Teleoperation of Concentric Tube Robots for Skull Base Applications: Pituitary Surgery at a Distance?

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Introduction: Teleoperation for surgical procedures and related activities is a long sought goal. This has become progressively within reach with advances in robotics as well as the speed of data transfer between operator and robot. Teleoperation would allow for the widespread dissemination of "expert" operations where personnel and equipment resources may be suboptimal, greatly expand access to advanced medical technology and knowledge worldwide, and present a myriad of training and other educational opportunities. Our laboratory has developed concentric tube robots for skull base surgery that has been described previously. These consist of concentric prebent nitinol tubes with various end effectors that can be precisely controlled by the operator using a hand held haptic device. In this work, the robot was used to resect a phantom pituitary tumor at a remote location (surgeon in Nashville, Tennessee, United States, robot in Chapel Hill, North Carolina, United States) using an Internet-based data link.

Methods: The sella of a plastic skull model was modified to include a 15 mm pituitary tumor. The lesion was represented with ballistics gel mixed to a consistency similar to that of a pituitary tumor, placed in the sella, and covered with a piece of plastic from inside the skull to represent the diaphragm. The robot was fitted with a small curette as well as an endoscope fixed at the face of the sella. The remote location, Chapel Hill, North Carolina, United States, is approximately 800km away from Nashville, Tennessee, United States, where the surgeon was located. Visual and auditory feedback were provided by a Skype video connection. Well-established metrics for the quality of a teleoperation link, including latency and packet interarrival time (IAT) were measured.

Results: Phantom resection experiments were performed at both locations without difficulty. The internet video stream and robot command instructions were transmitted with sufficient speed, and the video with sufficient speed and quality, the fact that the robot was 800km away was essentially imperceptible to the surgeon operator. Because of this, an experienced pituitary surgeon was able to perform the resection task without difficulty. Quantitatively, the average latency for the local procedure was 1.1ms with an IAT of 10ms. For the remote procedure, these numbers were 10 and 10.17ms, respectively. The latency for Skype communication was 20ms.

Conclusion: The potential advantages of teleoperation cannot be disputed, including its application to skull base surgery. Other studies suggest that dissociation between hand-eye movements occurs with a latency of greater than 300ms in teleoperation and issues with intuition/judgment can begin at 100ms. Our results fall well under this and are also similar to experiments using other robotic platforms for teleoperation in non-neurosurgical scenarios. This study demonstrates that teleoperation with our concentric tube platform when used in a phantom pituitary surgery can produce excellent latency times and may be used by the surgeon with relative ease.