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Efficacy of a High-definition Three-dimensional Exoscope in Simultaneous Transcranial and Endoscopic Endonasal Surgery: A Case Report

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Abstract

Owing to recent advances in medical optical technology, a high-definition (4K) three-dimensional (3D) exoscope has been developed as an alternative tool to using conventional microscopes for microscopic surgery, and its efficacy for neurosurgery has been reported. We report a case who underwent simultaneous surgery aiming for en bloc resection of an anterior skull base malignancy with concurrent exoscopic transcranial and endoscopic endonasal approaches using a 4K 3D exoscope. The patient was a 76-year-old woman who underwent en bloc resection for an anterior skull base olfactory neuroblastoma 13 years ago. After confirming the recurrence of progressive olfactory neuroblastoma, tumor resection was again decided to be performed. As with the first procedure, surgery was performed in an en bloc manner, using both transcranial and endonasal approaches. Exoscope provided enough space above the surgical field to allow us to perform transcranial and endonasal surgeries simultaneously. Moreover, the surgeons could maintain a comfortable posture throughout the procedure, and total tumor removal was successfully achieved without any abnormal event. To our knowledge, this is the first report of the introduction of an exoscope aiming for en bloc resection of an anterior skull base malignancy while performing simultaneous surgery with both transcranial and endonasal approaches. We believe that the more cases are accumulated, the more efficacy of a 4K 3D exoscope will be elucidated.

Keywords: exoscope, endoscope, en bloc resection, malignancy

Introduction

With recent advances in medical optics technology, the exoscope has been developed as an instrument to replace traditional microsurgery. ORBEYE (Olympus, Tokyo, Japan) is an exoscope that can display high-definition (4K) images on a three-dimensional (3D) monitor and is known to provide a safer and more accurate microsurgery than a conventional microscope.[1-3)]

There have been many papers on the use of a 3D exoscope for neurosurgery, and several effective points have been reported. One benefit is that the surgeon can operate in a comfortable position, even in situations where the 3D exoscope is tilted at an extreme angle.[4)] Another advantage is that spatial restrictions over the surgical field are lessened, and so access is greatly improved.[1,5)] While other several efficacies have been reported, surgery using an exoscope has not yet become widespread, and its use has not been fully accepted.[1)]

For the removal of malignant skull base tumors originating from the extracranial sinonasal area, such as olfactory neuroblastoma, the recommended procedure has been en bloc, with a normal stump for radical resection. Hence, head and neck surgeons create a surgical margin via a

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Fig. 1 Preoperative post-gadolinium enhanced MRI.
The recurring tumor originated from the anterior skull base extending to the intracranial and the endonasal cavity. A, axial image; B, coronal; C, sagittal image.
MRI: magnetic resonance imaging

transfacial approach, or an endoscopic endonasal approach, and neurosurgeons create a skull base osteotomy line from above (cranial side), following a craniotomy. The surgical techniques and steps are quite complicated and require a relatively long time.[6)]

In addition, in resecting anterior skull base malignancies, surgeons need to confront the anterior skull base so as to create the osteotomy line of the anterior skull base accurately. With conventional microscopes, surgeons need to tilt the visual axis of the microscope considerably, resulting in an uncomfortable posture. Furthermore, since the relatively large body of the surgical microscope is positioned just above the surgical field, it is not feasible for both head and neck surgeons, and neurosurgeons, to perform simultaneous surgery using the transcranial approach with the microscope, and the endonasal approach with an endoscope. Since the transcranial approach and the nasal approach are performed consecutively, the total operation time is relatively long.

Here, we report a case who underwent simultaneous surgery aiming for en bloc resection of an anterior skull base malignancy with concurrent endoscopic endonasal and exoscopic transcranial approaches using a 4K 3D exoscope. Due to the improved space availability over the surgical field, its ergonomic feature enabled us to achieve it successfully.

A written consent form from our participant was obtained.

Case Report

A 76-year-old woman underwent en bloc resection for an invasive anterior skull base neuroblastoma 13 years ago. The postoperative course was uneventful with no radiation treatment. Seven years after the initial onset, she experienced local tumor recurrence at the original site and underwent second radical resection with forearm flap reconstruction. Six years later, she experienced sudden nasal bleeding and presented at the outpatient clinic of the Department of Otolaryngology-Head and Neck Surgery. A biopsy was performed via the endonasal approach, and tumor recurrence was again diagnosed. Her consciousness scores were 1 on the Japan Coma Scale and 15 on the Glasgow Coma Scale (E4V5M6), with no abnormal neurological findings. Her preoperative cognitive function test scores were 28 points for Mini-Mental State Examination and 29 points for Hasegawa's formula. Contrast-enhanced magnetic resonance imaging (MRI) showed a homogeneously enhancing, multi-lobular large tumor originating from the anterior skull base, which compressed the left frontal lobe and extended into the nasal cavity (Fig. 1).

Operation (Fig. 2)

Under general anesthesia, a tracheostomy was performed, and the head and neck surgeons started the endoscopic endonasal approach, whereas the neurosurgeons commenced the exoscopic transcranial approach at the same time. In the transcranial approach, the previous coronal skin incision was incised, and the plastic surgeons first secured the blood flow in the radial artery graft, which is the pedicle of the previous forearm flap, while preserving the blood flow. The neurosurgeons then performed the craniotomy along the previous craniotomy margin and first approached a tumor that had recurred from the left frontal fornix to the anterior skull base. Using the navigation system, the dura mater was incised on the lateral and medial sides of the tumor, a cortical incision was made, the white matter was excised to prevent it from entering the tumor, and the normal dura was reached at the lateral part of the anterior skull base. While making an incision, the tumor margin could be obtained with the dura mater attached to the posterior edge of the sphenoid bone plane. With the endoscopic nasal approach, an osteotomy from the nasal cavity reached the anterior skull base simultaneously, and the tumor mass was successfully resected in an en bloc manner. Additionally, a small tumor

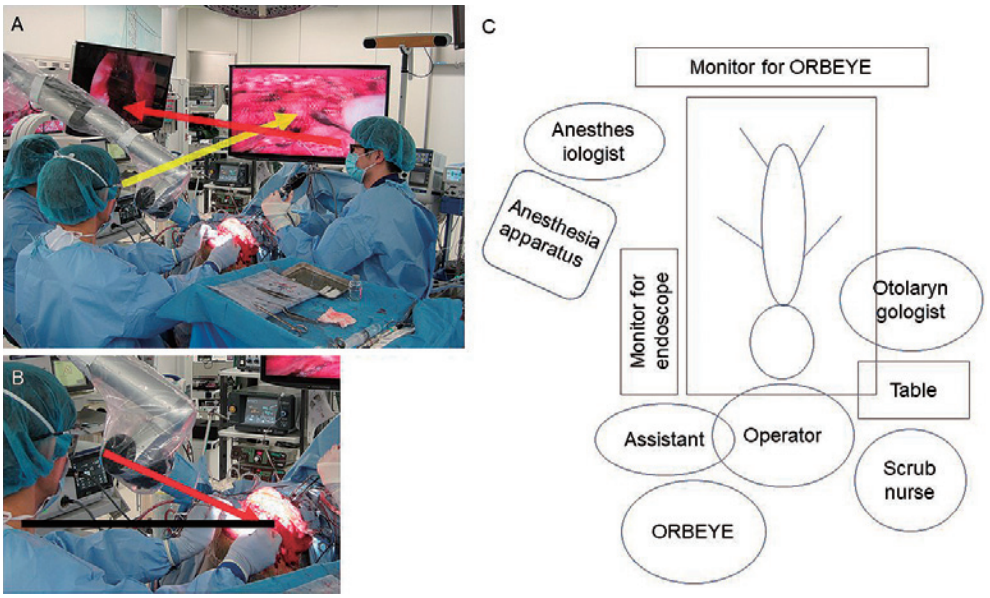

Fig. 2 Intraoperative scene.
A. The visual axis of the neurosurgeon (yellow arrow) and that of the head and neck surgeon (red arrow). Both surgeon's postures are upright, and there was no interference between them.
B. The red arrow is the visual axis of the ORBEYE, which is at an acute angle to the horizontal line (black line), indicating that the visual axis is tilted considerably.
C. Location of the surgeons, staff, and instruments in the operating room.

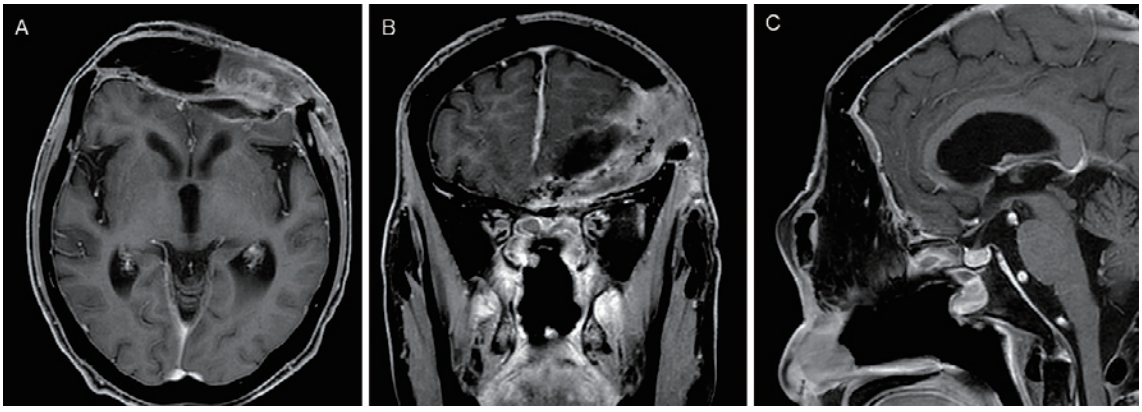

Fig. 3 Postoperative post-gadolinium enhanced MRI 2 months after en bloc resection.
The tumor was completely removed. There was no recurrence.
MRI: magnetic resonance imaging

that had recurred on the right frontal skull base was removed. For reconstruction, the watertight closure for the dural defect was performed using the femoral fascia, the rectus abdominis myocutaneous was flap harvested at the same time from the left abdomen and transplanted to the reconstructed part of the dura, and the skin was sutured to complete the operation. The total operation time was 12 h and 55 min, and blood loss during the surgery was 707 mL.

Postoperative course

The patient tolerated the surgery well and had no new neurological deficit. Histopathological findings were compatible with the recurrence of olfactory neuroblastoma. She underwent postoperative radiation therapy (66 Gy/33 fr) and was discharged 2 months after the operation with a Karnofsky Performance Scale score of 90. Two months after the operation, an MRI showed no recurrence of the tumor (Fig. 3).

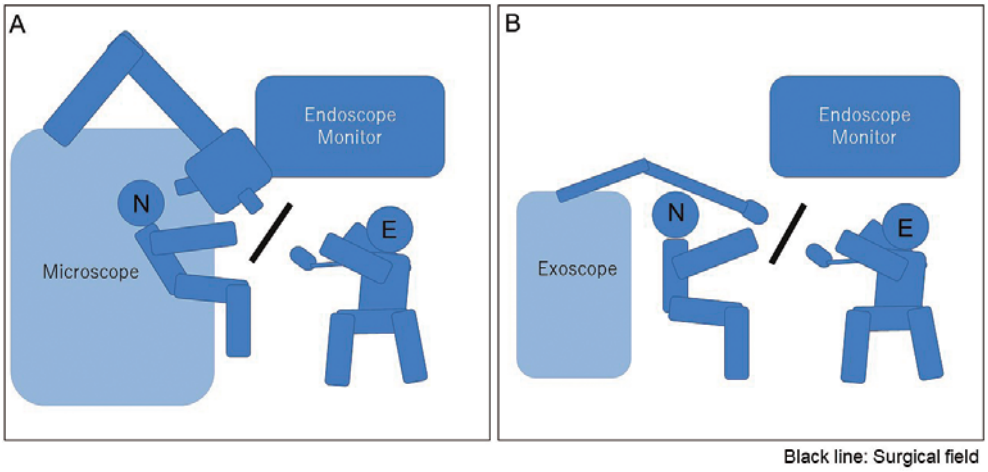

Fig. 4 Illustration of interference between the neurosurgeon (N) and the head and neck surgeon (E).
(A) Microscope and endoscope surgery. A conventional microscope tends to hide the endoscope monitor and to hinder the head and neck surgeon's movement. To confront the anterior skull base lesion, the visual axis needs to be tilted significantly. Using a conventional microscope, the neurosurgeon's posture is awkward.
(B) Exoscope and endoscope surgery. Replacing the conventional microscope with an exoscope provides space over the surgical field, improving the positions of both surgeons. The neurosurgeon maintains an upright, comfortable position even while operating in a relatively vertical surgical field.

Discussion

To the best of our knowledge, this is the first report using a 4K 3D exoscope to resect an anterior skull base malignancy, with both the transcranial and endonasal approaches being performed at the same time. These procedures are normally undertaken consecutively, with the transfacial/endonasal approach first, followed by the transcranial approach, resulting in a long operation time. It is ideal to undertake both approaches at the same time, but due to space restrictions on surgeons from the equipment, this has proven to be unworkable in the past.

Takahashi et al. mentioned the possibility of using an exoscope, instead of a conventional microscope, to achieve simultaneous surgery, in this case for transnasal endoscopic surgery and a craniotomy for Turkish saddle lesions.[1] There have also been reports of intracranial operations performed simultaneously using an exoscope and an endoscope in the same craniotomy field.[7] Space above the surgical field was created by utilizing an exoscope instead of a conventional microscope, and an endoscope could then be introduced into the same surgical field at the same time.

In the case reported here, by using an exoscope for the anterior skull base lesions, there was more space than with a conventional microscope, and simultaneous surgery could be performed without interference. Clearly, the introduction of an exoscope for this surgery proved to be effective (Fig. 4).

In approaching the anterior skull base lesions, the microscope's visual axis has to be tilted considerably. With conventional equipment, this forces the surgeon into an uncomfortable position for the manipulation (Fig. 4). They are forced to be in an uncomfortable posture that extended their arms in the case using a conventional microscope.[8] Iwata et al. reported the efficacy of an exoscope as a way to perform surgery comfortably, in an upright posture, for dural arteriovenous fistula of the anterior skull base.[9] In the present case, though we should tilt the visual axis at the surgical procedure for the anterior skull base lesion, we did not need to decline our postures. An exoscope permitted us to perform stable microsurgery in a comfortable posture regardless of the angle of the operative visual axis.[8] The surgical procedure for the anterior skull base lesion took a relatively long time, but the operation could proceed uneventfully, with no awkward positioning forced for surgeons (Fig. 4). The actual operation time was 12 h and 55 min, which was still a relatively long time. It was a recurrent case, and plastic surgeons also participated in the reconstruction, needing to reconstruct using a rectus abdominis myocutaneous flap. This is one of the reasons for the long surgical time, although the time from skin incision to tumor removal completion was no more than 5 h, which is a relatively short period. By accumulating similar cases of simultaneous surgery using the transcranial and transfacial/endonasal approaches, operation time is expected to lessen.

Some drawbacks using an exoscope have been reported. One major point is that comfortable stereoscopic viewing using 3D glasses itself cannot be easily achieved at first and can cause the surgeons' strain, for example, headache, eyestrain, and other physical discomfort.[10,11] These drawbacks are expected to be relieved by the further experiences for the surgeons and next-generation glasses and

display systems.[11]

To the best of our knowledge, this case was the first surgery following the introduction of an 4K 3D exoscope at our hospital. It has been reported that the exoscope has a relatively fast learning curve and is relatively easy to master.[12] It is thought that the further use of the 4K 3D exoscope should shorten the operation time for similar surgeries. In this way, we hope that the exoscope will provide the opportunity to reduce the invasiveness of en bloc resection for malignant skull base tumors.

Conclusion

We presented a case that successfully resected a recurrent anterior skull base malignancy using a 4K 3D exoscope, in which transcranial and endonasal approaches could be performed simultaneously, while surgeons keeping comfortable postures. The effectiveness of an exoscope could be realized from the viewpoint of ergonomics, less invasiveness. We believe that the more the surgeon becomes familiar with an exoscope, the more the efficacy of an exoscope will be clarified.

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Conflicts of Interest Disclosure

All the authors have no conflicts of interest.

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