CT Analysis of Renal Stone Composition: A Novel and Non Invasive Method to Analyse Stones

Abstract:

The treatment of renal stone disease is very dependent on the composition of the stone. Uric acid stones for example have a completely different elution and treatment pathway to calcium phosphate or oxalate stones. Until now, the diagnosis of renal stone disease was mainly done through urine analysis and formal stone analysis once the stone has been removed. There is now a novel method of analysing the composition of stones by using dual energy CT, a technology that we have recently introduced to Ireland. CT not only has the ability to detect stones with a sensitivity of close to 100%, but now has the ability to actually give a breakdown underlying composition of the stone. Renal stone disease is estimated to have a lifetime incidence of up to 15%, thus making it a common condition to both the primary care setting and emergency departments. The classical presentation of loin to groin colicky pain with haematuria is well known. More atypical symptoms include abdominal pain, fever, urinary frequency or difficulty voiding. The majority of renal stones are calcium oxalate stones and account for up to 75-80% of renal stones. Struvite (magnesium ammonium phosphate), calcium phosphate, uric acid, cysteine and mixed stones make up the remaining 20-25%).

Traditionally, plain radiographs of the abdomen aided in the diagnosis when a calcified density projected over the region of the kidneys or along the course of the envisaged ureters was seen. However, only 80% of stones are visualised and further information such as the presence of obstruction cannot be obtained. Intravenous pyelograms (IVP) have a higher sensitivity and specificity for the detection of stones and can also assess for hydronephrosis but are a costly exercise in both time and patient safety with significant radiation exposure and the necessary administration of intravenous contrast. In fact, in most departments IVPs have become obsolete. Ultrasound may be considered in the assessment of hydronephrosis however stones are frequently missed. The imaging test of choice today is non-contrast computed tomography of the kidneys, ureters and bladder (CT-KUB) which has an accuracy rate of close to 100% in the diagnosis of renal stones and is low in radiation dose thanks to new low-dose techniques.

While imaging can provide a definitive diagnosis of renal stone disease further investigations should be undertaken to determine the composition of the stone in order to initiate appropriate therapy. With approximately 50% of patients expected to present with recurrence of renal stone disease within 10 years of their initial presentation, consideration should be given to appropriate characterisation in order to commence appropriate preventative measures. In patients with established renal stone disease and given the high risks of recurrence, stone analysis is an essential part of their workup. 24-hour urine collection is a non-invasive investigation that can be used to determine the possible composition of a patient’s stone. However this test can be inaccurate and is time-consuming and reliant on patient compliance. Thus, stone fragment analysis is an important approach in the management of renal stone disease, but depends upon patient retrieval of passed stone or retrieval of stone during an invasive urological procedure.

Although only in its infancy, the emergence of dual energy CT as a method of renal stone analysis in vivo has the potential to make a significant impact on patient care as it not only allows non-invasive, pre-procedural stone composition analysis but can directly influence the management of these patients based on analysis findings. Dual energy CT is not a new concept and was first described in the 1970s. However, its use was not practical at that time due to timely acquisition of images, poor image quality and excessive radiation exposure. A number of basic physical principles should be first explained. CT relies on the production of X-ray beams by an X-ray tube, which are then passed through the body and received by opposing detectors. As the x-rays pass through a volume of tissue they may or may not interact with that tissue and become attenuated. Tissues are more likely to attenuate an X-ray beam at a given energy and it is known that the higher the density and the higher the atomic number of a material, the more likely attenuation will occur. For example, bone is much more likely to attenuate an X-ray beam compared to air.

The composition of the imaged volume of tissue is determined by the differing attenuations of X-ray beams which are received by the detectors and then computer processed and reconstructed to produce virtual slices of that particular volume of tissue. Within each slice we can confidently distinguish between bone, air, fat, soft tissue, fluid etc.

However, tissues which are of similar density and atomic number will look identical on conventional CT, for example a calcium oxalate and a uric acid renal stone will be indistinguishable. This is where the use of dual energy CT takes a step further into the realm of tissue characterisation. With this technique two X-ray tubes of different tube kilovoltage potentials, usually 80 kVp and 135 kVp, image the same tissues, or in this case a renal stone. Two stones of differing atomic composition will demonstrate differences in attenuation and this can be analysed using sophisticated post-processing techniques to provide information about tissue composition beyond that obtainable with single-energy techniques. Initial studies, both in vitro and in vivo, have been promising with dual energy CT correctly identifying renal calculus composition with 92-100% accuracy. Significantly, the recent use of dual energy CT has not demonstrated an increase in radiation dose to the patient and indeed has the capability to further reduce dose is possible in certain cases.

Dual energy CT as a method of non-invasive renal stone characterisation is an exciting and novel development with far-reaching implications in the investigation and diagnosis of patients and subsequent management of renal stone disease while obviating the need for time-consuming or invasive
procedures.

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References


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