Subependymal giant cell astrocytoma (SEGA) presents as a benign tumor usually centered at the head of the caudate nucleus and foramen of Monro and is most frequently associated with tuberous sclerosis complex (TSC). The International Tuberous Sclerosis Complex Consensus Conference reported that approximately 20% of patients with TSC have at least 1 SEGA, which can result in obstruction of CSF and hydrocephalus. Other sequelae of SEGA include seizures and occasionally focal neurological deficits. The global prevalence of TSC is approximately 1 million people, suggesting that SEGAs are lesions many neurosurgeons will evaluate and possibly treat during their career.

The management of SEGAs in patients with TSC includes clinical and radiological surveillance; tumors that exhibit growth or clinical symptoms, most often due to obstruction of CSF flow, are considered for treatment. Although craniotomy and microsurgical resection of the tumor have been the mainstay of SEGA treatment for many years, studies have demonstrated a high surgical complication rate, approaching 50% in some studies. Although advances in neuroendoscopic techniques have expanded therapeutic options for the management of intraventricular SEGAs, they can be useful only in a few selected cases.

Over the past decade, the pendulum has swung toward medical treatment with inhibitors of the mammalian target of rapamycin (mTOR), such as sirolimus and everolimus. Large studies have demonstrated a tumor volume reduction of over 50% after medical treatment; however, although mTOR inhibitors are well tolerated, they are expensive and require long-term therapy, with tumor regrowth documented after treatment is stopped. In addition, the acute treatment of obstructive hydrocephalus secondary to SEGA may not be amenable to medical treatment alone. Other treatment strategies, such as radiotherapy, have shown limited efficacy, likely because the slow progression of the disease results in diminished radioresponsiveness. There is also concern for increased risk of secondary malignancies in both children and patients with TSC who may be more susceptible to DNA damage.

**Abbreviations**  SEGAs = subependymal giant cell astrocytoma; TSC = tuberous sclerosis complex.

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Recently, MRI-guided stereotactic laser ablation has been shown to offer the possibility of effective, minimally invasive surgical treatment with a significantly reduced rate of complications for SEGAs and other deep-seated pediatric brain tumors. Dadey and colleagues reported the first case of laser ablation for the treatment of SEGA; however, the long-term efficacy and late-onset complications remain poorly understood. We present the case of a child with TSC and a growing SEGAs who was treated with stereotactic laser ablation on 2 separate occasions. The patient developed adhesions that caused obstruction of the foramen of Monro, which led to a trapped lateral ventricle and obstructive hydrocephalus 9 months after the second ablation.

Case Report
A 5-year-old boy with a history of TSC, epilepsy, and...
autism who had bilateral SEGAs was referred for neurosurgical evaluation from the oncology clinic. Other associated diagnoses related to TSC included a cardiac rhabdomyoma, renal angiomyolipomas, and developmental delay. Although the patient was undergoing immunotherapy with sirolimus, he had a history of poor compliance with the medication. After multidisciplinary discussion, the patient was considered to be a good candidate for laser ablation of the right-sided SEGA, which was significantly larger than the one on the left side. Three months after discontinuation of sirolimus, MRI demonstrated growth of the right-sided SEGA and a stable small left-sided SEGA (Fig. 1A). At this time, the patient underwent stereotactic laser ablation (Visualase, Medtronic) of the right-sided SEGA via a right frontal entry with a Leksell frame (Elekta) in an intraoperative 3-T MRI suite (IMRIS). Subtotal ablation was achieved, without procedural complications (Fig. 1B). After an uneventful postoperative course, the patient was monitored with surveillance imaging.

Despite an initial decrease in the size of the right-sided SEGA, MRI demonstrated significant interval growth of the residual tumor 18 months after the initial ablation. Therefore, the patient underwent a second laser ablation of the residual tumor (Fig. 1C–E). Immediate posttreatment MRI demonstrated near-complete ablation of the tumor but also hyperintensity of the right lateral ventricle on postcontrast FLAIR imaging, consistent with gadolinium extravasation into the ventricle (Fig. 1F). Noncontrast CT scanning the day after the procedure confirmed the absence of intraventricular hemorrhage and that the MRI-demonstrated signal abnormality within the right ventricle was gadolinium. The patient did well and was discharged to home on the 1st postoperative day. He was lost to follow-up after discharge for several months.

Nine months after the second ablation, the patient was evaluated by his ophthalmologist, who noted bilateral papilledema. The patient was referred to neurosurgery, and a repeat MRI demonstrated a significantly decreased size of the right-sided SEGA. Despite this, there was a trapped right lateral ventricle with obstructive hydrocephalus (Fig. 1G and H). Imaging distinguished avidly enhancing tumor laterally from T1-weighted hyperintense but nonenhancing intraventricular adhesions. The patient was treated with endoscopic septostomy (MINOP Modular Neuroendoscopy System, Aesculap) via a left frontal burr hole. This allowed clear visualization of the right foramen of Monro and revealed adhesions obstructing the right foramen of Monro (Fig. 2). Intraoperatively, the intraventricular tissue obstructing the foramen of Monro was clearly distinct from tumor, which was covered with ependyma laterally at the caudothalamic groove. By fenestrating these adhesions, the right foramen of Monro was visualized and appeared patent. As the endoscope was withdrawn through the septostomy into the left lateral ventricle, the left foramen of Monro was also visualized after relieving mass effect from the previously trapped right lateral ventricle. The patient tolerated the procedure well, and was discharged to home on the 2nd postoperative day.

**Discussion**

This case involved the development of intraventricular adhesions that led to hydrocephalus after laser ablation of a SEGA on 2 separate occasions, the second complicated by intraventricular extravasation of gadolinium. This case underscores the importance of long-term surveillance of patients undergoing laser ablation of intracranial tumors, especially periventricular lesions. A complete understanding of the full impact of laser ablation on tumor biology and ependymal surfaces remains unclear. Of note, because of the heat-sink effect of the ventricle, it is common to position the diffusing tip of the laser very close to the ependymal surface for periventricular targets. It is possible that changes in vascular permeability leading to significant intraventricular contrast extravasation in this case contributed to ependymal injury and intraventricular adhesion formation. However, previous reports have noted no significant complications from intraventricular gadolinium. Alternatively, it is possible that adhesion formation was a complication of the heat applied to an intraventricular target during the ablation procedure, independent of gadolinium extravasation. Because postoperative imaging, including noncontrast CT, did not reveal hemorrhage, it is unlikely that intraventricular blood complicated the procedure or led to the formation of intraventricular adhesions.

**Complications of Stereotactic Laser Ablation**

Laser ablation has shown potential efficacy for a number of neurosurgical conditions, including radiation necrosis, drug-resistant epilepsy, primary brain tumors, and...
The potential extravasation of gadolinium into the lateral ventricle may have implications for ventricular adhesion and obstruction. Previous studies have described both the purposeful and accidental administration of intraventricular gadolinium. Nayak et al. reported 2 cases of inadvertent intraventricular gadolinium administration, including the case of 1 patient who received a significant bolus of gadolinium via an external ventricular drain after resection of a meningioma, which led to cerebral edema and seizures. However, other patients have not shown adverse events after intraventricular gadolinium use. The role of intraventricular gadolinium extravasation in adhesion formation and obstruction of the foramen of Monro is unclear. Other possible causes of adhesion formation include unrecognized hemorrhage, thermal damage, or tumor necrosis, but in the current case, the extravasation may have contributed to the complication of delayed hydrocephalus.

Conclusions

This report demonstrates the potential for delayed complications after laser ablation of a periventricular tumor and a possible negative impact of intraventricular extravasation of gadolinium. These results add to the knowledge regarding stereotactic laser ablation of periventricular targets.

References


Metastatic brain tumors. In addition, a variety of pediatric tumors have been suggested as potentially amenable to laser ablation, including deep-seated lesions with high morbidity rates reported after microsurgical resection. Some lesions treated with laser ablation include thalamic tumors, choroid plexus xanthogranulomas, brainstem gliomas, recurrent medulloblastomas, vermian tumors, hypothalamic pilocytic astrocytomas, hamartomas, frontal gangliogliomas, and mesial temporal cavernomas, as well as SEGA. However, reports in the literature of complications following laser ablation remain limited.

Several studies have evaluated the safety of laser ablation (Table 1). Pruitt et al. reviewed 49 procedures that involved use of the Visualase laser ablation system. A total of 11 acute complications (22.4%) occurred, including 4 catheter malpositions, 3 intracranial hemorrhages, 3 cases in which thermal injury led to a focal neurological deficit, and 1 technical malfunction of the system. Hemorrhage after probe placement has been reported in other studies at a rate of 1%–5%. Neurological morbidity has been reported at a rate of 5.8% and catheter malposition at a rate of 1%–2% in a recent review of available reports.

Table 1. Rates of acute complications of laser ablation reported in the literature

<table>
<thead>
<tr>
<th>Complication</th>
<th>Sloan et al., 2013 (n = 10)</th>
<th>Mohammadi et al., 2014 (n = 85)</th>
<th>Haasli et al., 2013 (n = 17)</th>
<th>Jethwa et al., 2012 (n = 20)</th>
<th>Lee et al., 2016 (n = 63)</th>
<th>Pruitt et al., 2017 (n = 49)</th>
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<tr>
<td>Neurological deficit</td>
<td>10</td>
<td>20.6</td>
<td>17.6</td>
<td>12</td>
<td>6.1</td>
<td>17.6</td>
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<tr>
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<td></td>
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<tr>
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<tr>
<td>ICH</td>
<td>10</td>
<td>5</td>
<td>3</td>
<td>6.1</td>
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<td>Infection</td>
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<td>5.9</td>
<td>5.9</td>
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<td>DVT</td>
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<td>2.9</td>
<td>5.9</td>
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<tr>
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<td></td>
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<td>8.2</td>
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<tr>
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<td></td>
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</tbody>
</table>

DVT = deep venous thrombosis; ICH = intracranial hemorrhage.


**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: Bollo. Acquisition of data: Karsy. Drafting the article: Karsy. Critically revising the article: all authors. Reviewed submitted version of manuscript: all authors. Approved the final version of the manuscript on behalf of all authors: Bollo.

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