Review Article

Radiation Exposure during the Evaluation and Management of Nephrolithiasis

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Abbreviations and Acronyms

ALARA = as low as reasonably achievable

BMI = body mass index

CT = computerized tomography

ED = effective dose

FBP = filtered back projection

FT = fluoroscopy time

IVP = excretory urogram

KUB = plain x-ray of kidneys, ureters and bladder

LDCT = low dose CT

NCCT = noncontrast CT

PNL = percutaneous nephrolithotomy

SWL = shock wave lithotripsy

ULDCT = ultra LDCT

URS = ureteroscopy

US = ultrasound

W_T = weighting factor

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Purpose: There is rising concern over the increasing amount of patient radiation exposure from diagnostic imaging and medical procedures. Patients with nephrolithiasis are at potentially significant risk for radiation exposure due to the need for imaging to manage recurrent stone disease. We reviewed the literature in an attempt to better characterize actual risks and discussed methods to reduce radiation exposure for adult patients with nephrolithiasis.

Materials and Methods: A PubMed® search was performed using the key words nephrolithiasis, stones, radiation, fluoroscopy, ureteroscopy, percutaneous nephrolithotomy, computerized tomography and shock wave lithotripsy. Additional citations were identified by reviewing reference lists of pertinent articles.

Results: A total of 50 relevant articles were included in this review. Patients with a first time acute stone event are exposed to a significant amount of radiation. Most radiation is from computerized tomography. Patients undergoing percutaneous nephrolithotomy are exposed to an equal or greater amount of radiation than they received from computerized tomography. Risk factors for increased exposure during percutaneous nephrolithotomy include obesity, multiple tracts and a larger stone burden. Ureteroscopy exposes patients to approximately the same amount of radiation as plain x-ray of the kidneys, ureters and bladder. Risk factors for increased exposure during ureteroscopy include obesity and ureteral dilation. During shock wave lithotripsy the amount of radiation exposure is not well characterized. Interventions to reduce exposure to patients include using ultrasound when possible and implementing low dose computerized tomography protocols. The as low as reasonably achievable principle of radiation exposure should always be followed when fluoroscopy is performed. The use of an air retrograde pyelogram may also reduce exposure during percutaneous nephrolithotomy. Fluoroscopy time during ureteroscopy may be decreased by a laser guided C-arm, a dedicated C-arm technician, stent placement under direct vision and tactile feedback to help guide wire placement.

Conclusions: Patients with nephrolithiasis are at significant risk for increased radiation exposure from the imaging and fluoroscopy used during treatment. The true risks of low radiation exposure remain uncertain. It is important to be aware of these risks to provide better counseling for patients. Urologists must also be familiar with techniques to decrease radiation exposure for patients with nephrolithiasis.

Key Words: kidney, nephrolithiasis, radiation dosage, fluoroscopy, diagnostic imaging

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THERE is heightened awareness and increased concern over radiation exposure to the adult patient population in recent years. From 1982 to 2006 the per capita radiation exposure from medical sources in the United States increased nearly 600% from 0.54 to 3.0 mSv.[1] Increased use of CT is responsible for most of this change. The number of CTs performed in the United States increased from approximately 5 million in 1980 to 62 million in 2006.[2] In addition to CT, radiation from nuclear medicine studies, plain radiographs and fluoroscopy all contribute to the increase in medical radiation exposure.[1]

When discussing medical radiation exposure, an understanding of basic terminology and concepts is important. Absorbed dose is the amount of energy absorbed per mass of tissue or an organ.[3] The unit is J/kg or Gy. ED is a calculated value that relates the absorbed dose to the deleterious effects of exposure such as the risk of malignancy. The unit for ED is Sv. In the context of medical exposure ED is usually expressed in mSv. It is determined by directly measuring at least 20 individual organ absorbed doses.[4] These absorbed doses are multiplied by the appropriate tissue W_T of each organ to provide an equivalent dose. W_T is determined by the ICRP (International Commission on Radiological Protection).[3] It is weighted based on the relative radiosensitivity of different organs with a higher W_T given to more radiosensitive organs. The equivalent doses are summed to provide the ED. The dose area product is expressed in Gy cm^2 and calculated from the radiation dose to air multiplied by the area of the x-ray field. This value correlates well with the total energy imparted to the subject undergoing medical radiation exposure and, therefore, it relates to ED and overall malignancy risk. ED can be estimated by combining dose area product with the appropriate coefficient (varies for the protocol used and irradiated portion of body) derived from the Monte Carlo simulations with anthropomorphic digital phantoms.[4,5] FT is the value that represents the length of time that fluoroscopy is used during an intervention. FT is not a reliable measurement of dose as it does not account for the fluoroscopy dose rate or the dose due to radiography (ie digital subtraction angiography).[6] SSDI (size specific dose estimate) is a novel method of reporting patient radiation dose. The concept accounts for patient size and is derived from multiplying $CTDI_{vol}$ (volume CT dose index), a standardized measure of average scanner output, by a size dependent conversion factor. Increases in patient size decrease size specific dose estimates.[7]

There are 2 types of generalizable effects from radiation exposure, including deterministic effects and stochastic effects. Deterministic effects are characterized by having a threshold dose below which there is an absence of tissue reactions. Above the threshold dose there is tissue reaction and injury with increases in severity with increasing dose. An example of a deterministic effect is skin injury from radiation, which can occur above a threshold dose of 2 Gy. Stochastic effects are characterized by the absence of a threshold dose. Increased levels of exposure do not affect the type or severity of the effect but they do increase the probability of an effect.[3] The risk of malignancy from radiation exposure is a stochastic effect. Common malignancies include leukemia, multiple myeloma, and thyroid, bladder, breast, lung, ovarian and colon cancers. Currently the NCRP (National Council on Radiation Protection and Measurements) has recommended an annual occupational limit of 50 mSv.[8] In medicine there are no suggested limits for patient exposure. Instead the risks of radiation must be balanced with the clinical necessity and benefit of the imaging study or procedure.

Patients with nephrolithiasis are at risk for significant radiation exposure. Diagnostic imaging such as CT, KUB, IVP and nuclear medicine renal scans are all commonly used to evaluate stone patients. Fluoroscopy during PNL, URS and SWL also contributes to the overall radiation to which patients with nephrolithiasis are exposed. CT and KUB for followup of stone patients also contribute to radiation exposure.

MATERIALS AND METHODS

We performed a comprehensive PubMed® search of articles published from January 1, 2004 through December 31, 2014 using the key words nephrolithiasis, stones, radiation, fluoroscopy, ureteroscopy, percutaneous nephrolithotomy, CT imaging and shock wave lithotripsy. Relevant original research articles and reviews published in the English language and with an abstract available for review were considered. We excluded expert opinions, editorials and case reports. Additional citations were identified by reviewing reference lists of pertinent articles. Articles within the scope of this review were selected based on contents.

RESULTS

We retrieved a total of 835 articles. A total of 50 relevant articles were selected for inclusion in this review.

Exposure During Stone Event

Patients undergoing evaluation and management for nephrolithiasis are at risk for significant radiation exposure ranging from 1.18 to 37.66 mSv.[9] The use of imaging modalities has significantly increased in recent decades, particularly NCCT.