The Use of Teleoperated Concentric Tube Robots for Transsphenoidal Parasellar Surgery

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Congress Abstract

Introduction: Access to the anterior skull base via transsphenoidal routes is employed for a multitude of pathologic entities, the most common being for pituitary disorders. The rise of endoscopy has offered significant advantages over the classical sublabial route. However, significant limitations remain due the largely rigid coaxial constraints of currently available systems. This often prevents access to peripherally located pathology. Similarly, the advent of robotics offers a number of intraoperative advantages such as force and speed scaling, as well as segmentation of pathology on imaging to allow a volumetrically constrained workspace. Again, the size of the currently commercially available robotic actuators is too large and rigid to function via most minimally invasive skull base approaches. We present a new paradigm for robotic anterior skull base surgery.

Methods: We have developed a teleoperated robot, where each surgical instrument is less than 2 mm in diameter. Each manipulator consists of curved, concentric, elastic Nitinol tubes that extend telescopically and rotate at the same time. This causes the overall construct to bend in a complex and geometrically predictable and controllable fashion. We have conducted initial cadaveric feasibility studies as well as image segmentation to determine design parameters for the robot, and constructed a prototype that can simultaneously deliver four manipulators through a nostril. Current actuators include pituitary curettes and graspers. Cameras and light sources are also being developed. Phantom experiments have also been performed. Skull models have been modified with enlargement of the sellae and the placement of SIM-TEST ballistics gel within them to replicate pituitary lesions. The model tumors have then been removed with the robot, and the percent of excision determined by pre-and post-excision weights.

Results: Imaging studies provide a quantitative description of the volume available within the sphenoid sinus for multiple manipulators. The manipulators can be successfully operated on within the spatial constraints. We also present initial evaluation of forces and velocities required for endonasal surgery, and demonstrate that our robot is capable of exceeding both by a factor of 20 or more. Excision of phantom tumor was also quite successful. Resections via two authors (PR and KW) resulted in between 67 and 78% of the lesion by weight being removed. Although there was no specific time constraint to the trials, these were completed in a time which reasonably compared with true operative excision.

Conclusions: At this time, further advances in minimally invasive anterior skull base surgery are meeting with significant technical limitations. Both minimally invasive and robotic techniques offer promise, but are in need of significant advancement for these applications. The novel work described in this study addresses many of these and provides a miniaturized, teleoperated platform with easily scalable operation. Removal of phantom lesions in early pilot studies demonstrated an extent of excision comparable to published clinical studies within a reasonable operating time. This robotic platform also has the flexibility to allow addition of a virtually unlimited number of end effectors (instruments) and is being evaluated for several other intracranial applications.

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