CASE REPORT

Mismatch between Augmented Reality Navigation Images and Actual Location of a Cauda Equina Tumor : A Case Report

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Abstract : Background : Augmented reality navigation is the one of the navigation technologies that allows computer-generated virtual images to be projected onto a real-world environment. Augmented reality navigation can be used in spinal tumor surgery. However, it is unknown if there are any pitfalls when using this technique. Case presentation : The patient in this report underwent complete resection of a cauda equina tumor at the L2–L3 level using microscope-based augmented reality navigation. Although the registration error of navigation was <1 mm, we found a discrepancy between the augmented reality navigation images and the actual location of the tumor, which we have called "navigation mismatch". This mismatch, which was caused by the mobility of the spinal tumor in the dura mater, seems to be one of the pitfalls of augmented reality navigation for spinal tumors. Conclusions : Combined use of intraoperative ultrasound and augmented reality navigation seems advisable in such cases. J. Med. Invest. 71 : 174-176, February, 2024

Keywords **:** *augmented reality, spinal tumor surgery, microscope-based navigation, pitfall*

INTRODUCTION

Computer-assisted navigation technology has been widely used in spinal surgery in recent years (1). Augmented reality (AR) navigation is a type of navigation technology that allows computer-generated virtual images to be projected onto a real-world environment. In AR navigation, anatomical structures, including the dura mater, vessels, or a tumor, can be marked on preoperative images using specially designed software and then displayed intraoperatively. Use of this technique could improve the accuracy and safety of spine surgery (1-3).

AR navigation technologies have been used for insertion of spinal instrumentation, such as pedicle screws and intervertebral cages, and are described as having higher accuracy than conventional techniques (3, 4). Furthermore, AR navigation has been reported to be useful for minimum invasive and repeat surgery because it enables surgeons to obtain the correct orientation (4, 5).

There are few reports on AR navigation in spinal tumor surgery (2). Carl *et al*. (6) reported 10 cases of intradural spinal tumor that were treated surgically with microscope-based AR navigation. Their experience was that AR navigation afforded good intraoperative visualization of the tumor and surrounding structures in the field of view provided by the head-mounted display. However, although AR navigation can be used in spinal tumor surgery, it has been unclear whether this technique has any pitfalls.

The patient in the present report had a cauda equina tumor at the L2–L3 level. We performed complete resection using microscope-based AR navigation. However, although the registration error was <1 mm, there was a discrepancy between the AR navigation images and the actual location of the tumor, which we term "navigation mismatch". This report describes the intraoperative findings in this case and discusses the possible reasons for this navigation mismatch.

REPORT OF THE CASE

The patient was a 63-year-old woman. She had felt right lower limb pain and numbness since 10 years ago. She visited local orthopedic clinic and was diagnosed as having a cauda equina tumor at the L3 level. She was referred to our department for further examination and treatment. The neurological findings at her first visit indicated pain and numbness at the anterior surface of the right femur. There was no muscle weakness in either leg. All deep tendon reflexes were normal. Magnetic resonance imaging (MRI) of the lumbar spine revealed an intradural tumor at L3 with low intensity on T1-weighted images and slightly high intensity on T2-weighted images (Fig. 1-A, 1-B). The tumor showed diffuse gadolinium enhancement (Fig. 1-C). In view of her mild symptoms, she was treated conservatively with medication. However, her symptoms gradually worsened. MRI, which was performed 10 years after first visit, showed the spinal tumor grew and extended to the L2–L3 level (Fig. 1-D, E). Consistent with the findings on MRI, a computed tomography (CT) myelogram demonstrated the spinal tumor to be at L2–L3. Before surgery, we suspected the tumor to be schwannoma of the cauda equina or myxopapillary ependymoma of the filum terminale. Because she suffered from severe right lower limb pain and numbness, we performed laminectomy at L2–L3 and complete resection of the tumor using microscope-based AR navigation 3 weeks after last MRI evaluation.

Preoperatively, the spinal tumor and dura mater were segmented manually using the MRI and CT myelogram data, the Curve navigation platform (Brainlab AG, Munich, Germany), and Smartbrush software (Brainlab AG). The vertebra lamina

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of L2–L3 were exposed, and the reference array was attached to the L3 spinous process. The point matching surface registration was performed at the L3 lamina. Registration accuracy was measured by placing the pointer tip on L2 and L3. The navigation registration error was <1 mm. AR navigation images of the tumor and dura mater were projected into the microscope view by applying the Brainlab implementation for Kinevo 900 (Carl Zeiss Meditec, Oberkochen, Germany). Under AR navigation, laminectomy was performed at L2–L3 to create sufficient cranio-caudal space for tumor resection. Next, the location of the tumor was checked by intraoperative ultrasound before making an incision in the dura mater. The ultrasound examination demonstrated that the tumor was about 3 cm caudal to the AR navigation image (Fig. 2). After additional laminectomy of L3, the dura mater was incised. The tumor was yellowish, smooth, and encapsulated, arose from one of the cauda equina nerves, and was mobile within the dura mater (Fig. 3). We performed gross total tumor resection and the pathological diagnosis was schwannoma (Fig. 4).

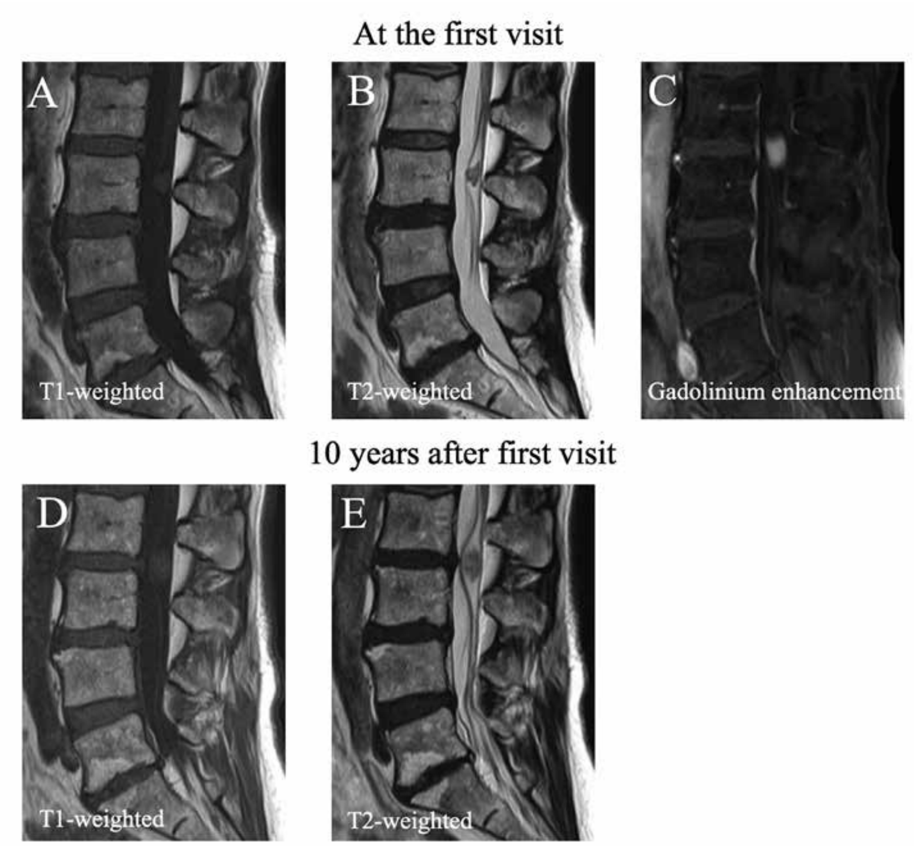

Figure 1. Magnetic resonance images obtained at the first visit (A, B) and immediately before surgery (10 years after first visit, C–E). (C) The tumor shows diffuse gadolinium enhancement. (A, B, D, E) show tumor growth and extension from the L3 to L2/3 level.

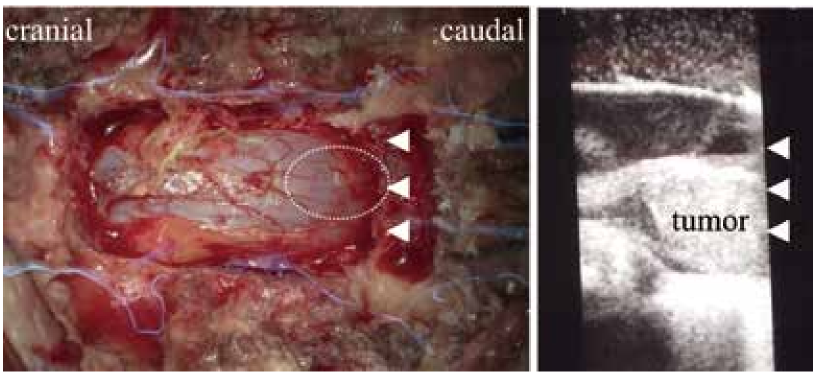

Figure 2. Microscope view after laminectomy at L2–L3 (left). Intraoperative ultrasound (right). Arrowheads show the cranial edge of the remaining lamina at L3. On ultrasound, the tumor was about 3 cm caudal to the augmented reality navigation location (circle).

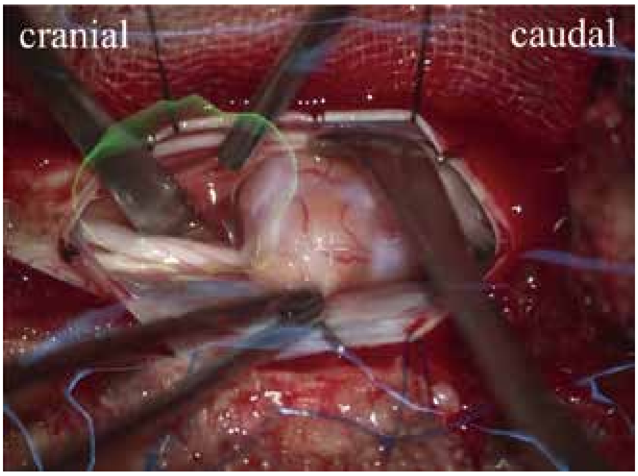

Figure 3. Microscope view after incision of the dura mater showing discrepancy between the augmented reality navigation images and the actual location of the tumor.

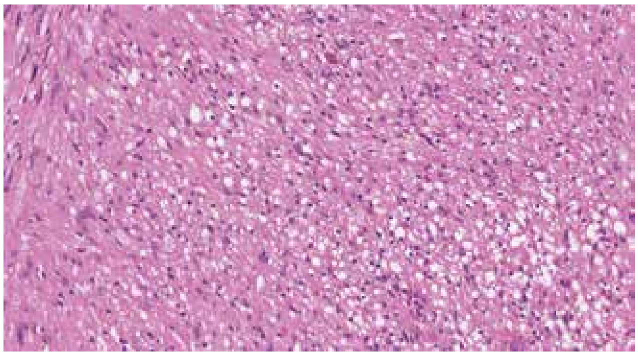

Figure 4. Pathological findings. Hematoxylin-eosin staining of the tumor shows a circumscribed spindle-cell tumor and cellular atypia. The pathological diagnosis was schwannoma.

DISCUSSION

There are few reports on AR navigation for a spinal tumor (2, 6). We have used this technology for a spinal tumor in some patients and achieved good workflow and safety. AR navigation affords good orientation and enables the surgeon to resect a sufficient amount of muscle tissue and perform laminectomy. However, it has been unclear whether this technology has any shortcomings.

In the present case, although the navigation had sufficiently high accuracy, a navigation mismatch was observed. This mismatch was caused by the mobility of the tumor in the dura mater, which has occasionally been reported before, especially for tumors in the cauda equina (7, 8). Navigation mismatch could be a drawback of the AR navigation technique because the images are created from CT/MRI data obtained before surgery. Intraoperative CT could be the solution for navigation mismatch ; however, additional time is required for manual segmentation. Furthermore, intraoperative CT cannot be used for a tumor that cannot be visualized on CT.

In this case, we detected the navigation mismatch using intraoperative ultrasound, which was performed to check that we had obtained enough cranio-caudal space for resection of the tumor. Navigation mismatch could occur when a spinal tumor, especially one that is small or in the cauda equina, is mobile within the dura mater. Therefore, in such cases, intraoperative ultrasound and AR navigation should be used together. Especially, intraoperative ultrasound should be checked before incision of the dura mater.

In conclusion, we have encountered a case in which microscope-based AR navigation was used for complete resection of a cauda equina tumor and a mismatch was found between the AR navigation images and the actual location of the tumor. This mismatch was caused by the mobility of the spinal tumor in the dura mater and seems to be a shortcoming of AR navigation when used in spinal surgery.

CONFLICT OF INTEREST

The authors have no conflict of interest to declare that is relevant to the content of this article.

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