Clinical application of robotic telemanipulation system in neurosurgery

Case report

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The NeuRobot is a telecontrolled microscopic micromanipulator system designed for neurosurgical procedures. The unit houses a three-dimensional endoscope and three robot arms that the surgeon operates without direct contact with the patient. The authors have successfully performed robotics-assisted neurosurgical procedures by using the NeuRobot in a 54-year-old man who had a recurrent atypical meningioma. Following the usual preparation of craniotomy and opening of the dura mater, a portion of the tumor was removed using the NeuRobot with the aid of microscopic observation. No complication related to the use of the NeuRobot was encountered and the patient’s postoperative course was uneventful. Although various kinds of robots have been developed for use in neurosurgery in recent years, a robotic telemanipulation system capable of performing several surgical tasks has not previously been introduced to clinical neurosurgery. This is the first case report in which neurosurgical manipulation by a robotics system is described.

KEY WORDS • brain tumor • robotics surgery • micromanipulator • neurosurgery

Case Report

History. This 54-year-old man, who had undergone surgery two times previously for an atypical meningioma in the left middle fossa, suffered from a headache and exophthalmus on the left side due to tumor regrowth.

Examination. Neuroimaging examinations revealed a 6-cm-wide tumor residing mainly in the left middle fossa and extending to the left cavernous sinus, sella turcica, left orbit, and left infratentorial space; the lesion was accompanied by perifocal edema (Fig. 1). Before surgery, we ob-

Fig. 1. Preoperative Gd-diethylenetriamine pentaacetic acid–enhanced MR images revealing the left temporal meningioma extending to the sella turcica and to the orbital and infratentorial regions. Edema is visible in the left temporal lobe.
tained approval for the clinical application of the NeuRobot from the Ethical Committee of Shinshu University School of Medicine and informed consent from the patient and his family.

Operation. The tumor was removed via the extended frontotemporal approach. After the dura mater had been opened, the slave manipulator, which had been cleanly prepared and fixed by the supporting device (Point Setter; Mitakakohki Co., Ltd., Tokyo, Japan), was introduced into the operative field. The slave manipulator was controlled by a neurosurgeon who watched its progression on a 3D monitor situated beside the operating table (Fig. 2 left). Portions of the tumor were removed using a variety of techniques executed by the system under microscopic observation (Fig. 2 right).

Tumor Dissection. The border between the tumor and brain tissue was partially dissected with the aid of a microdissector installed in the center robot arm while microforceps in bilateral arms retracted adjacent tissue.

Coagulation and Cutting. We used a bipolar coagulation system to coagulate the feeding artery and any bleeding from the tumor surface. Smoke produced during this procedure was aspirated through suction channels in the cylinder. The peritumoral arachnoid membrane was cut with a microscopic sharp hook located in the center arm while retraction was performed using the microforceps in the two lateral arms.

Tumor Removal. Part of the tumor was removed with the aid of a KTP/532 laser, which had a disposable 200-μm Endostat fiber (Laserscope Surgical Systems, San Jose, CA). The KTP laser was contained in the center arm and microforceps were housed in the bilateral arms. Four pieces of tumor (maximum diameter of each piece 7 mm) were obtained (Fig. 3). During exposure to the KTP laser, the surface of the brain was irrigated with saline to avoid heat injury. The procedures that were performed using the NeuRobot were accurate and took only 30 minutes; a total of 7 hours was spent removing the remaining tumor with the aid of the operating microscope. Portions of tumor located in intrasellar and infratentorial regions were left unresected (Fig. 4).

Postoperative Course. The patient’s postoperative course was uneventful, except for a transient bout of sensory aphasia, which was indicative of venous congestion in the left temporal lobe. No sign of infection or any other complication related to the use of the system was encountered.
largely. The swelling of the temporal lobe has decreased. Enhanced MR images demonstrating some residual tumor. The use of the NeuRobot and we confirmed the clinical safety of this system. The NeuRobot is capable of performing complex microsurgical procedures, such as cutting or dissecting, by the center robot arm while surrounding structures were retracted by the two lateral arms. The robot arms are moved within the endoscopic surgical field with three degrees of freedom: rotation, swing of neck, and forward/backward motion. Although movement of the robot arms is limited, it is possible for the NeuRobot to perform many neurosurgical procedures. It can carry various kinds of instruments—each 1 mm in diameter—in its arms, including a microforceps, KTP laser, monopolar coagulator, bipolar coagulator, sharp hook, and dissector.

In the present case, we used the NeuRobot not to achieve total removal of the tumor, but to remove only a superficial portion of it. This was indeed the first step toward clinical use of the NeuRobot and we confirmed the clinical safety of this system. The NeuRobot is capable of performing commonplace neurosurgical procedures such as dissection of the sylvian fissure; however, its intended use is not within a shallow operative field, where conventional microsurgical procedure is safely performed with the aid of an operating microscope. Instead, through its 10-mm-wide cylinder the NeuRobot can perform sophisticated procedures deep within the brain. We believe that the NeuRobot can be useful in the surgical treatment of deep-seated lesions in which classic microsurgical procedures cannot be adequately applied. We will expand the use of this system to the treatment of such lesions.

Conclusions

Robotics-assisted neurosurgery is feasible. This new technology may enhance surgical dexterity. Further developments in this field may have new applications in neurosurgery.

References


Fig. 4. Postoperative Gd-diethylenetriamine pentaacetic acid-enhanced MR images demonstrating some residual tumor. The swelling of the temporal lobe has decreased.

Discussion

Details of the NeuRobot have been reported previously.1–3 The main feature of the system is a rigid insertion cylinder, which is 17 cm long and 10 mm wide. This cylinder houses a 3D endoscope, irrigation and suction channels, and three robot arms. The robot arms are moved within the endoscopic surgical field with three degrees of freedom: rotation, swing of neck, and forward/backward motion. Although movement of the robot arms is limited, it is possible for the NeuRobot to perform many neurosurgical procedures. It can carry various kinds of instruments—each 1 mm in diameter—in its arms, including a microforceps, KTP laser, monopolar coagulator, bipolar coagulator, sharp hook, and dissector. In addition, the three robot arms can be controlled independently. In the surgery featured in this report, various procedures such as cutting or dissecting were performed by the center robot arm while surrounding structures were retracted by the two lateral arms.

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References


The micromanipulator system was developed under a contract from the New Energy and Industrial Technology Development Organization (NEDO) as a part of the National Research and Development Programs for Medical and Welfare Apparatus in Japan. The experiment was supported by the Japanese Ministry of Education, Culture, Sports, Science, and Technology by a Grant-in-Aid for the Development of Innovative Technology (Grant No. 13502).

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