Virtual reality may improve training of renal surgeons

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By exploiting the extra information available from 3D imaging in a virtual reality environment, surgeons can individualize the pre-planning of surgery on the kidneys.

The most frequent kidney cancer in adults is renal cell carcinoma. Certain features limit the successful treatment of this tumor, including resistance to radiotherapy and chemotherapy, so renal surgery is generally the best strategy to cure these patients.

Renal surgery is one of the more challenging procedures for today's urologist. Cure with a single procedure is a huge responsibility, especially with the complex anatomy involved and the major complications that can occur as a result of decisions during the surgery. However, partial kidney resections have undeniable advantages with respect to renal function preservation. In particular, minimally invasive procedures (laparoscopic, robotic, cryotherapeutic, and radiofrequency) have quite favorable cure rates, recovery times, medication requirements, blood loss, cosmetic results, and hospitalization lengths. These less invasive techniques also have limitations and additional difficulties for the urologist, including loss of tactile feedback, longer operating times (which impact renal blood supply), and learning curves.

Diagnostic imaging with computed tomography (CT) and magnetic resonance imaging (MRI) detects, characterizes and determines the stage of the disease. Other critical information obtained from these studies includes the number and localization of blood vessels, depth of the tumor, multifocality of disease, and involvement of adjacent organs. A comprehensive understanding of these factors allows the urologist to plan the surgery without invasive diagnostic procedures.^{1,2} Other researchers have refined this pre-planning step with the imaging system in a 3D environment.³

The most frequent application of 3D imaging and virtual reality in urological practice is probably renal surgery (see Figures 1 and 2), as the analysis of tumoral features and anatomy allows the surgeon to design a tailored approach for each particular case.^{1,2,4} Our group developed a virtual reality model of renal

Figure 1. A 3D virtual reality model of a left kidney with a calyceal diverticulum, a cyst-like lesion that usually requires no treatment.

tumor images that a urologist can manipulate on a laptop computer inside the operating room to obtain accurate information about the case.⁵ Other groups have also recreated surgical resections of renal tumors using virtual reality. These models allow the surgeon to visualize the spatial relationships of pathological and physiological features in each case, and hence avoid unexpected intraoperative injuries in cases with complex anatomy.⁶⁻⁸

Several techniques incorporating 3D imaging systems are currently used in clinical practice. Development of CT scanners with multi-detectors as well as new hardware and software allows endoscopic virtual navigation through the ureters, which aids in detection of small urothelial malignant lesions.⁹ Although this endoscopic navigation is useful, the technique has some tumor detection limitations in comparison with axial images.¹⁰ In other studies, multidetector CT urography exhibited an excellent ability to find renal tumors but had some limitations in the identification of ureteral tumors.¹¹

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Figure 2. A virtual reality model of the kidney (with the collecting system of the kidney in white) within the viewing environment of “The Cave” by Fakespace Systems (photo was taken at the National Research Council of Canada in London, Ontario, Canada).

Simulators and virtual reality are not new in urologic surgery.¹² For example, educators are evaluating virtual reality environments as teaching tools since the training of novice surgeons remains a challenge. We have validated that training on simulators improves the acquisition of the basic skill of gaining percutaneous renal access for minimally invasive kidney stone surgery, making it an option in percutaneous procedures.^{13,14} Others have shown the role of virtual reality in urologic procedures such as transurethral resection of the prostate, ureterorenoscopy, transurethral resection of bladder tumors, and urethrocystoscopy.^{7,8} Virtual reality simulators reduce the surgeon’s learning curve, which we believe will ultimately translate into better patient outcomes.

The ideal virtual reality simulator for use in renal surgery for tumors would reproduce the anatomy of the individual patient with high fidelity, using the digital imaging and communications in medicine (DICOM) data acquired from high resolution CT. It should also allow the urologist to perform the surgery ‘virtually’ by providing the same conditions expected for the actual procedure. In essence, the surgeon is able to perform a trial run. It would require vigorous validation to establish that the skills learned using the simulator can be transferred to improvements in real world performance (predictive validity). Such a simulator would be both an invaluable educational tool and a predictor of the surgeon’s performance in each procedure.

Important advances have occurred toward the ideal virtual reality model in renal surgery, but technological limitations still

exist, including real time organ deformation,¹⁵ insufficient tactile feedback, rudimentary 3D vision, and imperfect imaging systems. These are challenges for future study. We believe that encouraging researchers in this area will improve the skills of future urologists and, more importantly, improve the safety of complex procedures, leading to better patient care.

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