Distinguishing Meningioma versus Nonlesional Tissue and Predicting Tumor Grade Intraoperatively using Machine Learning and Non-Contact Fluorescence Spectroscopy

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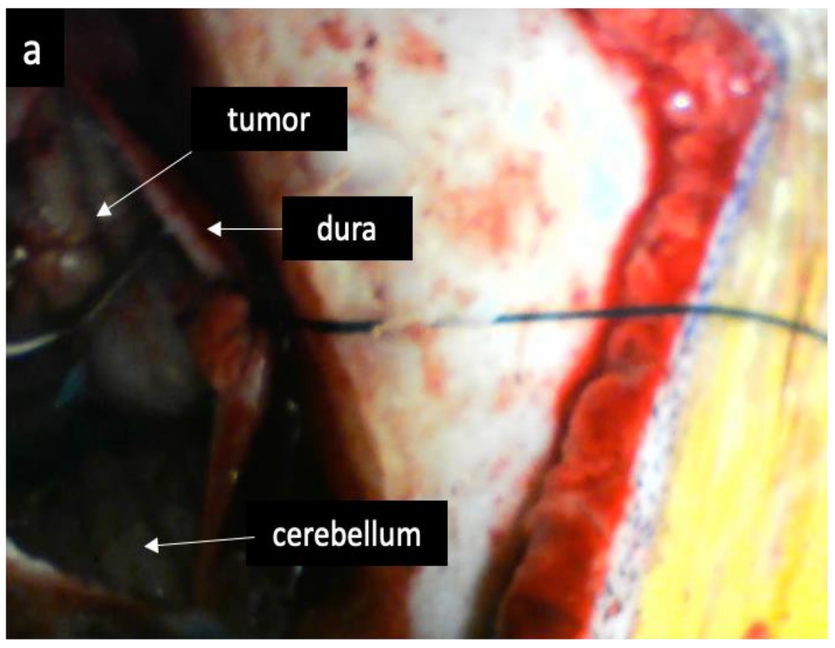
Introduction

The extent of meningioma resection is well-known to influence the rate of tumor recurrence and, in higher-grade lesions, overall survival. Surgical aggressiveness depends on 1) confidence that tissue is indeed pathological, and 2) presumed disease severity, inherently related to the WHO pathologic grade. Unfortunately, the process of sending frozen and permanent sections to confirm lesional tissue is time-consuming, tissue-destructive, effort-intensive, and costly. Our new technology, "TumorID", enables real-time tissue analysis based on laser-induced endogenous fluorescence spectroscopy, and it has shown promising results in differentiating tissue types *ex vivo*. In this proof-of-concept study, our aim is to apply machine learning methods to spectral emission data collected by TumorID *in vivo*, to both differentiate lesional versus normal tissue and predict WHO grade.

Methods

We used TumorID to scan intra-operative, *in vivo* tissue specimens during resection of a torcular meningioma in a 47-year-old female (MRI in **Figure 1**). Ten points were scanned on the tumor, nine on the dura, and eight on the cerebellum (**Figure 2**). The data were retrospectively analyzed. Additionally, based on a previous neural network model trained on *ex vivo* TumorID data, the lesional tissue was predicted to come from a Grade 1 versus Grade 2/3 tumor.



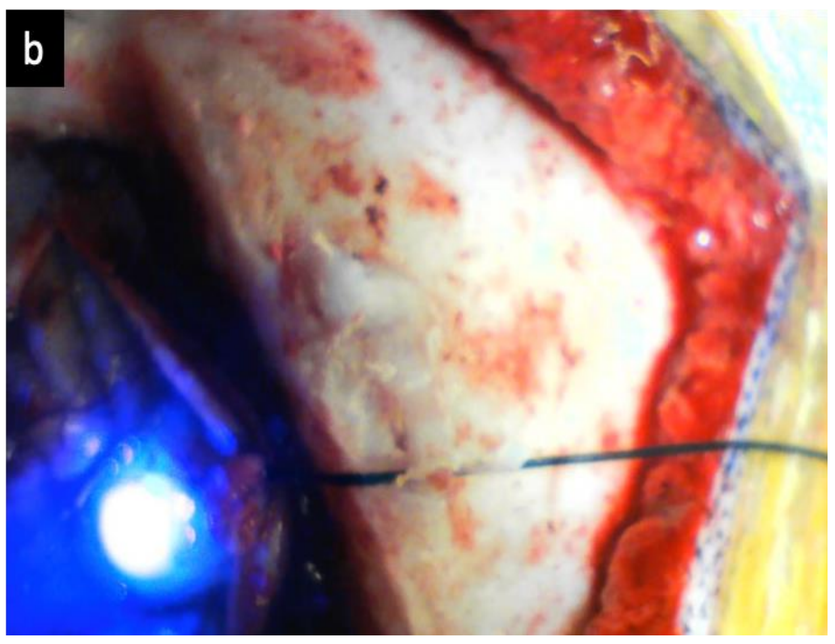


Figure 2. Intraoperative view after dural opening, showing both normal cerebellum and meningioma, a) in standard fashion and b) with TumorID laser focused onto tissue *(note, true spot diameter is 0.75 mm, much smaller than suggested by the camera artifact in this image).*

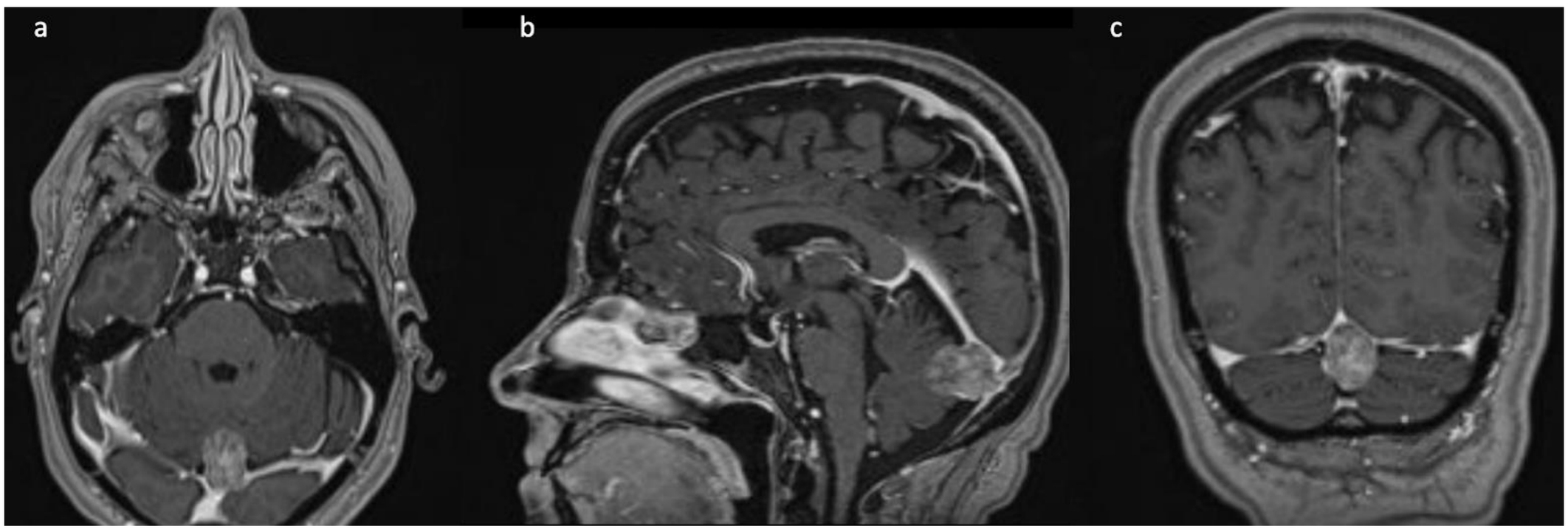


Figure 1. Preoperative T1 contrasted MRI with a) axial, b) sagittal, and c) coronal views of torcular meningioma.

Results

Spectral emission data showed visually distinct patterns for lesional tissue versus dura versus normal cerebellum (**Figure 3**). From wavelengths of approximately 450 to 600 nanometers, the lesional tissue demonstrated a notably higher intensity (**Figure 3, blue line**). Cerebellum and dura were more similar in their lower intensity emissions. The spike around 610 nanometers was artifact from operating room lights. The machine learning model correctly predicted for all 10 scans of the lesion that this was a WHO Grade 1 tumor as confirmed on final pathology. The patient had a gross total resection, with no recurrence at 7-month follow-up MRI.

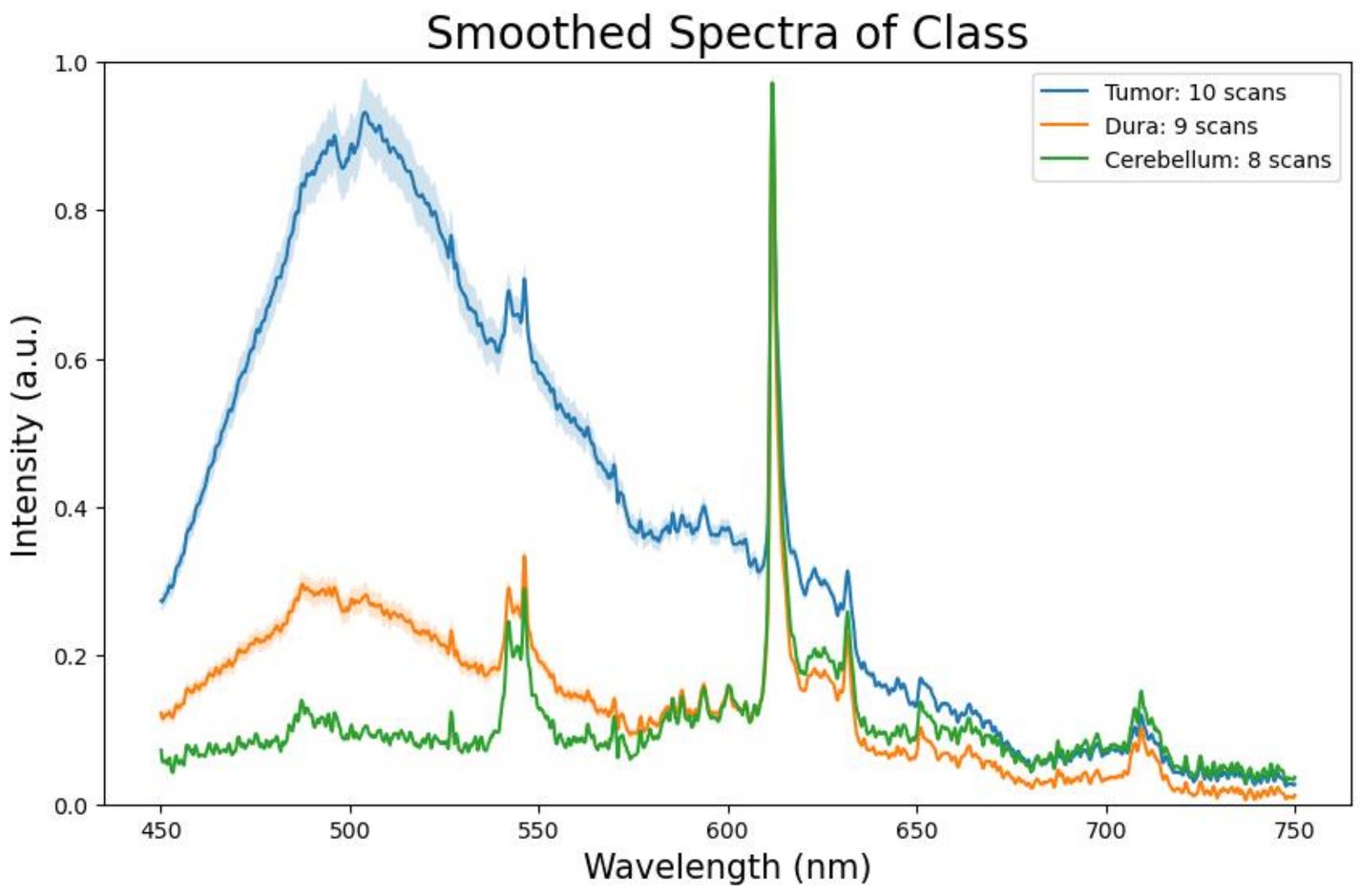


Figure 3. Spectral emission data from intra-operative scans.

Conclusions

In this trial study, TumorID enabled real-time, *in vivo* collection of data that retrospectively allowed differentiation of pathologic meningioma versus nonlesional tissue without requiring tissue destruction or pathologist expertise. With a machine learning algorithm applied to its data, TumorID also correctly predicted WHO pathologic grade *in vivo*. After these results are validated on much larger sample sizes, this tool may allow surgeons to optimize intraoperative decision making based on higher confidence of both lesional tissue and predicted WHO grade, ultimately leading to better patient outcomes.

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