Unequal distribution of medical resources is a serious problem worldwide.\textsuperscript{1,2} In China, there are huge gaps in medical resource distribution among different parts of the country.\textsuperscript{3} Therefore, to increase access to health interventions and healthcare services for patients in resource-limited areas, strategies for the allocation of medical resources across geographic boundaries,\textsuperscript{3,4} such as telemedicine, must be developed and implemented. Internet-based telecollaboration is the main form of surgical telemedicine. This system allows experienced surgeons to perform complex visual and verbal communication during the operation. The average video delay time is 184.25 msec (range 160–230 msec) with 4G mobile internet, and 23.25 msec (range 20–26 msec) with 5G mobile internet. Excellent image resolution enabled remote neurosurgeons to visualize all critical anatomical structures intraoperatively. Remote instructors could easily make marks on the surgical view; then the composite image, as well as the audio conversation, was transferred to the local surgeon. In this way, real-time, long-distance collaboration can occur. This system was used for 20 neuroendoscopic surgeries in various cities in China and even across countries (Boston, Massachusetts, to Jingzhou, China). Its simplicity and practicality have been recognized by both parties, and there were no technically related complications recorded.

**RESULTS** The MIMIT system allows two surgeons to perform complex visual and verbal communication during the operation. The average video delay time is 184.25 msec (range 160–230 msec) with 4G mobile internet, and 23.25 msec (range 20–26 msec) with 5G mobile internet. Excellent image resolution enabled remote neurosurgeons to visualize all critical anatomical structures intraoperatively. Remote instructors could easily make marks on the surgical view; then the composite image, as well as the audio conversation, was transferred to the local surgeon. In this way, real-time, long-distance collaboration can occur. This system was used for 20 neuroendoscopic surgeries in various cities in China and even across countries (Boston, Massachusetts, to Jingzhou, China). Its simplicity and practicality have been recognized by both parties, and there were no technically related complications recorded.

**CONCLUSIONS** The MIMIT system allows for real-time, long-distance telecollaborative neuroendoscopic procedures and surgical training through a commercially available and inexpensive system. It enables remote experts to implement real-time, long-distance intraoperative interaction to guide inexperienced local surgeons, thus integrating the best medical resources and possibly promoting both diagnosis and treatment. Moreover, it can popularize and improve neurosurgical endoscopy technology in more hospitals to benefit more patients, as well as more neurosurgeons.

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**KEYWORDS** telemedicine; endoscopy; telecollaboration; mixed reality
surgical specialists to guide surgeons in remote areas who have little or no relevant experience in a real-time interactive manner. The first case of telecollaborative systems used in surgery was reported in the 1960s when physicians performed open heart surgery via satellite broadcast videoconferencing. Since then, more and more surgical telecollaboration systems have been used for various surgical procedures. However, the application of telecollaboration in neurosurgery is not as comprehensive as in other disciplines. Limited space and high-precision micromanipulation requirements in neurosurgery limit the applications of telecollaboration.

Long-distance collaboration can be divided into three types: 1) real-time video conferencing, in which telemedicine specialists train local surgeons visually or verbally through live video and voice streaming or freehand sketching, 2) robot-assisted remote surgery, where remote surgical experts operate remote robots directly through the network, and 3) virtual interactive presence and augmented reality (VIPAR) systems, in which these systems display information on the screen of a flat-panel monitor or smart glasses, allowing the local operator to simultaneously perceive the surgical field and virtual instructions.

However, as described in the literature, the VIPAR system has some limitations. The first limitation is that erroneous interactions or serious surgical complications can result from network latency or outages in connectivity. Furthermore, due to the complexity of the system construction, highly skilled local surgeons are still required to address possible system failure or instability. Third, the software or hardware of the system is often customized, which limits its widespread adoption in remote areas.

In this paper, we describe a mobile internet-based mixed-reality interactive telecollaboration (MIMIT) system for neurosurgical procedures. The technical feasibility, clinical implementation, and possible business model for this telecollaborative system are reported and analyzed.

Methods

System Overview

The MIMIT system consists of a head-mounted mixed-reality device (HoloLens, Microsoft Inc.), a local video processing (LVP) station installed at the site of the procedure, and a remote mobile device (smartphone or tablet PC) connected over a 4G or 5G wireless connection, providing worldwide connectivity.

The LVP station captures a video feed from an endoscope system or a microscope and sends it to the remote device via a cloud server. The remote mobile device can be an iPad, an Android phone, a tablet PC, or a conventional laptop. The mobile device captures the virtual marks of the remote specialist (using fingers or a mouse) for video composition. The real-time hybrid video (operative video and the marks) is sent back to the local LVP station. The hybrid video is then transmitted to the head-mounted HoloLens via a local high-speed network so that a virtual holographic screen panel can be seen, providing effective interaction. A detailed schematic workflow of the MIMIT is given in Fig. 1.

We developed a specific app, “Telecollaboration for surgery” (Guangzhou Jincheng Airui Technology Co., Ltd.), which is downloadable on both iOS (iPad only) and Android mobile systems. Android device users can download the Android app install file (in APK format) at [Link].
the following link: https://drive.google.com/file/d/1-15w4-
IQNso0-ozH7Ny5p4NxOueNYAR/view?usp=sharing. Use of this app makes it a very straightforward process for the remote specialist to get detailed information of the case, perform the intraoperative telecollaboration, and collect payment after surgery.

**Local Station and Connectivity**

The LVP station is placed in the operating room of the local hospital, and the video of a neuroendoscope or an operating microscope is captured by the LVP station through a DVI/SDI video port. The LVP station is connected to a 4G or 5G mobile network. A head-mounted mixed-reality device is used to provide a virtual holographic display screen panel in front of the operator’s eyes for intraoperative real-time guidance. The intraoperative mixed-reality view is shown in Fig. 3 and Video 1.

**VIDEO 1.** Clip showing an intraoperative telecollaboration from case 1. Note the holographic display panel in front of the local neurosurgeon. In the small video window in the lower right corner, the remote instructor can be seen performing the collaboration with a conventional laptop PC. © Xiaolei Chen, published with permission. Click here to view.

**Remote Station and Connectivity**

A standard iPad, Android phone, tablet PC, or conventional Windows PC can be used as a remote workstation. In addition to the real-time audio conversation between the remote instructor and the local surgeon, the local operation video, transferred from the LVP station, can be displayed on the operation interface of our dedicated app so that a more experienced instructor can draw marks using his or her fingers or a mouse directly on the screen (Figs. 3 and 4). Before drawing the marks, the instructor can freeze the surgical view, so that different marks can be drawn on a steady surgical view. The color, size, and shape of the marks can be customized by the instructor. In this way, the remote instructor can provide real-time, long-distance interactive audio and video guidance with our telecollaboration app as long as there is mobile internet service, which makes telecollaboration available anywhere, without special meeting rooms. This novel setting even made a real “curbside consult” possible (case 3; Fig. 4A).

**Audio and Video Composite Latency**

For telecollaborative surgical procedures, audio and video latency is critical for both safety and clinical efficacy. In this study, both audio and composite video are transmitted via the 4G/5G mobile network. The latency depends on the transfer rate between the two workstations. Previous reports on remote interaction assessed the delay of internet transmission and video synthesis by intercepting offline video and performing frame-by-frame analysis. This requires too many human resources and is relatively subjective. To test the precise end-to-end latency, we programmed accurate time display software (millisecond clock; https://www.dropbox.com/s/umtllv131f70c2/Millisecond%20Clock.rar?dl=0), which can display the instant system time to a millisecond level. The program is installed on both the LVP station and a standard Windows PC at the remote site. Before each telecollaboration procedure, the LVP workstation, the remote station/device, and the standard Windows PC at the remote site are synchronized with internet time. Then, our millisecond clock program is started on both the LVP station and the PC at the remote site. The LVP workstation transmits the workstation millisecond clock video to the remote mobile device.

**FIG. 3.** Case 1. A: Intraoperative picture of a local neurosurgeon with a head-mounted holographic display device (HoloLens). B: The mixed-reality holographic panel screen (white arrow). Note a mark (in green) made by the remote instructor overlaid on the endoscopic view. The small window (red arrow) shows the remote instructor providing real-time guidance.
The remote mobile device, with the LVP time display, was then placed beside the PC running the millisecond clock, so that the remote instant time as well as the LVP local instant time (displayed on the remote mobile device screen) can be displayed in the same picture. Photographs of the remote PC screen and remote mobile device screen were taken every minute until 10 photos were taken for analysis. By comparing the screen-displayed millisecond time of the mobile device and remote station, a precise end-to-end latency can be calculated and recorded. The time difference (subtracting one time from the other) is the precise latency of the composite video in the visual field of both participants (Fig. 5A). We calculate the time difference of 10 photos and take the average. The linear distance between the local and remote sites is recorded for each collaboration procedure (Table 1).

**Payment Solution**

To make a sustainable business model, we included a payment solution in our telecollaboration app. The consulting fee is approximately renminbi (RMB) 1000 yuan ($158 USD) per hour. The patient’s representatives can pay with Alipay or credit cards online, just like many other popular online medical consulting apps. Fifty percent of the payment is used for telecollaboration online platform maintenance, 30% of the payment is collected by the remote instructor, while the rest (20%) is collected by the remote instructor, while the rest (20%) is collected by the remote instructor, while the rest (20%) is collected by the remote instructor, while the rest (20%) is collected by the remote instructor.
local surgeon. In this way, a legal payment system could be established.

**Liability Issues**

To avoid malpractice and potential liability issues, only qualified neurosurgeons who finished basic neuroendoscopic training can operate at the local site. For the remote instructor, only specialists who have more than 10 years of experience in neuroendoscopy can be enrolled. All the instructors are registered to an internet hospital (Jincheng Internet Hospital, China). A consent form for telecollaboration surgery was obtained from the patient or patient’s representatives before every procedure. The local hospital takes full responsibility in case of any liability issues.

**Results**

From February 2017 to December 2019, 20 cases were included in our study. Twenty telecollaborative neuroendoscopic procedures were successfully performed. A consent form for telecollaboration surgery was obtained from each patient or patient’s representatives before every procedure. The local ethics committee approved our study. A successful implementation and trial of the MIMIT system took place between cities in China and the United States. The linear distance between the local site and remote site ranged from 0.1 km (case 1, same building, different rooms) to 11,923 km (case 14, from Boston, Massachusetts, to Jingzhou, China). General information on all 20 cases, as well as the distance between them, is shown in Table 1. In all cases, a stable network connection and telecollaboration could be achieved. There were no technically related complications or liability issues recorded. All surgical procedures were completed uneventfully.

**Illustrative Cases**

**Case 1**

Case 1 was the first case in our study. An intracerebral cavernous malformation was removed by endoscopic port surgery. The LVP station was located in a standard operating room, while the remote instructor was seated in a different room in the same building. The instructor used one laptop PC to conduct the telecollaboration and marked on the surgical view using a mouse (Fig. 3, Video 1). The MIMIT telecollaboration was satisfactory with a mean latency of 160 msec. The delay was mild but still notable.

**Case 3**

Case 3 involved transphenoidal endoscopic removal for a recurrent pituitary adenoma. Intraoperatively, the local surgeon (in Nanchang, China) was confused by the abnormal anatomy. Hence, he requested telecollaboration with an experienced instructor in Beijing. At that time, the instructor was off duty and out of the hospital. Therefore, the instructor used his mobile phone and performed the telecollaboration in the street (Fig. 4A). This special situation made this case a true “curbside consult.” The surgery

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**TABLE 1. Detailed information of telecollaborative neurosurgical cases performed in this study**

<table>
<thead>
<tr>
<th>Case No.</th>
<th>Station</th>
<th>Procedure</th>
<th>Mobile Network</th>
<th>Distance Btwn Stations (km)</th>
<th>Mean Latency (msec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Beijing</td>
<td>Endoscopic port surgery for an intracerebral CM</td>
<td>4G</td>
<td>0.1</td>
<td>160</td>
</tr>
<tr>
<td>2</td>
<td>Beijing</td>
<td>ETV</td>
<td>4G</td>
<td>30</td>
<td>162</td>
</tr>
<tr>
<td>3</td>
<td>Beijing</td>
<td>Transphenoidal endoscopic removal of a recurrent pituitary adenoma</td>
<td>4G</td>
<td>1249</td>
<td>180</td>
</tr>
<tr>
<td>4</td>
<td>Beijing</td>
<td>ETV</td>
<td>4G</td>
<td>1901</td>
<td>178</td>
</tr>
<tr>
<td>5</td>
<td>Beijing</td>
<td>ETV</td>
<td>4G</td>
<td>1128</td>
<td>182</td>
</tr>
<tr>
<td>6</td>
<td>Beijing</td>
<td>Transphenoidal endoscopic removal of a recurrent pituitary adenoma</td>
<td>4G</td>
<td>1045</td>
<td>170</td>
</tr>
<tr>
<td>7</td>
<td>Beijing</td>
<td>ETV w/ tumor biopsy</td>
<td>4G</td>
<td>900</td>
<td>180</td>
</tr>
<tr>
<td>8</td>
<td>Beijing</td>
<td>ETV w/ tumor biopsy</td>
<td>4G</td>
<td>2489</td>
<td>198</td>
</tr>
<tr>
<td>9</td>
<td>Beijing</td>
<td>ETV w/ tumor biopsy</td>
<td>4G</td>
<td>2489</td>
<td>196</td>
</tr>
<tr>
<td>10</td>
<td>Beijing</td>
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<td>4G</td>
<td>1128</td>
<td>178</td>
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<tr>
<td>11</td>
<td>Beijing</td>
<td>ETV</td>
<td>4G</td>
<td>1901</td>
<td>180</td>
</tr>
<tr>
<td>12</td>
<td>Sanya</td>
<td>ETV w/ tumor biopsy</td>
<td>4G</td>
<td>2489</td>
<td>196</td>
</tr>
<tr>
<td>13</td>
<td>Sanya</td>
<td>ETV w/ tumor biopsy</td>
<td>4G</td>
<td>2489</td>
<td>190</td>
</tr>
<tr>
<td>14</td>
<td>Boston</td>
<td>Endoscopic fenestration of a trapped temporal horn</td>
<td>4G</td>
<td>11,923</td>
<td>230</td>
</tr>
<tr>
<td>15</td>
<td>Beijing</td>
<td>ETV</td>
<td>4G</td>
<td>1901</td>
<td>182</td>
</tr>
<tr>
<td>16</td>
<td>Beijing</td>
<td>ETV</td>
<td>4G</td>
<td>1901</td>
<td>186</td>
</tr>
<tr>
<td>17</td>
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<td>ETV w/ tumor biopsy</td>
<td>5G</td>
<td>2489</td>
<td>23</td>
</tr>
<tr>
<td>18</td>
<td>Sanya</td>
<td>ETV</td>
<td>5G</td>
<td>2489</td>
<td>20</td>
</tr>
<tr>
<td>19</td>
<td>Beijing</td>
<td>ETV</td>
<td>5G</td>
<td>2489</td>
<td>26</td>
</tr>
<tr>
<td>20</td>
<td>Beijing</td>
<td>Endoscopic fenestration of an arachnoid cyst</td>
<td>5G</td>
<td>2489</td>
<td>24</td>
</tr>
</tbody>
</table>

CM = cavernous malformation.

All locations (remote and local) were in China, except for the remote location in case 14 (Boston, Massachusetts).
was finally successfully performed. The telecollaboration lasted 1.5 hours. The tumor was completely removed and no complications occurred.

Case 14

Case 14 suffered from a trapped temporal horn following intraventricular hemorrhage. A telecollaborative endoscopic fenestration of the temporal horn was planned. The local surgeon was performing surgery in Jingzhou, Hubei, China, while the remote instructor was in Boston, Massachusetts (Fig. 4B and C, Video 2).

**VIDEO 2.** Clip showing MIMIT telecollaboration in case 14. The first part of the video was taken in Boston, Massachusetts, showing that the instructor collaborated with the local neurosurgeon for an endoscopic fenestration of the trapped temporal horn. The second part of the video was captured by the LVP station at the same time in Jingzhou, Hubei, China, showing clear and almost instantly updated marks on the endoscopic view. © Xiaolei Chen, published with permission. Click here to view.

The instructor used an iPad connected to 4G internet service. The linear distance between the local and remote sites in this case was the longest in our study (11,923 km). The latency was 230 msec, which was notable but still acceptable.

Case 17

Case 17 was the first case for us to test our MIMIT system on 5G mobile internet. An endoscopic third ventriculostomy (ETV) with pineal region tumor biopsy was successfully performed using the MIMIT system. The local surgeon was in Beijing, while the instructor was in Sanya, Hainan, China. The distance between these two sites is 2489 km. With 5G high-speed mobile internet, the average latency was as low as 23 msec (Fig. 5A). The audio and video delay was simply not perceptible.

**Video Composite Latency**

Video composite latency analysis was performed with the data calculated by our millisecond clock program (Fig. 5A). The local station to remote station video latency averaged 184.25 msec (range 160–230 msec) with 4G mobile internet and significantly lower (23.25 msec, range 20–26 msec) with 5G internet. Of the 20 telecollaboration procedures that have been successfully completed, the shortest straight-line distance was 0.1 km (same building, different rooms), and the longest distance was 11,923 km (Boston, Massachusetts, to Jingzhou, China). In the statistical graph (Fig. 5B), we can see that the latency increases with the straight-line distance. The delay is mild but still perceptible. After we started our MIMIT system over 5G internet, there was a noticeable drop in latency. Despite the distances involved, video latency did not significantly interfere with the surgical procedures. The relationship between latency, distance, and network connection is shown in Table 1 and Fig. 5B.

**Setup and Disassembly**

The LVP workstation is encased in a single conventional computer case, which makes the setup and disassembly very easy. Setting up the LVP station and breakdown at the end of a case took less than 5 minutes. For the remote site, because we use personal mobile devices such as mobile smartphones and tablets, the setup time for the distant station consists only of starting our telecollaborative app and logging in to the system, which takes less than 1 minute. Surgical procedure times were not believed to be significantly affected by the use of the MIMIT system.

**Clinical Implementation Analysis**

MIMIT was used throughout the endoscopic procedures, without unacceptable interaction delay or obstacles affecting communication between the two sides. Although noticeable video and audio delays occasionally happened when we used a 4G connection, the internet connection was never lost during the procedures. There were no hardware failures or surgical complications. Each participant strongly agreed that the system was very helpful for the successful implementation of surgery and professional real-time guidance. Up to the last follow-up evaluation, no technically related complications had been recorded. Before the use of our system, many endoscopic operations could not be performed in local hospitals, even if the relevant endoscopy equipment in local hospitals was complete.

**Discussion**

In China, high-end medical resources are unequally distributed. Most experienced neurosurgery specialists usually work in metropolitan areas along the east coast, such as Beijing, Shanghai, or Guangzhou. There are huge gaps between these metropolitan areas and inland cities in west China, both in medical technology and in the number of neurosurgical specialists. In recent years, with economic development, more investments in medical equipment are possible for inland cities. Hence, the gap in new equipment between the two regions has been gradually closed. However, the complexity of neurosurgical execution cannot be easily conveyed by only purchasing new equipment. Well-trained, experienced neurosurgeons are essential. In our study, the full set of neuroendoscopic equipment is available in all local hospitals. Unfortunately, most neurosurgeons in local hospitals have limited experience in neuroendoscopic procedures. This situation necessitates the development of technologies to geographically extend the reach of expert neurosurgeons. Although traditional remote robotic surgery has expanded the scope of geographic intervention for surgeons, many shortcomings remain in the application of robotics in neurosurgery, such as expensive investment, delayed movement-related safety issues, and the need for skilled robotic surgeons, which limit its neurosurgical use. In recent years, remote interactive systems have developed rapidly, allowing surgeons to conduct long-distance, real-time surgical guidance, which plays a vital role in surgeon training and telecollaborative complex surgical procedures.

For the MIMIT system we developed, the hardware is inexpensive and the system has proven to be technically feasible and helpful for improving local medical services as well as skill-building for local neurosurgeons. Theoretically, endoscopic, microscopic, and endovascular procedures, which can all export video signals, are ideally suited
to the implementation of our MIMIT technology. In our system, the LVP software is commercially available, while the remote instructor app is free and downloadable in the iOS or Android app store. The local site composite video can be viewed using either a HoloLens (holographic display panel) or an inexpensive standard PC panel monitor. This feature makes our system more flexible for different medical centers and different procedures. For example, during future possible microsurgical or endovascular procedures, use of a head-mounted HoloLens may not be possible, but a simple panel monitor can easily take its place.

We used our MIMIT system to successfully perform 20 telecollaborative neuroendoscopic procedures. Compared with previously reported remote interactive systems, in our system we objectively and precisely evaluated the composite video delay of all 20 procedures. The distance between the two sites where we perform long-distance, real-time operative interaction ranges from 0.1 to 11,923 km, and the latency of the composite video is 184.25 msec when we use a 4G mobile network. This latency was significantly shortened to 23.25 msec when we used the 5G network in 2019. The 5G network greatly reduces latency and brings a better and safer interactive experience for both participants, which is consistent with previously reported laparoscopic surgery. With the rapid deployment of 5G networks in China, we expect that our MIMIT technology can be used between more centers via this faster network.

For the training of local neurosurgeons, expert surgeons may spend short periods of time providing hands-on demonstration or training in local hospitals. The number of short-term surgical trips has increased dramatically over the past 30 years, but the lack of emphasis on training and the frequent absence of follow-up have led to criticisms of the short-term trip model. Although less experienced surgeons may alternatively visit the more experienced expert short-term travel model; the patient no longer needs the physical presence of the experienced expert. We expect that this technology will act as a mentorship bridge, i.e., taking a neurosurgeon with fundamental neurosurgical skills and providing real-time feedback to coach them toward true expertise.

Our ongoing efforts are underway to build a smart online case/mission recruitment and distribution system, as well as an online rating/comment system for both local neurosurgeons and remote instructors. We believe that the MIMIT system allows for real-time, long-distance, remote collaborative cases in 1 day and collect enough payments. For the local neurosurgeons, interactive telecollaboration systems such as the MIMIT serve as a bridge, providing new skills to local surgeons who are already generally trained for basic neurosurgical skills. They can gain not only firsthand operative experiences but also hands-on demonstrations from experts. In addition, their payments for telecollaboration can serve as a motivation. Lastly, the telecollaboration service company in our MIMIT system designates 50% of the payment for hardware and online platform maintenance. The hardware of the LVP station and a HoloLens cost approximately RMB 30,000 yuan ($4743 USD), which is not expensive. The local hospital can easily cover this part of the cost. However, the development of the MIMIT system, including hardware and software development, took 6 months and cost about RMB 800,000 yuan (about $126,000 USD). For maintenance, it costs about RMB 25,000 yuan ($4000 USD) per month for the rental fee of a web server and relevant cost of labor. The development cost and the later maintenance fee are first covered by a company (Guangzhou Jincheng Airui Technology Co., Ltd.). Like most companies providing an internet-based service, such as Uber, it is reasonable for the company to take 50% of the payment to reimburse the previous development and later maintenance costs. It is inexpensive for the local hospital to obtain the LVP hardware and start the business. The company also has ways to balance the development and maintenance investment in the long run, making the MIMIT system sustainable. Hence, our business model makes a win-win situation possible for the patients, local neurosurgeons, experts, and the online telecollaboration platform company.

Our MIMIT technology is not meant to replace standard neurosurgical training, but instead acts as a complementary method that facilitates mentoring without the physical presence of the experienced expert. We expect that this technology will act as a mentorship bridge, i.e., taking a neurosurgeon with fundamental neurosurgical skills and providing real-time feedback to coach them toward true expertise.

Our ongoing efforts are underway to build a smart online case/mission recruitment and distribution system, as well as an online rating/comment system for both local neurosurgeons and remote instructors. We believe that some basic concepts of successful online businesses, such as Uber or Facebook, can be carefully adopted for the redistribution of medical expertise and relevant resources in China. Future issues facing the widespread adoption of digital telecollaboration systems include reimbursement and liability, as well as rigorous assessment of the impact on patient outcomes.

Conclusions

The MIMIT system allows for real-time, long-distance telecollaborative neuroendoscopic procedures and surgical training through a commercially available and inexpensive system. It enables remote experts to implement real-time, long-distance intraoperative interaction to guide inexperienced local surgeons, thus integrating excellent medical resources and possibly promoting both diagnosis.
and treatment. Moreover, it can popularize and improve neurosurgical endoscopic technology in more hospitals to benefit more patients, as well as more neurosurgeons.

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References


Disclosures

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author Contributions

Conception and design: Chen. Acquisition of data: Chen, S Zhang, Li, J Wang, Q Wang, H Zhang. Analysis and interpretation of data: Zhao, Xiong, Gan, J Zhang. Drafting the article: Chen, S Zhang, Zhao, Gan. Critically revising the article: Chen, S Zhang, Li, Gan, Xu. Reviewed submitted version of manuscript: Chen, Xiong, Gan, J Zhang. Approved the final version of the manuscript on behalf of all authors: Chen. Study supervision: Chen.

Supplemental Information

Videos


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