Digital Tomosynthesis: A New Technique for Imaging Nephrolithiasis. Specific Organ Doses and Effective Doses Compared With Renal Stone Protocol Noncontrast Computed Tomography

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OBJECTIVE To determine organ-specific doses (ODs) and effective dose (ED) for digital tomosynthesis (DT) and compare it with our institutional renal stone protocol noncontrast computed tomography (NCCT).

METHODS A validated anthropomorphic male phantom was placed supine on a digital GE Definium 8000 radiological scanner. Thermoluminescent dosimeters were placed in 256 locations and used to measure OD. A routine DT study was performed consisting of 2 scout images and 1 tomographic sweep in a 14.2-degree arc over the phantom. Software is used to recreate a series of coronal images from the sweep. ODs were determined as the sum of the doses for the study. Equivalent doses were calculated by multiplying OD with the appropriate tissue weighting factor. ED is the summation of the equivalent doses. OD and ED were determined in a similar fashion (using dosimeters) for a renal stone protocol NCCT and doses were compared.

RESULTS ODs for DT are significantly lower compared with NCCT. The ED for NCCT is 3.04 ± 0.34 mSv. The calculated ED for DT is 0.87 ± 0.15 mSv (2 scouts at 0.17 mSv and 0.14 mSv and 1 sweep at 0.56 mSv), *P* <.0001.

CONCLUSION DT exposes patients to substantially less radiation than NCCT. This is particularly true for radiation-sensitive organs. Further studies are needed to compare the sensitivity and specificity of DT as compared with NCCT. However, its low overall radiation dose makes it an ideal study for the follow-up of recurrent stone formers in the office setting. UROLOGY 83: 282–287, 2014. © 2014 Elsevier Inc.

In the United States the average radiation exposure per capita was estimated to be 5.6 mSv in 2006 compared with 3 mSv in the early 1980s.[1] Reported annual effective doses (EDs) in Europe are estimated to range between 0.7 and 2.0 mSv. Medical procedures and diagnostics contribute more than 50% of the total radiation exposure in these populations.[2]

Multiple different imaging modalities such as plain kidney, ureter, bladder x-ray (KUB) with or without conventional tomograms, intravenous pyelography (IVP), and noncontrast computed tomography (NCCT) are available and currently used for the diagnosis of urolithiasis. Owing to its high sensitivity and specificity, and the ability to rapidly acquire images, NCCT is considered the gold standard imaging study for the diagnosis of urolithiasis in patients with renal colic.[3] However, a large part of the increase in radiation exposure is because of computed tomographic (CT) scans. It has been estimated that 62 million CT scans were obtained in 2007 compared with ∼3 million CT scans in 1980.[4] Patients after an acute stone event receive an average of 4 radiographic studies (including a median of 1.7 CT scans) in the first year.[5]

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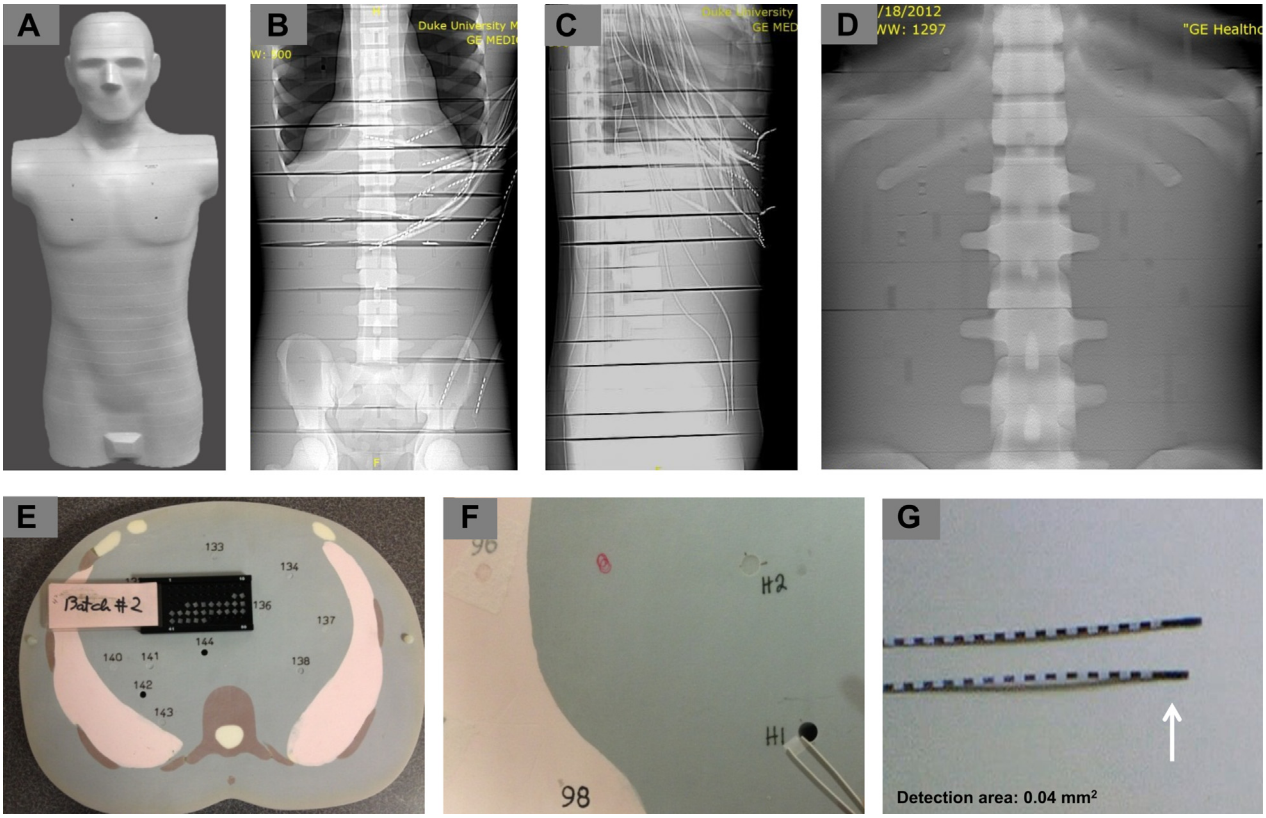

Figure 1. **(A)** Anthropomorphic phantom model; **(B)** computed tomographic scout image of the phantom ap (with metal oxide semiconductor field effect transistors); **(C)** computed tomographic scout image lateral; **(D)** digital tomosynthesis scout image ap (with thermoluminescent dosimeters [TLDs]); **(E)** representative slice of the phantom in axial view with a batch of TLDs to demonstrate size relations, numbers correspond to organ locations; **(F)** placing of a TLD at one location; **(G)** digital metal oxide semiconductor field effect transistor detectors. (Color version available online.)

Digital tomosynthesis (DT) is a new imaging technique based on a series of images, which are acquired with a digital detector during one tomographic sweep after performing 2 digital abdominal scout films. The data are later reconstructed into a series of coronal "slices" with computational software algorithms removing any overlying structures and providing depth information about the region of interest.[6] Start point of the slices and height can be defined by the user and do not require multiple sweeps as used for the traditional tomography. The primary use of this technology has been in chest radiography and breast imaging[7] and holds promise to reduce radiation exposure even further.

Only 2 studies have reported the experimental use of DT for the detection of urolithiasis.[8,9] One of these reported measured doses using a phantom model, but to our knowledge this is the first study reporting organ-specific doses (OD) for DT compared with the gold standard "low dose" NCCT. Furthermore, we calculated and compared EDs using a validated phantom model for the different imaging studies.

MATERIALS AND METHODS

An anthropomorphic male phantom (model 701-D; CIRS, Norfolk, VA; Fig. 1A), which has been previously validated for human organ dosimetry measurements was used to determine effective radiation doses for the DT and the renal stone protocol NCCT.[10,11] The phantom is 173 cm tall and weighs 73 kg (body mass index (BMI): 24 kg/m^2). It is composed of 39 contiguous axial slices, each 25 mm thick. The slices have numbered locations representing the anatomic location of internal organs as shown in Figure 1.

High sensitivity metal oxide semiconductor field effect transistor (MOSFET) dosimeters (Model TN-1002RD, Best Medical, Ottawa, Canada; Fig. 1) were placed at various locations for optimized organ dosimetry to measure ODs of radiation. The MOSFETs were calibrated to GE 64 beam (HVL 7.6 mmAl) for the CT scan or to the digital Definium 8000 radiological scanner for the DT before each run. An additional study was performed placing thermoluminescent dosimeters (TLDs, Thermo Scientific, Waltham, MA) at 256 locations (Fig. 1) to reconfirm OD for the DT study as ODs appeared to be very low, and TLD are more sensitive to detect low radiation doses.

Radiation exposure and doses from medical sources can be quantitated in different ways; absorbed OD (in milliGray), equivalent dose (milliSievert), and ED (milliSievert) are the best approach to report the risk of radiation exposure. Multiplying absorbed OD with respective radiation tissue weighting factors (W_t) determines equivalent dose; W_t are determined by the International Commission on Radiological Protection (ICRP) 103[12] and reported in milliSieverts.[12] The W_t is a surrogate of relative radiation sensitivity (ie, higher W_t means that organs are more radiosensitive). ED is a mathematical