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Technical Note & Surgical Technique

Skull bone tumor resection with intraoperative indocyanine green fluorescence imaging: A series of four surgical cases

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ABSTRACT

Background: Skull bone tumor resection is sometimes difficult, when tumor is hidden under the bone surface or similar to the normal bone in appearance. Indocyanine green (ICG) fluorescence has been used in various surgical fields for visualizing vascular and tumor tissues. This is the first report to show that intraoperative ICG fluorescence is useful for skull bone tumor resection.

Case description: Four patients underwent skull bone tumor resection from June to December 2014. Two patients had Langerhans cell histiocytosis, and the others had hemangiomas. During surgical treatment, intraoperative ICG injection revealed the bone tumors hidden in normal bone tissue in real time. Three of the four tumors were identified as a high intensity area, and the other, a cavernous hemangioma, as an area lacking fluorescent enhancement. Each area was marked and then removed en bloc with an outside margin of 1 cm. On pathological examination, the surgical margin corresponded to the actual margin. In all cases, Postoperative course was uneventful, and there was no tumor recurrence.

Conclusion: Our experience illustrates that intraoperative ICG fluorescence examination might be a useful supplemental method for skull bone tumor resection, especially for tumors extending under the bone surface or similar to normal bone in appearance.

1. Introduction

In tumor resection surgery, distinguishing between tumor and non-tumor tissue during the procedure is a significant challenge. Surgeons try to achieve total tumor resection and preserve normal tissue as much as possible. For successful surgery, operation support systems have been developed, such as intraoperative computed tomography (CT) scanning, magnetic resonance (MR) imaging, neuronavigation system with preoperative imaging, and intraoperative pathology consultation. Indocyanine green (ICG) fluorescence is one of the intraoperative support methods that has been widely used in various surgical fields to visualize vascular and tumor tissues in real time [1,11,15].

Skull bone tumors account for 4.12% of all bone tumors, and if the upper jaw, nasal cavity portion, and the lower jaw are included, it is up to 7.41% [18]. Tumors must be removed when malignancy is suspected, when there is growth, or when the tumor is symptomatic. In surgical treatment, total tumor resection is required, and in benign tumors it is desirable to minimize normal bone defects for cosmetic and functional reasons. However, it is sometimes difficult to define the tumor margin by the naked eye during the procedure when the tumor is hidden in the bone cortex or is similar to normal bone.

This is the first report to show that intraoperative near-infrared (NIR) imaging with indocyanine green (ICG) fluorescence is useful for skull bone tumor resection for visualizing bone tumor hidden in normal bone tissue.

In the present report, four patients underwent surgical treatment for skull bone tumors at the Department of Neurosurgery, Nakamura Memorial Hospital and Takikawa Neurosurgical Hospital from June to December 2014. Two patients had Langerhans cell histiocytosis, and the others had hemangiomas. All patients underwent X-ray, CT, and MR imaging before and after the operation. The operations were performed under general anesthesia. Skin incision and periosteal elevation were performed so that the tumor lesion and surrounding normal bone surface could be sufficiently exposed. After visual inspection, palpation and neuronavigation measurement, ICG dye, 0.2 mg/kg, was injected into a peripheral vein as a bolus. The fluorescence image was recorded using a surgical microscope (OPMI Pentero, Carl Zeiss) equipped with a fluorescent 700–780 nm light source and 820–900 nm filter. ICG

Abbreviations: ICG, Indocyanine green; CT, Computed tomography; MR, Magnetic resonance; NIR, Near-infrared; H&E, Hematoxylin and eosin stain.

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fluorescent contrast area was marked during NIR imaging time and then the area was removed en bloc with an outside margin of 1 cm. After craniotomy, repeated dose of ICG was performed to confirm no residual tumor presence. On postoperative pathological examination, each bone operculum was cut 0.4–0.6 cm and the slices were stained with hematoxylin and eosin. The tissue type of the tumor was diagnosed, and the boundaries of tumor and normal bone tissue were identified to evaluate whether the surgical margin corresponded to the actual margin. Furthermore, side effects of ICG were also evaluated.

A series of four surgical cases is presented, and the use, limitations, and future prospects of intraoperative ICG fluorescence imaging for skull bone tumors are discussed.

2. Case reports

2.1. Case 1

An 11-year-old boy was seen at our hospital complaining of a solitary, painful focus at the left frontal region. A mass lesion was observed at the left frontal skull bone, a part of which had osteolysis on CT. T2-weighted MR imaging showed that a tumor invaded up to 2.8 cm into the bone diploe in a spindle shape (Fig. 1A–C). During operation, after peeling off the periosteum, only a 1.2-cm tubercle lesion was exposed on the skull bone surface, the central part of which showed partial necrosis and needed coagulation for bleeding. A large part of the tumor had spread under the cortical bone surface and could not be distinguished by the naked eye (Fig. 1D). After administration of the ICG fluorescence dye, except for the necrotic part, the bone tumor including the hidden lesion was gradually seen as a high intensity circular area of 3 cm (Fig. 1E). The tumor began to be contrasted from 10 s and was most strongly enhanced at 26 s after injection. The enhanced area was corresponded to preoperative radiological tumor imaging. The tumor was resected en bloc with a margin of 1 cm beyond the enhanced area. Postoperative CT and MR imaging showed that no tumor remained. On pathological examination, the diagnosis was Langerhans cell histiocytosis (Fig. 1F), and the boundary between tumor and normal bone tissue was located 0.9-cm inside of the resected bone plate. Total tumor resection was confirmed, and because there had been only a single lesion, radiation and chemotherapy were not performed. Postoperative course was uneventful and there were no side effects of ICG. At 1.5-year follow-up, there was no tumor recurrence.

2.2. Case 2

A 7-year-old boy became aware of a palpable mass with tenderness at the left frontal region after head trauma. CT and MR imaging revealed a skull bone tumor of 2.9 cm in the left side of the frontal bone, which extended into the lamina interna of the skull bone (Fig. 2A–C). During surgery, a 1.7-cm, white, nodular lesion was exposed on the bone surface. However, the hidden part of the tumor covered by bone cortex could not be recognized on macroscopic inspection (Fig. 2D). After ICG administration, the exposed nodular portion on the bone surface and the hidden portion under bone cortex were both enhanced, showing a 3-cm lesion (Fig. 2E). From 11 s after ICG injection the lesion began to light, and the contrast effect reached its peak at 23 s. The enhanced area corresponded to preoperative radiological imaging. The tumor was resected with a margin of 1 cm beyond the enhanced area. In postoperative CT and MR imaging there was no tumor residual. On histopathological examination, the diagnosis was Langerhans cell histiocytosis (Fig. 2F), and the boundary of the tumor tissue was located 0.8-cm inside of the resected bone operculum. Since the tumor was a single nodular lesion, radiotherapy and chemotherapy were not given.

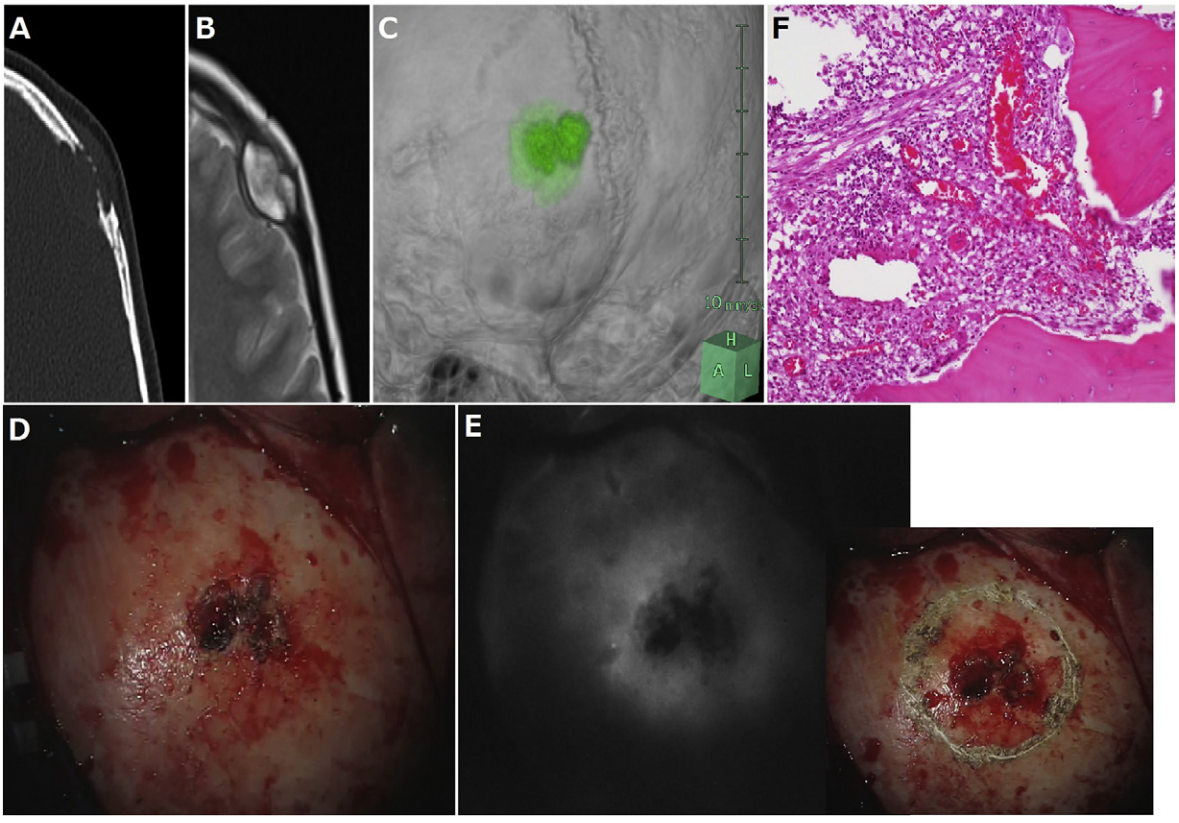

Fig. 1. Case 1, Langerhans cell histiocytosis. Axial CT bone window (A) shows an osteolytic lesion at the left side frontal bone. Axial T2-weighted MR image (B) shows a 2.8-cm mass in the bone plate. Fusion 3D image with CT scan and MR imaging (C) shows that a large part of the tumor is buried in bone cortex. Only a part of the tumor exposed on the skull bone surface is bleeding and needed coagulation (D). ICG fluorescence image shows the hidden part of the tumor in the bone plate. The outline of fluorescent area was traced with monopolar coagulation (E). Microphotograph (F) shows Langerhans cells and lymphocytes with vascular structures bounded by normal bone tissue (hematoxylin and eosin stain, ×200).