Feasibility of CT scan studies with triple split bolus intravenous contrast medium technique and reduced radiation dose for potential kidney donors

Viabilidade do estudo tomográfico com triplo fracionamento do contraste endovenoso e redução da dose de radiação para candidatos a doadores renais

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ABSTRACT

Objective: To show that it is possible to reduce the radiation dose in the examination of potential kidney donors by splitting the contrast injection followed by a single scanning, enabling evaluation of vascular structures, renal parenchyma and collecting system/ureters, using computed tomography protocols with reduced mAs.

Methods: Twenty-six potential donors were evaluated based on the following criteria: image quality, radiation dose reduction, and complications associated with the exam. The criteria were scored by two examiners, and the differences were resolved by consensus.

Results: For each item assessed, 85 to 90% of studies were scored as very good or excellent with regards to image quality. There was excellent interobserver agreement, and there were no significant differences between the exams with low radiation dose compared to those with the conventional dose. No exam-related complications were observed.

Conclusions: The CT scan study with triple-split bolus technique and low dose is effective for reducing the dose of radiation to potential kidney donors.

Keywords: Control over radiation exposure; Donor selection; Tissue donors; Tomography, spiral computed/methods; Tomography, spiral computed/adverse effects

INTRODUCTION

The current surgery of choice for kidney donors is videolaparoscopic nephrectomy. Because of visual field limitations associated with this procedure, an image exam is paramount in order to study the urinary system in details, especially the vessels of potential donor tissues¹⁻². It is fundamental to perform an anatomical evaluation of renal arteries and veins, of the kidney collecting system and parenchyma in potential renal donors, since the feasibility of donation depends on a rigorous preoperative evaluation of these structures³⁻⁵. Figure 1 shows the anatomy of this region.

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Multiple detector spiral computed tomography (MDCT) is fast, not very invasive and allows replacing, with a single and better test, excretory urogram, ultrasound and arteriography. For these reasons, MDCT with a dedicated protocol (urotomography or Uro-CT) became the test of choice for preoperative evaluation of potential kidney donors. Nonetheless, the MDCT submits potential donors to high radiation doses, when compared to other methods – which is especially concerning when considering young and healthy individuals.

Thus, it is desirable to have a technique which allows for a maximum reduction in radiation dose, without significant loss in the diagnostic quality of the test within the ALARA (as low as reasonably achievable) concept.

Radiation dose automated modulation is calculated before the test, through the analysis of the abdomen topogram in two views (front and side views), as per illustrated in figure 2.

The parameters are automatically adjusted according to the amount of background noise accepted. Thus, in the ‘low dose’ protocol, more noise is accepted in the image when compared to the ‘standard dose’ protocol.

Besides being possible to reduce the radiation dose by reducing mAs and having an automatic dose modulation in the state-of-the-art MDCT devices, they also provide the option to reduce the number of test phases – since routinely MDCT for donors is carried out in four phases (pre-contrast, arterial/cortico-medullary, venous/nephrographic and excretory).

Contrast triple splitting is based on the intravenous injection of a standard dose of iodine contrast split into four injections, seven minutes apart from each other (for the excretory phase), one minute (venous phase) and 30 seconds (arterial phase), followed by one single scan. As an example, we showed a standard urotomography test in its arterial, venous, excretory phases, respectively, in Figure 3, and the merging of these three phases by this new protocol (Figure 4).

**OBJECTIVE**

The goal of this study was to reduce the radiation dose used in the MDCT testing of potential kidney donors, by means of a single scanning which allows physicians
METHODS

Twenty-six potential kidney donors who underwent CT scan for a preoperative evaluation from March 2008 to May 2009 were assessed, using the following criteria:
- image quality (a 0 to 5 scoring system, in which 0 is no diagnosis and 5 is excellent) for each structure assessed (renal parenchyma, collecting system, ureters, bladder, renal arteries and veins);
- dose reduction in relation to the conventional test.

The tests were carried out using a 64-channel Aquilion CT scan device (Toshiba, Otawara, Japan), with contrast administration in three injections, 30 ml (seven minutes before image acquisition for the excretory phase), 45 ml (one minute before image acquisition for the venous phase) and 0.6 ml/kg (30 seconds before image acquisition for the arterial phase).

In the standard dose kidney donor protocol, the mA (55) and the rotation time (0.5 s) are fixed, resulting in one mAs of 110. An acceptable noise level is established in the dose modulation and the equipment alternates the mA according to the thickness of the anatomical region irradiated.

The criteria were evaluated by two examiners. The statistical analysis was carried out using the Kappa method of interobserver agreement and a nonparametric test.

RESULTS

For each item assessed, most studies were scored as very good (4) or excellent (5) as far as image quality goes, as seen on Table 1.

The bladder and ureters had a lower score when compared to other parameters – however, all of them were good, very good or excellent —, probably because of the lack of maneuvers for a specific bladder study and the lack of complementary image acquisition for the ureters when not properly contrasted. Thus, even these structures were satisfactorily evaluated.

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The Kappa value for the interobserver agreement measure obtained from the analysis was 0.752 (p < 0.001, 95% confidence interval), characterizing a good agreement between observers.

Out of 26 potential donors in this study, 11 had a reduced dose also by mAs (low dose), and 15 did the test with the regular mAs standards for an abdominal CT. An analysis was carried out on these two populations by the same image quality criteria. In order to assess potential differences between the approaches, we used the Mann-Whitney nonparametric test, using the median values, as per depicted on table 2.
Both protocols were considered very good (median 4) as to diagnosis, and there was no significant diagnostic difference between them. Images from both methods are depicted on figures 7 and 8: figure 7 shows the kidney donor protocol with the standard dose, and figure 8 shows the kidney donor protocol with low dose.

The radiation measured in Sievert (Sv) – which is the equivalent dose calculated in human tissue – of a conventional urotomography in MDCT in our ward, was approximately 48 mSv. The kidney donor protocol standard dose was about 20 mSv and with low dose of approximately 14 mSv. Total dose reduction was roughly 70% when compared to a complete Uro-CT study, bringing the same necessary anatomical information for a proper preoperative planning.

**DISCUSSION**

Potential kidney donors require a broad preoperative assessment, including an accurate radiological exam. The anatomical information required for laparoscopic nephrectomy in live kidney donors include number, size, location and branching pattern of the kidney veins and arteries, as well as a detailed assessment of the parenchyma and renal collecting system.

MDCT proved to be an accurate alternative for surgical planning purposes. MDCT advantages include fast data acquisition, broad anatomical coverage, proper opacification of vessels and collecting system, and outstanding spatial resolution. In recent years, MDCT has been established as the method of choice for the preoperative evaluation of potential kidney donors. However, since the MDCT submits potential kidney donors (usually young and healthy individuals) to high doses of radiation, one alternative is a maximum
radiation dose reduction without reducing diagnostic power\(^\text{(6,8-9,11)}\).

Magnetic resonance angiography (angio-MRI) is a doable test modality for the preoperative evaluation of kidney donors. Recent MRI studies with gadolinium have shown high rates of accuracy – comparable to conventional angiography and to the Angio-CT regarding the assessment of live donors. Jha et al. assessed 64 patients submitted to laparoscopic nephrectomy, and reported that MRI showed arterial anomalies with an 89% sensitivity, 94% specificity, and 91% accuracy\(^\text{(12)}\). Nonetheless, MRI is a more expensive test, less available, longer in duration and with a lower spatial resolution when compared to the MDCT, and it also does not detect occasional small stones in the collecting system\(^\text{(10,12)}\).

ALARA means as low as reasonably achievable, and it is a radioprotection concept applicable to numerous radiological methods. Part of the principle assumes that there is no safe radiation dose, and all the noxious biological effects increase as dose increase, regardless of how small it is. Therefore, it is important to keep radiation doses in the lowest possible limit, especially when considering young and healthy patients\(^\text{(13)}\).

Thus, it would be ideal to have a method that reduced to a minimum the radiation dose used in the test, without any significant loss of quality. Numerous studies have been carried out testing protocols, adjusting image acquisition parameters or trying fewer phases. Some groups, such as Kawamoto et al. and Foley, described methods eliminating one of the phases: venous and excretory, respectively, nonetheless with critics from many authors because of a greater difficulty in characterizing some structures\(^\text{(14-15)}\).

The most promising recent study in this context used a protocol called Split Bolus. With the goal of reducing the radiation dose received by patients submitted to uroscopy to investigate hematuria, Chow et al. proposed the use of two tomographic image acquisitions: before and after contrast injection. The studies were carried out with the contrast volume to be injected (120 ml) being divided into two doses as follows: the first, 40 ml at 2 ml/s, and the second was 80 ml, also injected at 2 ml/s. The interval between injections was four minutes, with a 120-second delay after the second dose, thus allowing visualization of the nephrographic and excretory phases at the same time\(^\text{(16)}\). However, in this protocol there is no arterial phase study, since the idea is to diagnose the cause of hematuria. Thus, this protocol leaves much to be desired in those cases when it is necessary to carry out an arterial anatomy study, as is the case with kidney donors.

Aiming to meet this demand, this study suggests a protocol with three different iodine contrast injection turns (triple-split), and each is responsible for contrasting each of the systems one intends to study. Thus, with one single post-contrast tomographic image acquisition, one can obtain a simultaneous contrasting of the arterial, venous and collecting systems and, at the end of the test, one can achieve a proper study of the entire anatomy necessary for surgical planning, thus reducing the dose of ionizing radiation employed.

Another way to reduce the radiation dose for potential donors is by modulating the CT radiation dose. From the conventional Uro-CT to the triple-split protocol there was a 58% drop in the radiation dose, by only reducing the number of phases in the test. From the triple-split protocol to the triple-split with dose modulation protocol there was an additional 23% reduction in the radiation dose. In total, this study was able to reduce approximately by 70% the radiation dose when compared to a complete Uro-CT study, producing the same necessary anatomical information for a proper preoperative evaluation.

The present study has numerous limitations. First, we were unable to obtain surgical anatomy confirmation. Another limitation was the small sample size in this preliminary study. There was no matching of potential donor groups submitted to the protocols with standard dose and low dose of radiation. We believe further studies with a larger sample and surgical confirmation of the findings must be conducted in order to corroborate the results obtained in this investigation.

CONCLUSION

This study showed that contrast triple split MDCT with mAs reduction is an effective technique to reduce the preoperative radiation dose used to assess kidney donors, without significant loss of image quality.

REFERENCES


