Automatic Segmentation of the Trigeminal Nerve on MRI using Deep Learning

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JULY 12–16 2020 VIRTUAL
JOINT AAPM | COMP MEETING
EASTERN TIME [GMT-4]

INTRODUCTION

The trigeminal nerve is a complicated neurological structure near the skull base whose normal appearance varies significantly between subjects. The complexity of the trigeminal nerve on medical imaging is partly the result of the drastic changes in nerve fiber density as the trigeminal nerve courses from the pons through Meckel's cave [1]. This variation in appearance prevents the effective use of traditional intensity guided automatic segmentation and relies instead on the expertise of the operator [2]. Thus, segmenting the trigeminal nerve for radiosurgery treating trigeminal neuralgia is a difficult and time consuming task with pronounced operator variability.

PURPOSE

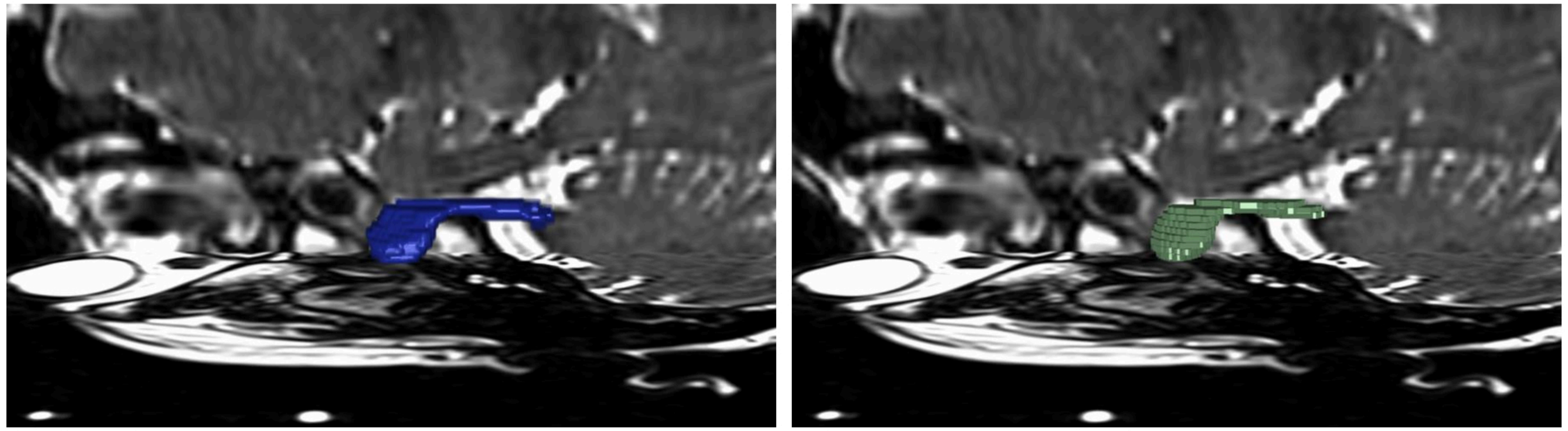
The purpose of this work is to train and test a deep learning based model for robust automatic segmentation of the trigeminal nerve. The trigeminal nerve has an uneven appearance on MR imaging that makes it difficult to minimize operator variability. An automatic segmentation model based on deep learning would remove that variability and could decrease the amount of time spend contouring these structures during treatment planning.

METHODS

1.5-Tesla preoperative T1 and T2-weighted MRI volumes were acquired from 150 patients who underwent stereotactic radiosurgery for trigeminal neuralgia. The T2-weighted image volumes were registered to the T1-weighted image volumes. The trigeminal nerves extending from the pons through the trigeminal ganglion including Meckel's cave were contoured independently by three experts in neuroanatomy and then reviewed for consensus. A 3-D U-net convolutional neural network architecture was trained to perform automated segmentation [3]. Dice coefficient was used to gauge the effectiveness of the model, and binary cross-entropy was used to monitor the progress of model training. 120 volumes were used to train the model, 20 to validate, and 10 to test. In total, the model was trained for a maximum of 250 epochs over a time-span of 10 hours. Early stopping checkpoints were used during training to prevent overfitting.

RESULTS

The Dice coefficients for the training, validation, and test sets were 0.87, 0.82, and 0.81 respectively. The model produces masks with excellent visual agreement to the manually segmented volumes. Below, the manually segmented trigeminal structure on the left in blue, and the automatically segmented trigeminal structure on the right in green. Importantly, the model generated masks do not overlap with brainstem or temporal lobe tissue. The model seems to have the most difficulty in the region immediately superior to the petrous ridge.



CONCLUSIONS

This work suggests that a deep-learning model could be used to perform automatic segmentation of complicated normal-appearing tissue structures near the skull base. Future work will explore the use of this model for automated treatment planning for radiosurgery and percutaneous procedures in trigeminal neuralgia where a mapping of the ganglion within Meckel's cave could be used to avoid nearby venous structures.

ACKNOWLEDGEMENTS

This work is supported by NIH grants P41 EB015894 and P30 NS076408

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