Virtual Endoscopy: Navigation within Pelvicaliceal System

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ABSTRACT

Purpose: To evaluate the use of virtual endoscopy (VE) for the investigation of the pelvicaliceal unit and the depiction of its anatomic deformities.

Patients and Methods: Two study groups were prospectively enrolled in our protocol: ten patients with nonurologic pathologies, and thus without any known deformity of the pelvicaliceal unit (group A), and five patients with caliceal obstruction (group B). Virtual endoscopy represented a non-invasive technique providing amplification of the image in three-dimensional space.

Results: Virtual endoscopy was feasible in all patients, and in all cases succeeded in demonstrating the three-dimensional morphology of the region of interest. The entire processing time ranged from 10 to 15 minutes (mean 12.6 minutes), and the three-dimensional image could be viewed from different angles, allowing better evaluation of the collecting system and its deformities than is possible with conventional intravenous urography or percutaneous nephrostomography.

Conclusion: Virtual endoscopy enabled the creation of endoluminal views of the renal pelvis and calices from spiral tomographic images, thereby allowing diagnostic-preoperative and postoperative evaluation of the pelvicaliceal unit.

INTRODUCTION

A Variety of radiologic imaging techniques such as intravenous urography (IVU), ultrasonography, and CT have been widely used over the past decades for the diagnosis of urologic disease. The advent of spiral CT and MRI has further broadened the imaging armamentarium for the evaluation of the urogenital tract and provided images with high soft-tissue contrast, better resolution in three-dimensional (3D) reconstruction, and direct imaging in multiplanar reproduction. In addition, the continuous evolution of computer software has paved the way for intriguing new imaging methodologies (i.e., virtual endoscopy [VE]).1–6

Virtual endoscopy is a new imaging technique using computer processing of 3D datasets, such as those from CT or MRI scans, to create simulated views of specific organs similar or equivalent to those produced by standard endoscopic procedures. Additionally, VE allows exploration of body regions that are inaccessible with the standard endoscopic procedures. Furthermore, virtual-anatomy navigation and measurements at selected angles of view and lighting can be performed, because VE provides intraluminal, as well as extraluminal, information in all possible directions. There have been previous reports regarding the application of the latter technique in the imaging of various organs such as the trachea, colon, and bladder.1–10 The upper urinary tract has been evaluated with MRI-VE by Neri and colleagues, with encouraging results.11 The aim of the present study was to evaluate the feasibility of VE for the investigation of the pelvicaliceal unit and the depiction of its anatomic deformities.

PATIENTS AND METHODS

Between January 2002 and June 2003, 11 men and 4 women with a mean age of 58 years (range 35–86 years) were prospect-
tively enrolled in our study in two groups: 10 patients with nonurologic pathologies, and thus without any known deformity of the pelvicaliceal unit (group A), and 5 patients with caliceal obstruction (group B). Group A patients had a mean age of 57 years (range 35–82 years) and group B patients a mean age of 66 years (range 54–86 years). Group A patients visited the Radiology Department of our Institution for a spiral CT scan. Group B patients presented with dilated calices secondary to a stenotic infundibular neck that had previously been documented by IVU, percutaneous antegrade nephrostomography (PAN), or both. In three patients from group B, caliceal obstruction was secondary to previous renal surgery (anatrophic nephrolithotomy). The degree and location of stenosis was correlated among VE and IVU, PAN, or both. Informed consent was obtained from all patients.

Image acquisition was performed on a Somatom Plus 4 Power scanner (Siemens, Erlangen, Germany) at deep inspiration with the administration of 100 mL of non-ionic contrast medium (Visipaque; Nycomed). Scanning was performed 5 minutes after injection of the contrast medium aiming to depict the pelvicaliceal system. Radiologic parameters were set at 140 kV and 171 mAs, with 3-mm collimation and 3-mm/sec feed, while reconstruction was set to 3 mm. Images were transferred to the DICOM server of our hospital through an ATM-based LAN. The medical physicist from our Image Processing Unit queried the DICOM server and retrieved the images of each patient.

Image processing was performed on a workstation running ANALYZE 4.0 (Mayo Clinic). Initially, a 3D object was formed by assembling all the transverse images. Thresholding was applied to exclude any information not pertaining to the area of interest. The VE tool was then loaded, and navigation within the pelvicaliceal system was performed. Positioning of the corresponding points of interest (eye of the navigator and aiming area) followed in three planes (coronal, sagittal, and transverse). The navigation proceeded both cephalad and caudal, rotated both to the right and to the left, enabling visualization of the entire region (Figs. 1 and 2) and measurement of the orifice of any given calix (Fig. 3).

RESULTS

Virtual endoscopy of the pelvicaliceal unit was feasible in all patients and in all cases succeeded in demonstrating the 3D morphology of the region of interest. In all cases, care was taken to select datasets obtained in strict apnea, thus minimizing mo-
tion artifacts and ensuring high-quality 3D images. We did not encounter any pierced-surface artifacts.

The entire processing time ranged from 10 to 15 minutes (mean 12.6 minutes), and the image could be seen from different angles, allowing better evaluation of the collecting system. In group A, there was no evidence of any urology-related pathology in any of the patients. Thus, in these patients, VE proved to be a useful diagnostic tool, obtaining information from axial CT slices and, with the use of proper hardware and software, providing amplification of the image perception in 3D space and allowing endoscopy-like depiction of the entire pelvicaliceal system. In group B, the presence of caliceal obstruction was ascertained by VE in all cases.

In addition, VE revealed the exact location of the infundibular stenosis, as well as the exact morphology of its lumen (Fig. 4). Conventional IVU and PAN failed to depict the stenotic caliceal neck accurately because of the interposition of the contrast agent within the dilated calix and the caliceal duct itself. Furthermore, objective assessment of the degree of stenosis was feasible with the aid of VE by measuring the remaining nonobstructed lumen area in pixels. The morphology of obstruction was also shown (elliptical, circular, etc.). In addition, in the three patients from group B who had previously undergone an anatrophic nephrolithotomy, perioperative nephroscopy validated the location and morphology of the stenotic infundibula.

**DISCUSSION**

The rapid pace of technological medical advance has enabled the simulation of endoscopic images on the basis of helical CT datasets and has introduced VE as an amplifier of current diagnostic and therapeutic capabilities. Compared with other standard diagnostic radiologic methods (IVU, CT, MRI), VE is a perspective imaging technique that simulates an endoscopic
view, is well tolerated by patients, and is not time consuming, with a cost no more than that of a spiral CT scan. Nevertheless, VE is still in its infancy, and the visual fidelity of current-generation VE images is not yet optimal for diagnostic accuracy. As scanner resolution improves, the resolution of VE is continuously improving, and thus, VE is rapidly emerging as a major diagnostic tool.1,6

There is a broad range of potential applications for VE, such as diagnosis or preoperative planning, simulation of a surgical procedure for training purposes, and prognostic planning. Previous experience with VE has been encouraging when depicting various arterial lumen abnormalities, the trachea, the colon, the urinary bladder,2,5,7–10 when evaluating the pelvicaliceal unit, VE can offer endoluminal views of the renal pelvis and calices, facilitating its use for educational or training purposes, as well as for diagnostic or therapeutic planning. The urologist will be able to study the collecting-system anatomy prior to a critical operation and even practice the procedure preoperatively. The ultimate goal would be to create the perfect virtual depiction of the human body that would provide a new generation of diagnostic and therapeutic opportunities and would even pave the way for a very intriguing interface with robotic surgery. Thus, the patients would not require sedation, insertion of an endoscopic instrument, or hospitalization or ambulatory observation after the procedure.

One of the main disadvantages of VE is its inability to differentiate and capture the fine detail in the mucosal lining of the pelvicaliceal system that can be seen with conventional endoscopy, and it certainly does not allow biopsy of lesions. However, in contrast to conventional endoscopy, the precise location, size, and shape of structural abnormalities such as lesions and masses can be determined accurately from any orientation both within and outside of the region of interest. In addition, VE can be obtained in a noninvasive manner without the need to insert an endoscopic device into the collecting system.3–5

The main goal of the present study was to evaluate the feasibility of VE for the investigation of the pelvicaliceal unit and the depiction of its anatomic abnormalities. Indeed, a 3D view was obtained in all cases. In addition, VE allowed objective assessment of the degree of stenosis and the exact morphology of the caliceal infundibula. Thus, the present study adds to our understanding of and preoperative planning for the upper urinary tract. In addition, the aim of the present study was to compare VE findings with other gold standard radiologic imaging modalities such as IVU and PAN. We did not attempt a comparison with standard endoscopy techniques (i.e., antegrade or retrograde ureteroscopy). The comparison or validation of virtual with real-time endoscopy was certainly not within the scope of this study. The validation of VE was based on its correlation with the two aforementioned imaging modalities. In group A, there was no need for a frontline comparison, as there were no abnormalities of the pelvicaliceal system, and thus, VE proved to be as efficient as the other two techniques. In group B, VE proved to be more efficient than the other two methods.

CONCLUSION

Depiction by CT VE of the pelvicaliceal system certainly merits particular attention, as VE is undoubtedly an emerging aid in diagnostic and therapeutic planning. The technique promises to produce a “virtual voyage” within the pelvicaliceal system, allowing diagnostic depiction and facilitating therapeutic planning. There is a critical need for systematic validation of VE as a clinical diagnostic tool, evaluating its sensitivity, specificity, and reproducibility. Further development of computer software will enable the differentiation of the various pathologies, and then, VE could even be used in combination with other minimally invasive therapeutic modalities.

REFERENCES


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