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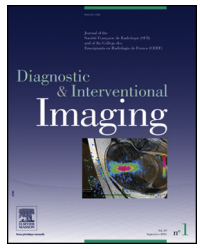

REVIEW /*Genito-urinary imaging*

How to perform low-dose computed tomography for renal colic in clinical practice

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Abstract Computed tomography (CT) has become the reference technique in medical imaging for renal colic, to diagnose, plan treatment and explore differential diagnosis. Its main limitation is the radiation dose, especially as urinary stone disease tends to relapse and mainly affects young people. It is therefore essential to reduce the CT radiation dose when renal colic is suspected. The goal of this review was twofold. First, we wanted to show how to use low-dose CT in patients with suspected renal colic in current clinical practice. Second, we wished to discuss the different ways of reducing CT radiation dose by considering both behavioral and technological factors. Among the behavioral factors, limiting the scan coverage area is a straightforward and effective way to reduce the dose. Improvement of technological factors relies mainly on using automatic tube current modulation, lowering the tube voltage and current as well using iterative reconstruction.

Since unenhanced (or plain) computed tomography (CT) was introduced in the 1990s, it has become the reference tool for the diagnosis of renal colic [1—3]. This is because CT has many advantages. It is fast, does not require intravenous administration of iodinated contrast material, has high diagnostic capabilities [2,4], helps exclude other conditions that are clinically similar to renal colic [5—8], provides direct information relative to the size and attenuation value of urinary stones [9] and helps predict spontaneous stone passage [10].

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Its main limitation, however, is the radiation dose given to the patient, especially because urinary stone disease tends to relapse and mainly to affect young people. Katz et al. report that 4% of the patients that undergo CT for suspected renal colic have had at least three CT examinations for the same indication, with cumulated doses ranging from 20 to 154 mSv [11]. Considering the ALARA principle (As Low As Reasonably Achievable) and the potential risks of radiation-induced cancer caused even using low doses of X-rays [12,13], dose reduction in CT for suspected renal colic is hence essential. In this context, many studies have shown that it is possible to detect renal colic with low-dose CT. Doses may be reduced by 75 to 90% compared to standard acquisition doses, without modifying the diagnostic performance [4,14—18]. However, a recent study showed that in most imaging centers low-dose CT protocols were not used to diagnose renal colic [19].

The goal of this review was twofold. First, we wanted to show how to use low-dose CT in patient with suspected renal colic in current clinical practice. Second we wished to discuss the different ways of reducing the CT radiation dose by considering both behavioral and technological factors.

What is low-dose CT?

The definition of low dose is controversial. The term refers to CT scans where, compared to a ''normal'' or ''standard'' dose scan, the image quality has been deliberately modified to reduce the exposure dose while preserving the diagnostic performance [20]. Renal colic is particularly appropriate for low-dose CT because of the excellent spontaneous contrast between most urinary stones that are spontaneously hyperattenuating (between 200 and 2800 HU) [2] and the soft tissues that surround them. Thus, even if the dose reduction is substantial, the naturally high contrast between urinary stones and the surrounding soft tissues prevents too much deterioration of the contrast-to-noise ratio while preserving good diagnostic performance [9].

Data from the literature reveal that the effective ''low dose'' to detect renal colic, is between 1 and 3 mSv [4,19]. The threshold of 3 mSv (i.e. a dose length product [DLP] of 200 mGy.cm) is arbitrary but has become the standard threshold for low-dose CT when investigating renal colic [19] because it corresponds more or less to the average radiation of intravenous urography that used to be the reference modality in the past [21]. If we consider that the average dose of a standard abdomen and pelvic CT is between 10 and 12 mSv [22,23], a low-dose scan of less than 3 mSv corresponds to a dose reduction of more than 75%.

Despite this significant dose reduction, various studies have shown that the diagnostic performance of low-dose CT remains excellent compared to normal-dose CT. A meta-analysis published in 2008 showed an average sensitivity of 96.6% and an average specificity of 94.9% [4]. At the same time, it was shown that low-dose CT could explore differential diagnosis, just like normal-dose unenhanced CT [24] (Fig. 1) and also that there was no significant difference when determining the size and density of the stones [17,25].

Recently, experts have suggested using ''ultra-low-dose'' CT, below the level of 1 mSv and close to the dose used to perform a plain abdominal radiography, i.e. 0.7 mSv [21]. Despite the recent technological advances and the use of new very powerful iterative algorithms for reconstructions, these ultra-low-dose protocols perform less well than low-dose protocols for detecting small urinary stones below 3 mm [18,21].

How to perform low-dose CT to detect renal colic?

The modalities to reduce dose in CT are based on the radioprotection principles of CT dose justification and optimization [26]. These modalities have already been extensively described [27—33]. In this review, we discuss them and concentrate on how to reduce the dose of abdominal and pelvic CT when looking for renal colic. The different modalities depend both on behavioral factors, independent of the CT equipment, and technological factors, some of which depend on how recent the CT equipment is. The behavioral factors are the level of awareness of the medical and paramedical teams, the principles of substitution and justification, as well as limiting the scan coverage area. The technological factors include reduction of the tube current and voltage, automatic tube current modulation and iterative reconstructions, as well as optimization of the pitch and slice thickness.

Compliance with the indications and substitution with a non-radiating imaging technique

Due to its excellent diagnostic performance, CT has become the reference investigation to diagnose renal colic. In 2014 the European Association of Urology has recommended low-dose CT as the first-line imaging modality in case of suspected renal colic (grade A recommendation) [34]. In 2008, the French-speaking Society of medical Emergencies (Société Francophone d'Urgences Médicales) [35] recommended radiologists to perform plain abdomen radiography together with an ultrasound or an unenhanced CT as a first-line examination for suspected non-complicated renal colic. However, CT should be favored if a complicated case is suspected or in special situations (pregnancy, single kidney, transplanted kidney, known uropathy or renal failure) or if there are signs of complications (signs of infection; oliguria, anuria or algesia) and in case of doubtful diagnosis. In pregnant women, ultrasound must be used as first-line modality and, in case of doubtful ultrasound, magnetic resonance imaging should be used as a second-line imaging modality before CT [36].

Raising the awareness and training the medical teams

Raising the awareness and training the radiologists and clinicians is also essential [37]. Clinicians must be able to detect renal colic and ask explicitly the radiologist to look for it. The radiologist must use a low-dose CT protocol with pre-adjusted parameters. It is also essential that clinicians and radiologists agree to seek, not the best possible image quality, but one that is sufficient for diagnosis. For radiologists