Resection of Pituitary Lesions in a Phantom Model using Concentric Tube Robots with Endoscopic Visualization

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Introduction: Operation at the skull base possesses a multitude of unique challenges for access to and successful treatment of a wide variety of pathology. These include, but are not limited to, a deep operative field and narrow corridor, inadequate lighting at depth, and a suboptimal linear path that avoids vital structures. Use of robotics to address these issues has been limited because of the rigid nature and large size of the systems currently available. To address these problems, we use a robot with a telescoping tool shaft that can bend and elongate called a concentric tube robot. We use this robot for experiments in a phantom model of pituitary adenoma to demonstrate how this unique technology to overcome many of the aforementioned current limitations. This robot is thin, flexible, and is computer driven, which allows for motion scaling, image guidance, and other benefits of robotic surgery.

Methods: The sellar region of a plastic skull model was modified to accommodate a ballistics gel pituitary adenoma model with a maximum diameter of 1.5 cm. The face of the sella was also drilled to simulate that of a standard transnasal endoscopic approach. Visualization and illumination were achieved using a rigid rod-lens endoscope and a suction tube was fixed immediately proximal to the face of the sella. A three-tube nitinol precurved concentric tube robot with a diameter of 1.2 mm was utilized with a ring curette as the end effector. The skull was weighed empty and then the sella filled with ballistic gel of appropriate consistency and weighed again. Covering the sella with rigid plastic represented the diaphragm. The lesion was then maximally resected and the skull reweighed and the percent removal calculated. The time for removal was also calculated. All 20 resections were performed by the same pituitary neurosurgeon.

Results: The system performed well in all 20 runs with an average percent removed by weight of 79.8 5.9%. The average time to complete removal was 12.5 4.1 minutes. There was the expected suggestion of a learning curve, since we noted a trend in the experimental data toward decreased operating times and increased percent resection with increasing number of experiments performed by the surgeon.

Conclusion: Robotic techniques for anterior skull base surgery have the potential to provide myriad benefits especially when considering novel systems, such as that described above, versus those currently commercially available. The percent tumor resected using this system as well as the operating time compares favorably with those currently experienced clinically, even when considering the potential opportunities for enhancement of the early-stage robot prototype used in these experiments. Current ongoing improvements in the system will enable simultaneous delivery of multiple novel end effectors via multiple tubes, tube-end chip cameras, and haptic feedback.