Ultra-Low Radiation Dose Renal CT Examinations

- Concern has been growing about healthcare-related radiation exposure; to address this concern, Mass General Imaging has developed a number of initiatives to lower CT radiation dose.
- One initiative has dramatically lowered the CT radiation dose for renal stone examinations.
- The reported average radiation dose for abdominal/pelvic CT is 15 mSv. At Mass General Imaging the dose is about 5.4 mSv for initial diagnosis.
- If follow-up imaging is indicated in patients with a history of renal stones, we now utilize ultra-low dose CT imaging (1.1-3 mSv).
- This ultra-low CT radiation dose compares favorably with standard two-view kidney/ureter/bladder (KUB) radiography that has a radiation dose of about 1.2 mSv.

Increasingly, the growing number of CT examinations performed and the associated population-based radiation exposure has generated concern, even though the radiation risks are small (Table 1) and the benefits of rapid diagnosis with the help of CT are well-established. In response to this concern, number of different initiatives have reduced radiation exposure associated with CT imaging, many of which have been described in previous Radiology Rounds articles.

<table>
<thead>
<tr>
<th>Age</th>
<th>Risk: Abdomen/Pelvis CT*</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>20</td>
</tr>
<tr>
<td>15</td>
<td>20</td>
</tr>
<tr>
<td>30</td>
<td>10</td>
</tr>
<tr>
<td>50</td>
<td>7-8</td>
</tr>
<tr>
<td>70</td>
<td>3-5</td>
</tr>
</tbody>
</table>

*From Berrington de Gonzalez et al., 2009

These efforts include the development of customized protocols that take into account the patient’s age, body mass and clinical indication. This allows for lower dose scan parameters and targeted scanning to cover only the region of interest and thereby limit oversampling. In addition, new iterative image reconstruction techniques can improve image quality on low dose, higher noise CT scans. As a result of these initiatives, radiation dose at Mass General Imaging has dropped dramatically. In the past year, the median radiation dose for an abdominal/pelvic CT examination has been decreased to approximately 5.4 mSv (Table 2). Even lower radiation doses may be achieved for some CT examinations, such as that for renal stones.

Renal Stone Imaging

The role of CT in establishing a diagnosis of renal stones is well established. Renal stones are dense, attenuate strongly (Figure 1), and can be detected with confidence on non-contrast CT when they are as small as 1 mm. For stones greater than 3 mm, non-contrast CT examinations have a reported sensitivity and specificity of 97-100%.
Table 2. Comparison of Radiation Doses

<table>
<thead>
<tr>
<th>Abdominal Radiology Examination</th>
<th>Reported Median Radiation Dose, mSv (IQR)*</th>
<th>Background Radiation Equivalent</th>
<th>Median Radiation Dose at MGH Dose, mSv</th>
<th>Background Radiation Equivalent</th>
</tr>
</thead>
<tbody>
<tr>
<td>X-ray KUB (2 views)</td>
<td>1.2</td>
<td>16 weeks</td>
<td>1.2</td>
<td>16 weeks</td>
</tr>
<tr>
<td>IVP</td>
<td>3 (2-4)</td>
<td>1 years</td>
<td>3 (2-4)</td>
<td>1 years</td>
</tr>
<tr>
<td>Non-contrast Abdomen/Pelvis CT</td>
<td>15 (10-20)</td>
<td>4 years</td>
<td>5.4†</td>
<td>1.2 years</td>
</tr>
<tr>
<td>Ultra-low Dose Abdomen/Pelvis CT</td>
<td>N/A</td>
<td></td>
<td>3.0†</td>
<td>1.1† (advanced scanner)</td>
</tr>
</tbody>
</table>

* From Smith-Bindman et al., 2009; IQR, interquartile range
† Since August 2010, average dose

In comparison, radiography has an accuracy of about 70%, cannot assess the degree of obstruction. In addition, phleboliths and other extraluminal calcifications can be confused with renal or ureteral stones in radiographic images. Intravenous pyelograms (IVPs) have the disadvantages of the requirement for contrast agents as well as the potential delay in diagnosis because of the need to wait for the delayed radiographs that show the contrast agent in the collecting system.

Ultrasound is also significantly less sensitive than CT. Renal calculi appear as echogenic foci that usually show posterior shadowing. Proximal and distal ureteral stones can be clearly identified, but much of the ureter can be obscured by bowel gas, which lowers the sensitivity. Color Doppler imaging can detect jets of urine arriving in the bladder as a result of peristaltic activity in the ureter. In patients with acute obstruction, ultrasound can show signs of hydronephrosis and hydroureter.

Using CT for renal stone evaluation is of particular concern because these renal stones commonly occur in a relatively young and otherwise healthy population. Often, a large number of repeat examinations are performed in those with recurrent disease. Therefore, there has been considerable interest in the development of renal CT protocols with ultra low radiation dose. These low-dose methods have a similar sensitivity and specificity for renal stones as standard CT imaging. Moreover, recent technologic advances in CT and the introduction of dual-energy CT have also empowered CT with capabilities to accurately detect and characterize urinary stone composition.

![Figure 1. Renal Stone CT](A) Low-dose abdominal/pelvic image for initial diagnosis of a patient with suspected renal colic, with a radiation exposure of 3.1 mSv. (B) Ultra-low dose abdominal/pelvic image for follow-up of patient with a diagnosis of renal stones, with a radiation exposure of 1.2 mSv. Note that despite the greater image noise, the renal stones can be clearly seen.
However, lowering radiation dose increases image noise (Figure 1b), which lowers the sensitivity for diagnosing other causes of flank pain, which account for approximately 25% of patients with suspected renal colic. By using a number of dose-reduction techniques, initial diagnostic imaging is achieved with a radiation dose of approximately 5.4 mSv in order to detect alternate pathologies for patients without a previous diagnosis of nephrolithiasis. This radiation dose is considerably lower than that reported in the literature (Table 2).

If there is a high level of concern about any radiation exposure, for example in children or pregnant women, ultrasound may be considered as an alternative first examination. MRI is not recommended because the data on accuracy are insufficient, the examination is time-consuming, and the interpretation is difficult.

**Follow-up Examinations**

If imaging is required for follow-up after intervention to assess the success of renal stone therapy, ultra low-dose CT (1-3 mSv for a normal sized patient) is the preferred method for several reasons. The images can be readily compared with the base-line images, and CT has the ability to detect small stones that cannot be seen using other modalities. It is also superior for planning future treatments and for assessing for complications. The radiation dose associated with ultra low-dose CT is no more than the standard KUB radiography (Table 2). Ultra low dose CT may also be appropriate for patients who have had renal stones in the past and whose current symptoms suggest the likelihood of a recurrence of nephrolithiasis.

**Other Applications of Ultra-Low Dose CT Imaging**

Ultra-low dose CT is also useful for follow up in other patients with a recent prior diagnosis of non-cancerous conditions. For example, it can be used to assess abscess drainage or to verify interventions such as catheter placements. In both of these examples, image contrast is high and image noise does not detract from interpretation. In addition, very low dose CT can be considered for conditions in which repeat imaging is necessary, such as for the management of Crohn’s disease or pancreatitis. In these latter cases, imaging is performed on a scanner that is equipped with iterative image reconstruction technology, which reduces image noise compared to standard image reconstruction methods.

**Further Information**

For more information about CT radiation dose and renal stone imaging, please contact Dushyant Sahani, MD, Director of CT Imaging, Mass General Imaging, at 617-726-3937.

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References


