GL Wi-Fi Wireless-G Broadband Router (Linksys, Irvine, California, USA) installed in the operating theater provided connectivity to the local internet service provider. The XCom Global Mobile Wi-Fi Hotspot (XCom Global, San Diego, California, USA), which uses a local 3G mobile phone network to deliver internet connectivity, also was evaluated. A local area wireless network was used at the distant station for both trials. Upload speeds, download speeds, and mean transit times were measured for each method of connectivity using Network Analyzer (Techet; http://www.techet.net/),

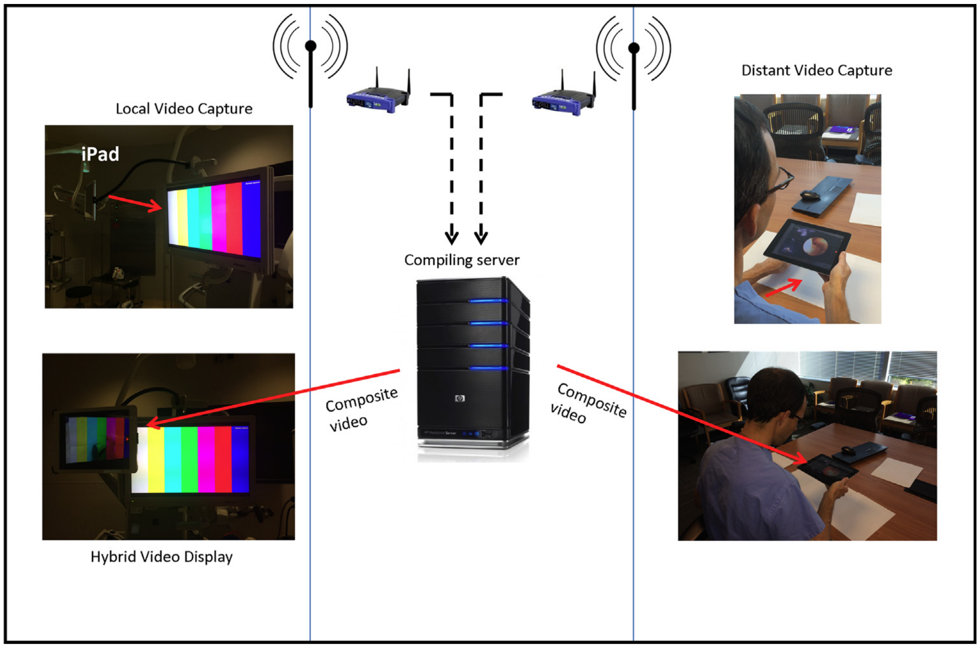

Figure 1. Diagram of the virtual interactive presence and augmented reality system. Local and distant video and audio feeds are compiled to create a single composite with each surgeon viewing a common field. The distant video feed is seen as a semitransparent overlay on the background of the local video feed.

a commercially available application downloadable onto iOS devices.

Audio and Video Composite Latency and Accuracy Analysis

Time difference between images depends on local processing times, which typically are fixed, and internet transmission delay, which can fluctuate. Delays in internet transmission and image compilation were assessed through off-line video analysis. An endoscopic third ventriculostomy and choroid plexus coagulation (ETV/CPC) with the use of VIPAR was used for evaluation of system performance. Independent videos of the local and remote composite fields were recorded. Video clips were synchronized to audio and identifiable movements at each station, and the delay between each video assessed in milliseconds. Composite accuracy was assessed by each surgeon touching the same indicated point and providing verbal confirmation they see the other surgeon touching the same point.

Clinical Utility Analysis

Both the local and distant surgeons were queried on overall utility of the telecollaboration experience via questionnaire by the use of a 5-point Likert scale. Both surgeons were asked to rate the VIPAR system on the following criteria, where 1 indicates strongly disagree; 2, disagree; 3, neutral; 4, agree; and 5, strongly agree:

Use of the telecommunication system:

a) changed the course of the procedure (1–5)

b) resulted in a safer procedure (1–5)

c) resulted in a more effective procedure (1–5)

d) was useful overall (1–5)

e) resulted in increased fatigue (1–5)

Cost Analysis

Assessment of both direct and indirect costs associated with institution of the VIPAR system was performed. Expense data were subdivided as follows: visiting team expenses, local station hardware, distant station hardware, proprietary software, internet connection, and technical support.

RESULTS

Successful implementation and trial of the VIPAR telecollaboration system took place as part of ongoing neurosurgical collaboration between Children's of Alabama Hospital and Children's Hospital #2 in Ho Chi Minh City, Vietnam. A strong relationship exists between these institutions, with regular exchange of general surgery and neurosurgery teams. Cases requiring either the endoscope or operative microscope were performed using VIPAR assistance. After the return of the visiting team to their home institution, VIPAR was effective in providing transnational intraoperative assistance.

Local Hospital

All cases were performed at Children's Hospital #2 in Ho Chi Minh City. Five pediatric neurosurgeons provide care for the full spectrum of pediatric neurosurgical disease and train one

Figure 2. Setup of local and distant stations for neuroendoscopy. The local station within the operative suite is depicted on the left, whereas the setup for the distant station is shown on the right.

pediatric neurosurgeon per year. Southern Vietnam, with a population of nearly 50 million, is served by 10 pediatric neurosurgeons (D. Can, personal communication, 2015), with varying levels of subspecialty training. In certain cases, pediatric neurosurgery training is distinct from adult neurosurgery residency and consists of a 3-year program started immediately after completion of medical school, which lasts either 4 or 6 years. There are 2 pediatric neurosurgery training programs for all of Vietnam, one located in Ho Chi Minh City, and the second located in Hanoi. For the calendar year 2014, 613 total pediatric neurosurgical procedures were performed at Children's Hospital #2 (breakdown of cases provided in Table 1).

VIPAR Local Trial

Initial trials took place while the visiting team was present to provide immediate hands-on intraoperative assistance if needed.

Endoscopic Trials. *Case 1.* An ETV/CPC was performed in a 7-month old boy with hydrocephalus and a Dandy-Walker malformation variant. A STORZ 2.2-mm flexible endoscope was used with display on a high-definition 26-inch, 16:9 HD format, 1920 × 1200-pixel resolution digital monitor. The local station was set up as described previously (Figure 2). One expert neurosurgeon remained scrubbed throughout the case, whereas a second visiting neurosurgeon set up the distant station in an adjacent room. Stations were connected over the same local area wireless network. One episode of dropped call occurred, which required less than 1 minute to correct. Several subsecond episodes of noticeable transient video delay occurred. No audio delay was detected. Excellent registration was observed. VIPAR was used for a total of 2 hours and 11 minutes, with 16% battery usage over that time.

Case 2. ETV/CPC with biopsy of a third ventricular mass was performed on a 2 year-old boy using the set-up described

Table 1. Neurosurgical Cases Performed at Children's Hospital#2 During 2014

Case Type	Number of Cases
Craniotomy for trauma	96
Craniotomy for tumor or biopsy	123
Craniotomy for infection*	38
Ventricular shunt†	127
ETV/CPC	44
Craniosynostosis correction	18
Craniotomy for vascular pathology‡	14
Craniotomy for other§	49
Diagnostic cerebral angiogram	44
Neuroendovascular intervention	1
Spine for trauma	2
Spine for tumor or vascular lesion	14
Spine for neural tube defects	43

ETV/CPC, endoscopic third ventriculostomy with choroid plexus coagulation.
*Includes primary brain abscess, empyema.
†Includes placement of new ventricular shunts, revisions, exploration, removal, and replacement.
‡Includes evacuation of spontaneous intracranial hemorrhage, encephaloduroarteriosynangiosis.
§Includes Chiari malformation repair, encephaloceles, wound washout, and other miscellaneous cases.

previously. No episodes of dropped call, audio or detectable video delay occurred during a 40-minute run period.

Operative Microscope Trial. *Case 3.* A right pterional craniotomy was performed for biopsy of an enhancing infundibular mass in a 5-year-old girl who presented with diabetes insipidus. The local iPad was fixated to the operative microscope and directed at the display screen, while still viewable by the operating surgeon (Figure 3). Resolution was adequate to allow the remote surgeon to identify all relevant microsurgical anatomy.

Video

Video available at WORLDNEUROSURGERY.org

VIPAR international Trial

An attending pediatric neurosurgeon in the United States was contacted with VIPAR while a visiting neurosurgeon remained scrubbed during an ETV/CPC on a 6-month-old female patient, allowing collaboration spanning 14,904 kilometers. VIPAR was used throughout the endoscopic portion of the procedure, without noticeable interaction delay or appreciable difference in resolution between the 2 sites. The system allowed for discussion of procedural strategy and visual conveyance of surgical maneuvers that would not have been possible with standard video conferencing. Video 1 demonstrates the system in use at both the local and remote stations.

Audio Latency. Optical fiber cables provide long-distance telecommunication through the transmission of light impulses. Minimum latency time is dependent on the speed of light (299,792 kilometers per second in a vacuum) and a standard fiber delay ratio, estimated at 1.52 for the purpose of this study. Most telecommunications networks connect between multiple nodes, significantly increasing total distance a signal must travel between each station. Even if a single fiberoptic cable connected directly between the 2 stations in this study, a minimum lag time of 75.54 milliseconds would be expected simply for light to travel from one station to the other. Despite the great distances involved, audio delay was not perceptible to participants at either station.

Video Composite Latency

Off-line analysis was performed by the use of independent videos of the local and remote stations. Video clips that included unique movements and audio were used for synchronization and frame-by-frame analysis. The local-to-remote station video latency averaged 237 milliseconds relative to the audio signal (range,

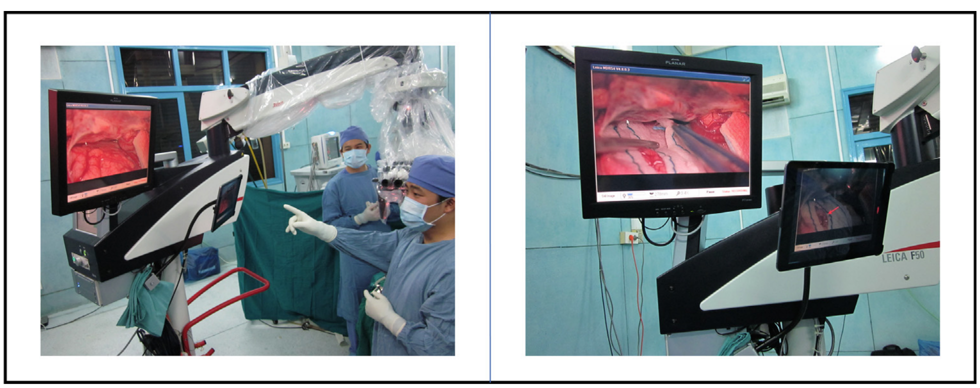

Figure 3. Setup of local station for cases requiring use of the operative microscope. The local iPad is pointed toward the microscope display, whereas the screen is directed toward the surgeon, outside of the operative field.

93–391 milliseconds). While the surgeon at each station therefore viewed their counterparts' field as slightly delayed relative to their own, this did not interfere with performing the procedure. The number of elapsed frames between the synchronized videos was used as the metric of latency time between the two stations.

Composite Accuracy. Confirmation of accuracy between stations was performed by the distant surgeon pointing at specific anatomic structures at the request of the local surgeon, and tracing clearly identifiable borders of the local video feed. Each participant agreed the spatial accuracy was sufficient such that any difference was imperceptible. This was confirmed on off-line video analysis.

Connectivity

Local station area wireless upload speeds ranged from 7.25 to 8.24 Mbps, with download speeds from 3.97 to 5.54 Mbps (IP address 192.168.4.187). Distant station wireless upload speeds ranged from 26.39 to 27.62 Mbps, with download speeds from 31.90 to 34.43 Mbps (IP address 138.26.72.17). Round trip time ranged from 321.71 to 363.41msec over 200 test packets. 3G mobile wireless upload speeds ranged from 2.39 to 3.31 Mbps, with download speeds from 2.98 to 5.28 Mbps.

Set-Up and Disassembly

Setting up the local station and breakdown at the end of a case took less than 10 minutes to complete. Setup time for the distant station consists only of finding a white background toward which to direct the iPad camera. Operative times were not felt to be significantly affected by use of the VIPAR system.

Cost

Financial data collected included visiting team expenses, local station hardware, distant station hardware, proprietary software, internet connection, and technical support. Three main internet service providers in Ho Chi Minh City (Vietnam Posts and Telecommunications group, Viettel, and FPT) offer fiber-based and 3G mobile wireless connectivity. Internet costs for this study included $80 USD for placement of a Linksys WRT54GL Wi-Fi Wireless-G Broadband Router within the neurosurgery operating theater, with no additional cost incurred for use of Children's Hospital #2 internet access. Individual subscriber internet access ranges from 260,000 to 2,070,000 Vietnamese Dong ($12–$96 USD) per month in Ho Chi Minh City based on connection speeds and data usage, and these rates are used for cost analysis. Total costs for establishing the VIPAR system were $14,930.39 USD for one calendar year; $12,504.60 of this was associated with the 2-week visiting team experience. A breakdown of financial data is presented in Table 2.

Table 2. Financial Outlay of Establishing an International Telecollaboration System for 1 Year

Breakdown of Costs (USD)		
Local station		1576.89
iPad Air 2	548.90	
Lime subscription (1 subscriber, $25 per subscriber per month)	300.00	
Wireless internet access (12 months, mean $54 per month)	648.00	
Wireless router	79.99	
Visiting team expenses		12,504.60
Flights (3 participants, round-trip flights)	7254.60	
Accommodations (2 hotel rooms, 14 total days)	4200.00	
Meals (3 participants, $25 per diem)	1050.00	
Distant station		848.90
iPad Air 2	548.90	
Lime subscription (1 subscriber, $25 per subscriber per month)	300.00	
Total expenditures		14,930.39

USD, U.S. dollars.

Ongoing Collaboration

After the return of the visiting team, VIPAR continues to be used for intraoperative assistance and training for neuroendoscopic cases. Fifteen additional ETV/CPC procedures have been performed with VIPAR for long-distance collaboration since the visiting surgical team has returned, each without complication or hardware failure. As mentioned previously, excellent registration and resolution were observed in 14 cases. In one case, there was a transient loss of audio connectivity without disturbance of video connectivity. This did not interfere with the procedure because visual graphics tools were used to point out anatomy and suggestions for location of the ETV. Twelve of the 15 patients remain shunt-free as of last follow-up. There have been no other complications observed in any cases. Over the 6 months immediately before the introduction of VIPAR, 27 ETV/CPCs were performed at Children's Hospital #2, all for aqueductal stenosis. Complications before VIPAR included severe intraventricular bleeding requiring an external ventricular drain in 2 patients (7.4%), subdural hematoma in 1 patient (3.7%), postoperative cerebrospinal fluid leak in 1 patient (18.5%), and death from hemorrhage from a basilar artery injury in 1 patient (3.7%).

VIPAR has been used additionally for global telecollaboration during cases that require the use of the operative microscope, including resection of a large cerebellar tumor and clipping of a distal posterior inferior cerebellar artery aneurysm.

Clinical Utility

Local and distant surgeons reported the VIPAR telecommunication system to be very useful for operating neurosurgeons in Ho Chi Minh City, Vietnam. On a 5-point Likert scale where 1 indicates strongly disagree and 5 indicates strongly agree, each surgeon strongly agreed that VIPAR was useful overall (5) and resulted in a more effective procedure (5). Each surgeon also agreed VIPAR changed the course of the procedure (4) and resulted in a safer procedure (4), and disagreed with the statement: "VIPAR resulted in increased fatigue" (2).

DISCUSSION

In the coming years, the global shortage of surgeons is only expected to worsen.[7,8] Surgical disease is 1 of the top 15 causes of global disability,[54] and surgical intervention fills a crucial role in global public health.[55] This gap necessitates the development of tools to geographically extend the reach of expert surgeons. Although robotic systems provide an extended geographic reach of a single surgeon, the VIPAR system allows long-distance assistance during complex cases as well as training of local surgeons. Although the VIPAR system initially was created for use through a binocular videoscope or attachment to the operative microscope, the technology has been adapted to other commercially available systems in which both video recording and display are possible, such as Google Glass or iPad. These devices are relatively inexpensive and may prove to be valuable tools for global neurosurgical education and capacity building. Endoscopic, endovascular, and microsurgical cases already rely on video projection for the critical portion of the procedure and are ideally suited to implementation of VIPAR technology. ETV/CPC, increasingly used for primary treatment of infant hydrocephalus throughout the world,[37] provided an excellent example in our series.

Surgical outcomes are heavily influenced by technical acumen, and unexpected intraoperative situations may arise that would benefit from the expertise of a more experienced or specialized surgeon. Additionally, geographically remote surgeons may be called upon to assist with an emergent procedure that cannot wait for transfer to greater levels of care. In both instances, the value of a feasible paradigm that permits the digital presence of an expert surgeon within the operative field becomes clear. Telecollaboration has been demonstrated for the education of orthopedic surgery residents[53] but has never been used for international surgical training. The VIPAR system is both practical and simple, and it provides a visual adjunct to verbal description of complex surgical procedures and techniques.

Expert surgeons may have the ability to spend short periods of time providing hands-on training in developing countries but not able to commit to longer periods. The number of short-term surgical trips has increased dramatically during the past 30 years,[56] but the lack of emphasis on training and frequent absence of skilled follow-up have led to criticisms of the short-term trip model.[57,58] Although surgeons hailing from developing countries may alternatively visit the United States for longer-term observerships, actual participation in surgery is largely prohibited. Immersive learning paradigms emphasizing active participation are essential for developing new skills.[59,60]

As a result, the ideal method for capacity building involves hands-on training of surgeons in their home country, performing cases on their own patients. In trauma and critically ill patients, nonvirtual interactive tools for extending the expertise of subspecialists are associated with reduced morbidity and mortality.[61,62] A versatile and scalable digital telecollaboration technology to enmesh the expertise of a remote surgeon into the operative field could serve as a valuable adjunct to in-person training efforts. In this study, VIPAR allowed for ongoing skill and knowledge transfer after the return of the visiting team to their own clinical practice.

The complexity of surgical execution cannot be easily conveyed by face-to-face video, and evolving technologies provide novel solutions for surgical training and remote assistance. General and orthopedic surgery programs have adopted surgical simulators for training in laparoscopic, arthroscopic, and robotic techniques,[63,64] observing shortened trainee learning curves and no decline in patient outcomes[65-72]; however, sophisticated, high-overhead costs limit the application of simulators in the developing world, and current simulators cannot reproduce the wide range of potential complications. Additionally, surgical simulators do not presume even the most basic training. By contrast, complex and cumbersome robotic actuators still require highly skilled local surgeons to cope with unstable circumstances or system failure, limiting their application in neurosurgery.[47] Interactive telecollaboration systems such as VIPAR serve as a bridge, providing new domain skills to local surgeons who already possess a functional skill set.

Such technology is not meant to replace standard neurosurgical training but rather act as a complementary method that facilitates mentoring without physical presence of the experienced surgeon. We envision this technology as providing that last bridge of mentorship, taking a competent surgeon with fundamental neurosurgical skills and providing real-time feedback to coach them towards true expertise. Although telecollaboration has great potential for capacity building, elective cases should not be performed without local expert support readily available, unless the local surgeon has adequate training to complete the case without VIPAR assistance. Technical delays or loss of internet connectivity may leave the local surgeon without expert assistance, and thus caution is warranted if use of long-distance telecollaboration tools leads a local surgeon to "over-reach" in case selection. For emergent cases, backup internet access using mobile 3G wireless internet connectivity is recommended in the event of local area wireless internet failure, to decrease the risk of losing all contact with the distant expert.

Ongoing efforts are underway to create a network of Vietnamese neurosurgeons who use VIPAR technology to increase collaboration both within Vietnam and with our group in Alabama. Within the United States, VIPAR is currently under evaluation for utility in the outpatient setting as well. Issues facing the widespread adoption of digital telecollaboration tools include reimbursement and liability, as well as rigorous assessment of the impact on patient outcomes.

CONCLUSIONS

Giving remote experts the ability to guide and mentor less-experienced surgeons has great potential for global surgical education and capacity building. VIPAR is one example of evolving interactive technology that allows for real-time global surgical telecollaboration and education through commercially available and inexpensive platforms. Use of such technology may increase the safety of surgical intervention and has great potential for training, research, assessing surgical competence for maintenance of certification, and fostering relationships between geographically isolated physicians.

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Conflict of interest statement: Use of proprietary software was provided by Vipaar, LLC. This work was additionally supported by a grant from the Children's of Alabama Global Health Program Initiative and the Kaul Foundation.

Received 21 July 2015; accepted 7 August 2015

Citation: World Neurosurg. (2016) 86:103-111.
http://dx.doi.org/10.1016/j.wneu.2015.08.053

Journal homepage: ***www.WORLDNEUROSURGERY.org***

Available online: ***www.sciencedirect.com***

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