Evaluation of Upper Urinary Tract Obstruction Using Image-Pro® Plus

Victor Neeman Ph.D. – Department of Applied Physics / Electro-Optics Engineering, Jerusalem College of Technology, Jerusalem, Israel

Introduction
Researchers at the Jerusalem College of Technology (JCT) are developing an image analysis method that will enable a quantitative estimation of the degree of upper urinary tract obstruction in patients.

JCT researcher Dr. Victor Neeman explains that obstruction of the upper urinary tract is a common urological pathology that results from obstructing stones, tumor, or stenosis. Patients with this pathology are being evaluated with intravenous urography, antegrade ureterography, or retrograde ureterography using sequential x-ray imaging to evaluate the contrast media clearance from the upper urinary tract as a clue for obstruction. The contrast media clearance method allows evaluation via visual monitoring of a contrast agent image in a renal pelvis. The diagnostic accuracy of this method is debated, however, due to its subjectivity.

The JCT researchers assume that changes in the contrast material radio-density in x-ray fluoroscopy can be utilized to measure the upper urinary tract clearance rate. This can be performed by analyzing the time dependence of the contrast media radio-density measured in sequential images of the whole renal pelvis area. Furthermore, the researchers assume that this method can also be used to calculate the contrast agent clearance rate.

Imaging Software
Media Cybernetics Image-Pro Plus 4.5.1.22 software was utilized for this study; the JCT researchers have been using Media Cybernetics software since 1991. Digital fluoroscopic images of radiological phantoms and fluoroscopic images of different patients undergoing x-ray examination were acquired using an OEC 9900 mobile C-arm system (GE Healthcare) in DICOM 14 BPP format and exported to TIFF format using GE firmware software.

Image-Pro Plus was utilized to perform processing and measurements of digital fluoroscopic images. It was used to create image preprocessing and measurement algorithms, including noise reduction, ROI and objects detection, background extraction, image segmentation, and intensity and spatial calibration. The software was also used for image measurements automatization as well as measurements report creation.

Methods and Results
In this study, the JCT researchers attempted to evaluate, quantitatively, the upper urinary tract clearance rate using sequences of images acquired in routine fluoroscopic imaging of the upper urinary tract during pyelography. The fluoroscopic images of renal pelvis were captured after injection of the contrast agent by using the last-frame-hold mode of the C-arm at 3 frames per second, with 2 frame averaging. The captured images were acquired with a resolution of 1024 x 1024 pixels.

Figure 1 displays two digital fluoroscopic images of a right kidney captured during upper urinary tract examination. Figure 1a demonstrates an initial stage of the pyelography, in which the injected contrast agent was already transported by the urine to the ureter. At a more advanced stage of the examination, the radio-density of the contrast agent in the pelvis is higher,
but the area it occupies is already reduced. Figure 1b demonstrates the final stage of the examination, in which both the radio-density of the contrast agent and the area it occupies are reduced.

In order to estimate the amount of the contrast agent from the acquired images, system response calibration and semi-quantitative densitometry approaches were utilized. Linearization of the system response was performed for calibration purposes. The semi-quantitative densitometry approach included a normalization procedure, logarithmic processing of the system response, and the removal of nonspecific density variations.

To implement these approaches, fluoroscopic images were captured with internal standard (the reference sample), which was placed in the field of view of the image intensifier. The response linearization was performed using a transformation function that was calculated by using radiographic wedges of a constant step height and fitting the gray levels of the different wedge steps. The calibration curve was obtained by measuring contrast agent concentration standards.

The normalization procedure, based on reference samples, compensates for the Automatic Brightness Control (ABC) and Automatic Gain Control (AGC) performed by the electronic circuits to modify the system response. The logarithmic processing of the system response was performed for scaling image data to density values. Removal of nonspecific density variations, such as soft tissue density and x-ray scattered radiation, was performed by subtraction of the data obtained from the template image. The template image was obtained in the beginning of pyelography, prior to contrast agent injection. The semi-quantitative densitometry approach was used to measure the contrast agent concentration in arbitrary units. Density values obtained by this method must be proportional to the amount of the contrast agent.

The method was tested by analyzing seven nephrostogram and three retrograde pyelography studies. The clearance rate was estimated by measuring the clearances curve. Regression fitting of the clearances curve by an exponential decay yielded a correlation coefficient of 0.94±0.02. The integrated radio-density of the contrast media was found to decrease by 6±3% per minute; the area of the contrast agent in the renal pelvis decreased by 5±2% per minute. The radio-density measurements during the first 10 minutes of the examination were sufficient to yield the overall exponential clearances curve.

The JCT researchers conclude that this method will enable a quantitative estimation of the degree of upper urinary tract obstruction by using a routine urological modality.

Figure 1. (a/b) Fluoroscopy images obtained during upper urinary tract examination.