

Dual Source/Dual energy- renal applications

Adubeiro Nuno¹, Nogueira Luísa², Guedes Mónica³, Pinho Ernesto⁴

^{1,2,3,4}Docente da área da Radiologia

Escola Superior de Tecnologia da Saúde do Porto, Portugal

¹*nca@estsp.ipp.pt*, ²*lpn@estsp.ipp.pt*, ³*mag@estsp.ipp.pt*, ⁴*efp@estsp.ipp.pt*

ABSTRACT

Development of Dual Source Computed Tomography (Definition, Siemens Medical Solutions, Erlanger, Germany) allowed advances in temporal resolution, with the addition of a second X-ray source and an array of detectors to the TCM 64 slices.

The ability to run exams on Dual Energy, allows greater differentiation of tissues, showing differences between closer attenuation coefficients.

In terms of renal applications, the distinction of kidney stones and masses become one of the main advantages of the use of dual-energy technology.

This article pretends to demonstrate operating principles of this equipment, as its main renal applications.

Key words: Computed Tomography, Dual source, dual energy

RESUMO

O desenvolvimento da Tomografia Computorizada Dual Source (TCDS) (Definition, Siemens Medical Solutions, Erlanger, Germany) permitiu avanços na resolução temporal, com a adição de uma segunda fonte de raios X e de uma fileira de detectores à TCM de 64 cortes.

A capacidade de executar exames em Energia Dupla, permite uma maior diferenciação dos tecidos, evidenciando diferenças entre coeficientes de atenuação próximos.

Relativamente a aplicações renais, a distinção de cálculos renais e massas tornam-se uma das principais vantagens do uso da tecnologia em energia dupla.

Este artigo pretende demonstrar princípios de funcionamento do equipamento em questão, assim como as principais aplicações a nível renal.

Palavras-chave: Tomografia computadorizada, fonte dupla, energia dupla

1. INTRODUCION

The dual source computed tomography (DSCT) or dual energy computed tomography (DECT) is a method that achieves a temporal resolution significantly better than the 64-multislice computed tomography cuts. In terms of its clinical applications, the cardiac study, especially the coronary arteries, obtained through a very

effective in its analysis. Ratings of abdominal organs like liver, kidneys and other could also potentially benefit of this new technology. The ability to run tests on dual-energy, allows the differentiation of different materials, something that gives it enormous potential and clinical diagnosis. The absorbed dose to the patient may be decreased due to its operation. Several limitations can be pointed to its applicability, because the physical aspects of the equipment and the operation itself. Clinical trials already undertaken show a great potential in this new method, however there are still, in some fields and insufficient data regarding the application. (Flohr 2007; Hofman 2008; Macari 2009)

2. DUAL SOURCE/DUAL ENERGY TECNOLOGY

2.1 Physical Principles

In the evolution of computed tomography (CT) one of the objectives was to improve the temporal resolution. For that, the increase of the speed of rotation of the x ray source, was one option . However these increases are limited to the ability of equipment. This limitation make possible the idea of developing the concept of using two X-ray tube with two engagements of detectors with the same rotation time of the x ray tube (330ms) increasing the temporal resolution. (Flohr 2007; Hofman 2008; Macari 2009)

In the reconstruction of images, data of half of a rotation are needed. Thus, a single source CT reconstruction needed of a segment of at least half the time of rotation of the x ray tube. With the DSCT, the reconstruction of a segment can be obtained by merging data from $\frac{1}{4}$ of rotation of each X ray tube, reducing the time of reconstruction to 83ms. For a reconstruction of two segments, DSCT has a temporal resolution of 60ms (with a minimum of 42ms. (Flohr 2007; Hofman 2008; Macari 2009)

It should be noted that this concept of using a multiple source of x-rays is not new in CT. Decades behind existed a CT with various sources of X-rays to study the heart, using a cylindrical scan. Consisted of a semicircular arc where light bulbs have 14 X-ray However, due to its weak signal - noise ratio and ability to image reconstruction, it was only used for research. (Flohr 2007; Hofman 2008; Macari 2009)

The TCDS is then composed of two X-rays tubes with an identical capacity to TCM single source of 64slices. These x ray tubes are arranged orthogonally within the same gantry. (Figure 1 and 2)

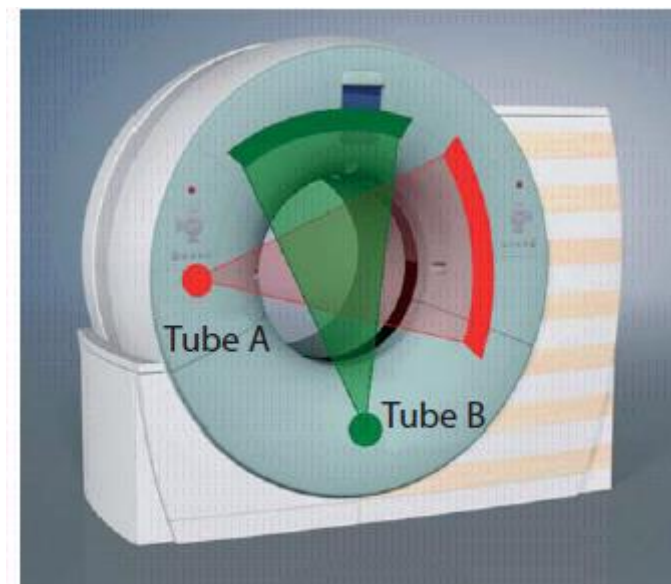


Figure 1: Representation of DSCT

Source: Macari, Michael et al. 2009. Dual energy CT: preliminary observations and potencial clinical applications in the abdomen. *Eur Radiol*, 19, 13-23

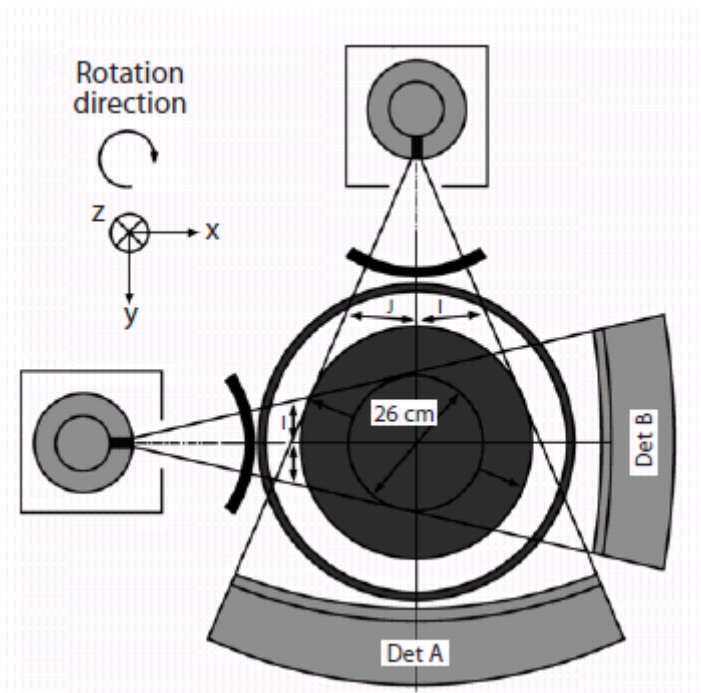


Figure 2: Disposition of the detectors and the x ray tubes. Note the different size of the detectors A and B

Source: Macari, Michael et al. 2009. Dual energy CT: preliminary observations and potential clinical applications in the abdomen. *Eur Radiol*, 19, 13-23

They can work with identical or different kilovoltage (Kv) and milliamperage (mA). When using different Kv, dual-energy technology happens. Both x ray tubes have the Z-flying technology, which allows the acquisition of 64 slices from a detector of 32 slices. (Flohr 2007; Hofman 2008; Macari 2009)

To capture the radiation that will contain data, there are two engagements of detectors in the TCDS. These dispose within the same gantry, with the opposite position to the source of X-ray (Fig. 2) Each range of detectors has a identical geometry to the 64-slice CT (32x0, 6mm or 24x1 = 192cm, 2mm = 28.8 cm) with one exception. Due to space constraints inside the gantry, a range of detectors (50 cm) is larger than the other (26cm). The smaller range is normally sufficient for images of small fields of view (FOV), such as the study of coronary arteries. Because of this limitation is important that the subject is correctly placed in the isocenter of the gantry and for dual-energy applications the region of interest must have a sufficient size to fit in the FOV of 26 cm from the smallest range of detectors. (Flohr 2007; Hofman 2008; Macari 2009)

The DSCT image born by combining data from both detectors. This will bring the peculiarity that part of the escape radiation from one of the sources, the detector will interact with the other source. Studies have shown that this secondary radiation is not negligible. To help reduce the artifacts created by this cross-radiation, there are special correct algorithms that minimize the effects derived from the operation of the TCDS. (Flohr 2007; Hofman 2008; Macari 2009)

Taking into account the technical characteristics of equipment, it can run with different Kv and mAs as described above. This enabled the ability to differentiate materials taking into account their different degree of attenuation at different energies originating from the X-ray tube, with only one exposure. (Flohr 2007; Hofman 2008; Macari 2009)

The dual source technology for tissue differentiation is used taking into account, that the tissues have different degrees of attenuation concerning their properties and materials that constitute it, before exposure to different energy X-ray spectra. For example, iodine and calcium attenuate more photons of low energy and consequently have a higher number of TC to lower Kv than higher Kv. Most of the soft tissues, except fat, is close to the density of water, so most calibration systems of CT did not show significant differences for the different attenuation Kv. The attenuation values of tissues rich in fat, are however lowest to lower Kv than

high Kv. Differences in attenuation at different Kv between calcium and iodine are used in angiography TCDS for removal of bone, since iodine is used as a contrast product in blood vessels. A beam of 80kv will be more attenuated by iodine than one beam of 140kv, due to the atomic number and properties of the atomic cloud. In contrast, this difference in calcium is no longer visible. This means that when they combine data from beams with different energies are able to subtract the bone and soft tissue, iodine and maintaining their vessels. With only a single exposure is possible to obtain data that would be generated in another TC with two different exposures. Using the dual mode of energy you can get an virtual" image" without contrast and another with contrast with just a scan. (Flohr 2007; Hofman 2008; Macari 2009)

3. CLINICAL APPLICATIONS

2.1 Major applications

The major applications of dual source dual energy are in the study of the hearth, mainly the coronary vessels. Organs like the liver, lungs, spleen and kidneys are objects of study by this type of technology. (Flohr 2007; Hofman 2008; Macari 2009)

Due to this type of technology the distinction of kidney stones in relation to its chemical composition is possible, as well as the differentiation of renal masses and other medical conditions. (Flohr 2007; Hofman 2008; Macari 2009) In the figures 3, 4, 5, 6 and 7 are showed some cases of kidney dual source/dual energy applications.

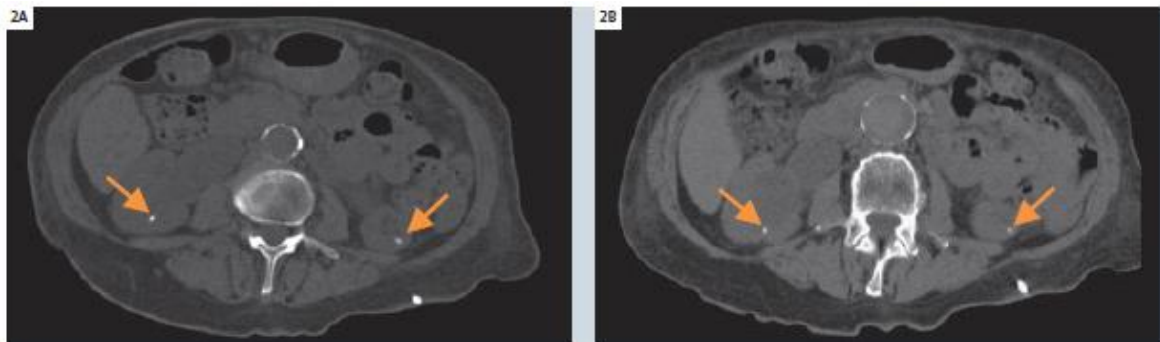


Figure 3: A 70-year-old female patient presenting with acute pyelonephritis and left sided ureteral obstruction. CT was performed after nephrostomy and pigtail insertion on the left side. A: Standard non-enhanced CT image at the level of the kidneys shows bilateral urinary stones (arrows). B: Virtual non-enhanced CT image similarly demonstrates the urinary stones on both sides.

Source: Macari, Michael et al. 2009. Dual energy CT: preliminary observations and potencial clinical applications in the abdomen. *Eur Radiol*, 19, 13-23

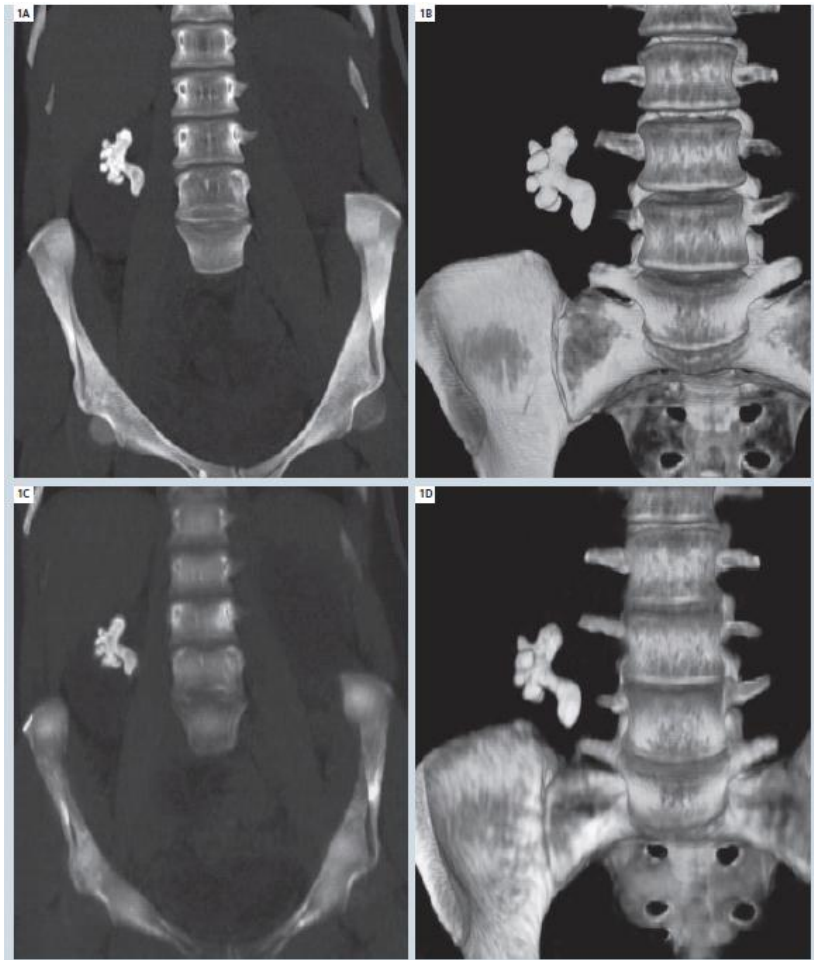


Figure 4: Comparison of standard non-enhanced CT and dual energy virtual non-enhanced CT reconstruction. A 43-year-old female patient with a history of chronic urinary stone disease. A + B: Standard non-enhanced CT reconstructions at the level of the kidneys show a staghorn calculus in the right renal pelvis (1A: transverse image; Fig. 1B: volume rendered image). C + D: Virtual nonenhanced CT reconstructions from contrast-enhanced. Dual Energy CT similarly demonstrate the right pelvic urinary stone (C: transverse image; D: volume rendered image).

Source: Macari, Michael et al. 2009. Dual energy CT: preliminary observations and potential clinical applications in the abdomen. *Eur Radiol*, 19, 13-23

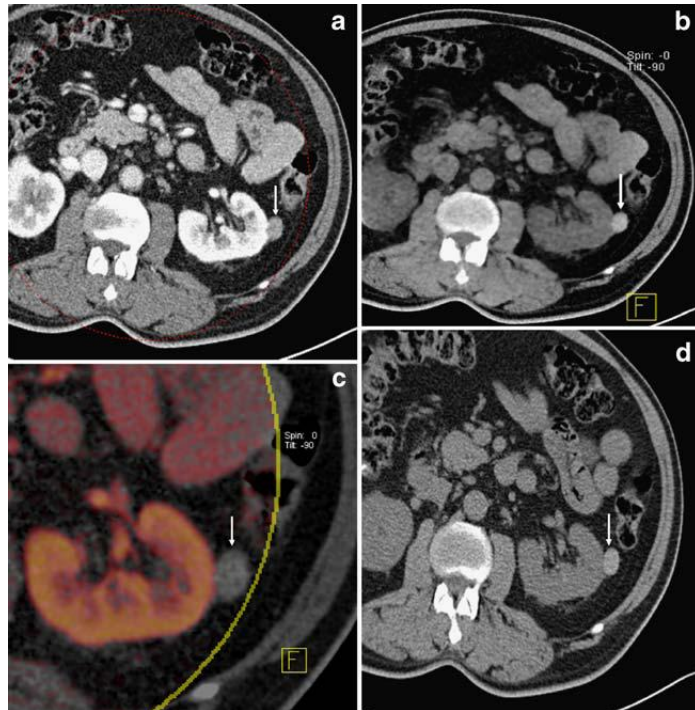


Figure 5: DECT for characterization of renal masses. A. Axial contrast-enhanced CT image of the upper abdomen in a 75-yearold man. Weighted average DECT image showing a hyperdense lesion in the left kidney (arrow) measuring 75 HU. B. Virtual unenhanced image at the same slice position shows the lesion (arrow) has high density (70 HU). The yellow rim corresponds to the B detector field of view. Note in this large patient the periphery of the abdomen is not included in the B detector FOV (yellow circle). C. Colorcoded DECT image showing that the lesion (arrow) does not enhance. D. True unenhanced image in same patient shows the lesion has high density, measuring 72 HU. This case demonstrates how a virtual unenhanced image can be used if a true unenhanced is unavailable.

Source: Macari, Michael et al. 2009. Dual energy CT: preliminary observations and potential clinical applications in the abdomen. *Eur Radiol*, 19, 13-23

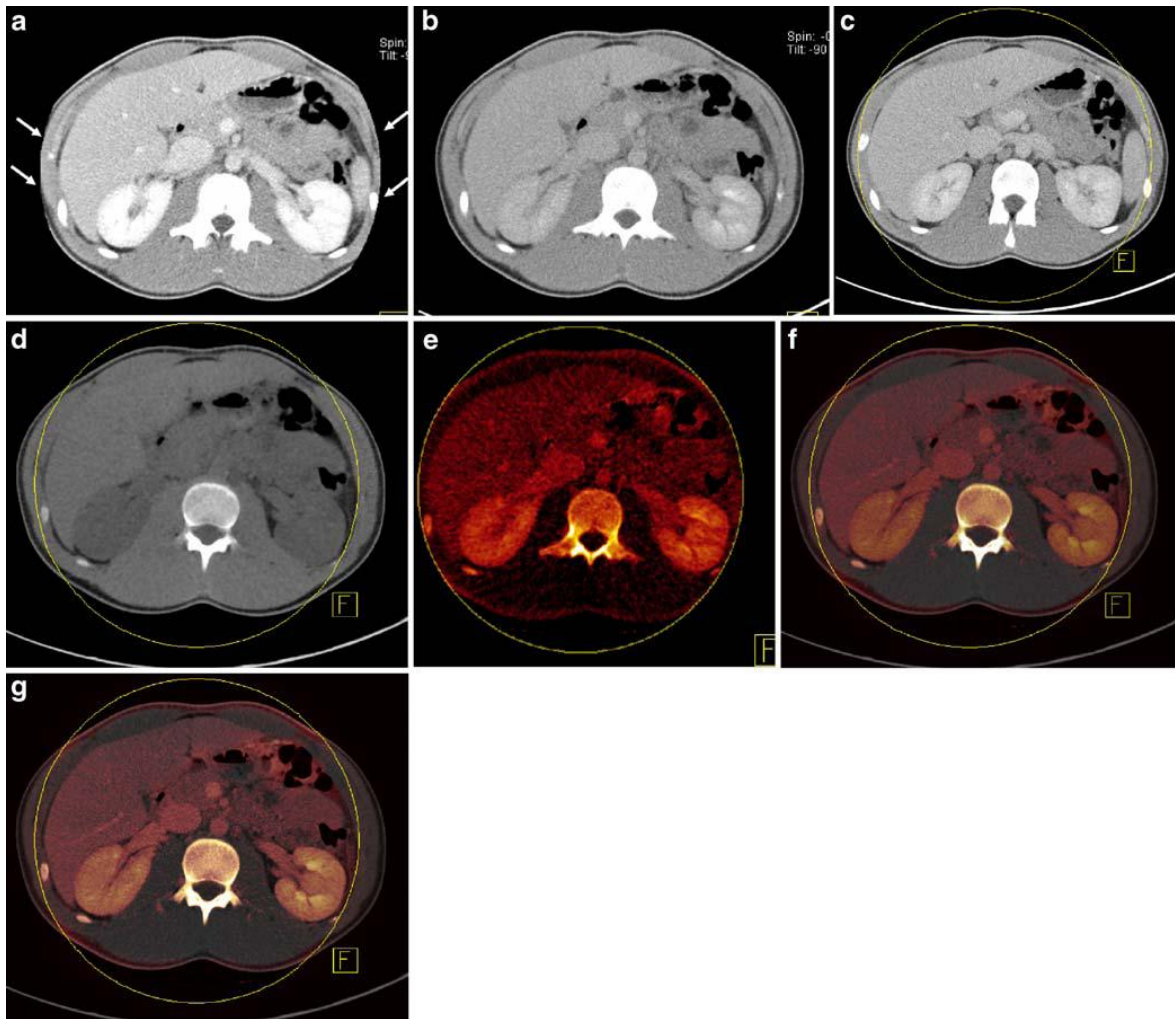


Figure 6: Image data generated from a dual energy acquisition. A. Axial CT image obtained at 80 kVp and 400 mAs. In this slim patient, only the left lateral abdominal wall is not included in the 27 cm FOV (arrows). B. Axial CT image obtained at 140 kVp and 96 mAs. Note entire abdomen is included in the standard 50 cm FOV. C. Axial CT image obtained with weighted average of 80 and 140 kVp data sets. This image equals a 120 kV image from a standard CT system. The yellow line represents the B detector FOV. D. Virtual unenhanced image. Note slightly increased image noise and FOV of the B detector (yellow line). E. Color coded iodine image showing distribution of iodine in the scan field of view (compare bright color in the kidneys). F. Virtual unenhanced image with color coded iodine overlay. Note simultaneous display of iodine distribution and unenhanced CT providing anatomical detail. G. Weighted average image with color coded iodine overlay. This image shows greater anatomical detail and information about iodine distribution.

Source: Macari, Michael et al. 2009. Dual energy CT: preliminary observations and potential clinical applications in the abdomen. *Eur Radiol*, 19, 13-23

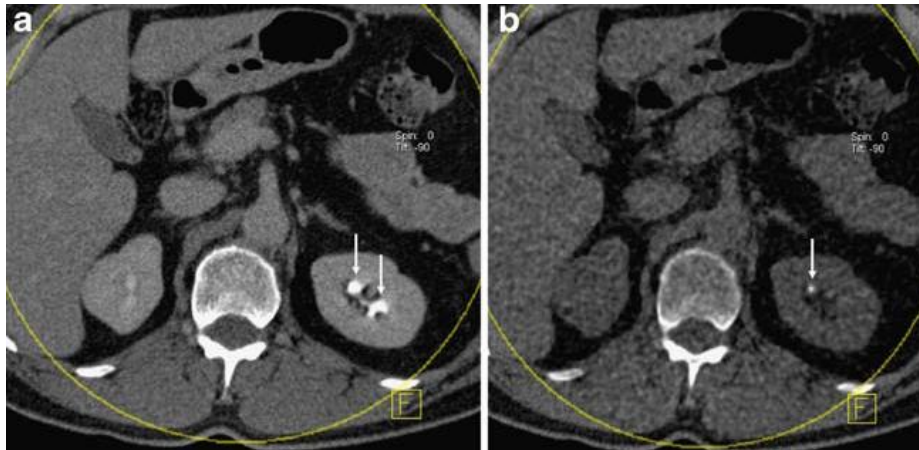


Figure 7: DECT for the evaluation of hematuria. A. Axial weighted average DECT image in the urographic phase shows contrast agent in the left renal collecting system (arrows) in a 63-year-old male imaged for evaluation of hematuria. B. In the same patient, virtual unenhanced image at the same slice position identifies a 4-mm stone in the anterior left collecting system (arrow). The stone only becomes visible after subtraction of iodine from the image.

Source: Macari, Michael et al. 2009. Dual energy CT: preliminary observations and potential clinical applications in the abdomen. *Eur Radiol*, 19, 13-23

4. CONCLUSION

The dual energy/ dual source technology has undoubtedly bring several advantages for diagnostic imaging, but limitations on the equipment operation, makes sometimes this technology very limiting. (Flohr 2007; Hofman 2008; Macari 2009)

Relatively to kidney applications, the dual-energy technology has brought new diagnostic capability with regard to the difference in composition of the stones and makes possible in just one acquisition with contrast media, the differentiation of hyperdense contrast stones. Renal masses, hematuria and other conditions may also be more easily distinguished. (Flohr 2007; Hofman 2008; Macari 2009).

5. REFERENCES

- Flohr, Thomas 2007. Material differentiation by dual energy CT: initial experience. *Eur Radiol*, 17, 1510-1517
- Hofmann, Lars K. et al. 2008. *Dual source CT Imaging*. Berlin. Springer.
- Macari, Michael et al. 2009. Dual energy CT: preliminary observations and potential clinical applications in the abdomen. *Eur Radiol*, 19, 13-23