MODELING AND SIMULATION FOR FLEXIBLE URETEROSCOPY

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Introduction: The flexible ureteroscope is a small caliber endoscope that serves as an important tool for diagnosing and treating stones, scar tissue and tumors in the ureter and collecting system of the kidney. Presently, surgical planning decisions (e.g., understanding patient-specific calyceal anatomy, identifying the size and location of stones, and scope selection and manipulation) are based on imaging data taken externally via X-Ray fluoroscopy and CT, and internally by a fiber-optics-based system at the tip of the scope. Presently, synthesis of these different (essentially 2D) data modalities into a common mental model is done by the individual practitioner, with no opportunities for patient-specific procedural rehearsal. We report on preliminary work aimed at improving the efficacy of the surgical decisions made by the urologist by using a combination of physical and virtual prototyping in 3D. Specifically, 3D-printing techniques are used to generate, from CT scan data, a physical model of the collecting system (calyces) on which scope manipulations can be practiced. A computer-based interface and associated algorithms are under development to facilitate simulation studies and interaction with a virtual model.

Methods: We used MIMICS software (www.materialise.com/mimics) to extract a 3D surface mesh of the collecting system from contrast-CT data. This included thresholding (identifying regions of interest based on pixel intensity), region-growing (connecting identified regions), and model creation (stitching the regions into a 3D model). The threshold parameter (pixel intensity) that best captured the details of the collecting system was found by trial and error and was aided by the presence of contrast. The output was in STL format, as a set of unordered triangles and their outer normals (30,552 triangles). The mesh surface was thickened by 2mm for structural integrity, the model was split into two halves by a plane (to allow stone placement), and rectangular alignment tabs were added. The model was then sliced into layers and fabricated by the PolyJet process (www.solidconcepts.com), which prints the layers successively, using a UV-curable photopolymer resin (TangoPlus). The model was tested in a saline bath with a DUR8E ureteroscope, single-action pump navigability, and stone extraction capability.

In parallel work on the virtual prototype, we have developed an efficient algorithm to convert the STL format to the more informative DCEL format for better downstream processing, written functions for viewing and manipulation (clip, zoom, pan, rotate, fly-through), and designed a basic graphical user interface, all in JAVA. Work is underway on developing efficient geometric algorithms to compute appropriate motion parameters for the scope relative to target stones.

Results: The physical model was soft and flexible, had a flesh-like feel, and captured faithfully the relevant features of the calyceal anatomy (left and middle figures). The tactile feedback was realistic, as was the view through the eyepiece. Despite leakage of saline outside of the collecting system, it was possible to snare stones in the renal pelvis (but not in the calyces). More simulations are planned.

Conclusion: The development of a patient-specific physical prototype of the collecting system is feasible and, with proper validation, may prove beneficial in training residents in flexible ureteroscopy.



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