Diagnostic efficacy and image quality of 64-slice CT angiography of the abdominal aorta and abdominal arteries at 100 kVp versus 120 kVp

Poster No.: B-345
Congress: ECR 2011
Type: Scientific Paper
Topic: Vascular
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Keywords: Arteries / Aorta, Vascular, Contrast agents, CT-Angiography
DOI: 10.1594/ecr2011/B-345

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Purpose

In 2005, approximately sixty two million Computed Tomography (CT) examinations were performed in the United States, and CT has become the leading medical source of ionizing radiation [1,2]. Although the linear no-threshold relationship between the radiation dose range administered by CT and the risk of cancer is still debated [3], many concerns and warnings have been raised about the possible role of CT in carcinogenesis [4]. Children, adolescents, females, and patients exposed to repeated examinations would be at greatest risk [1].

A reduction of the radiation dose delivered during CT has therefore become an important issue, and various techniques and patient-based strategies have been described.

Consequently, the radiology community's responsibility is to try to limit the dose received by each patient during each examination in accordance with the As Low As Reasonably Achievable (ALARA) principle.

The present research is an exploratory retrospective study of a cohort enrolled in a previously reported trial [5]. This trial focused on abdominal MDCT angiography and essentially demonstrated the non-inferiority of a 350 mgI/mL contrast medium (iobitridol) as compared to a 400 mgI/mL contrast medium (iomeprol) in terms of diagnostic efficacy, confirming that a lower total amount of iodine does not yield inferior diagnostic contribution results. It also confirmed the high robustness and reliability of abdominal MDCT angiography across multinational, multivendor practices.

The purpose of the present study was to assess the influence of x-ray tube voltage (100 vs 120 kVp) on various efficacy parameters (diagnostic efficacy, image quality, arterial enhancement) and effective dose in abdominal MDCT angiography. The impacts of body mass index (BMI), endoprosthesis and iodine concentration were also assessed.
Methods and Materials

Inclusion/Exclusion criteria

Inclusion criteria were patients aged 18 to 85 years, with common indications for abdominal MDCT angiography: pre-therapeutic assessment of abdominal aorta aneurysm, follow-up of surgical or endovascular treatment, or staging of certain abdominal malignancies. Patients with hemodynamic instability, uncompensated heart failure, or severe hypertension (systolic blood pressure > 180 mmHg or diastolic blood pressure > 110 mmHg) were not included. Pregnant women and nursing mothers, patients with severe renal insufficiency (estimated creatinine clearance below 30 mL/min), taking treatment with diuretics or biguanides during the 48 hours prior to CT angiography, with known thyrotoxicosis, or a history of hypersensitivity to iodinated contrast agents were also not included. For CT angiography, patients received either iobitridol 350 mg/mL (Xenetix®, Guerbet, France) or iomeprol 400 mgI/mL (Iomeron®, Bracco, Italy).

CT angiography

All examinations were performed on 64-slice single-source CT systems (Siemens Somatom Sensation, GE Lightspeed VCT, Philips Brilliance) and on a dual-source Siemens Somatom Definition used as a single-source. An unenhanced CT scan of the abdomen was followed by enhanced abdominal CT angiography during the arterial first pass. When clinically indicated, additional venous or late-phase scans were performed, but were not part of the study protocol. All nine study centres were free to use their own routine abdominal CT angiography protocol including voltage and current intensity. In particular, patients were not assigned to a specific CT protocol depending on their age, BMI or endoprosthesis status. In eight out of the nine centres, automatic mAs modulation was used while current intensity was fixed in one. The technical requirements of the trial were limited as follows: a volume of contrast medium not exceeding 150 mL, the use of bolus detection software (either automatic or manual) to launch acquisition, and coverage in the z-axis extending from the suprarenal aorta to the femoral bifurcation. Iodine doses were calculated.

Patients’ body habitus and CT parameters

The BMI, presence or absence of vascular prosthesis and radiological parameters (kVp, current intensity time product (mAs)) were prospectively recorded. In addition, the estimated doses provided by the manufacturers were retrospectively collected as follows: Dose Length Product (DLP) and volume CT Dose Index (CTDItvol) assessment from the angiographic part of the MDCT.
Diagnostic efficacy (primary endpoint)

Image assessment was prospective and performed on site by an experienced radiologist. The radiologist rated the diagnostic efficacy using a four-point scale ranging from 0 (not satisfactory at all), over to 3 (totally satisfactory) with intermediate levels 1 (not satisfactory, not providing all the expected information) and 2 (satisfactory).

Vessel image quality

Sixteen different arterial segments were rated for image quality: the suprarenal, juxtarenal, and infrarenal aorta, the celiac axis and its two branches, the superior and inferior mesenteric arteries, the right and left renal arteries, the right and left common and external iliac arteries, the right and left hypogastric arteries, and the right and left common femoral arteries. The following four-point scale was used for each of these segments: 0 (null), 1 (poor), 2 (good), and 3 (excellent). If the segment was not in the field of view, this segment was scored as "not applicable".

Quantification of arterial enhancement

To estimate the absolute and relative arterial enhancement (expressed in Hounsfield Units, HU), regions of interest (ROIs) were defined on unenhanced and on enhanced scans in the same table position. Enhancement was measured in eight predefined segments (suprarenal and infrarenal aorta, right and left renal arteries, right and left common iliac arteries, and right and left common femoral arteries). For measurement purposes, ROIs were defined as round surfaces in the lumen of the vessel, the circumference of which should not extend beyond the internal limit of the arterial wall.

Statistical analysis

All analyses were performed on all available data of the intent-to-treat population using SAS software version 9.1.3 for Windows (SAS Institute Inc, Cary, North Carolina). Mean, median, standard deviation, minimum and maximum values were used to describe continuous variables. Absolute and relative frequencies converted into percentages were used to describe categorical variables.
Results

Three hundred and ten patients referred for CT angiography of the abdominal aorta and/or abdominal arteries were enrolled in this trial from August 2006 to February 2008. Exposure parameters (tube voltage, kVp, and mAs) were recorded for 307 patients (244 men and 63 women, mean age: 66.5 years, mean BMI: 26.5± 4.4 kg/m^2).

Study population

Table 1 summarizes the gender, age, confounding factors (BMI, endoprosthesis and iodinated contrast agent) and type of CT used for these 307 patients. The baseline characteristics of the study population were balanced between groups. Fifty six patients (18%), including 34 (61%) with BMI #25 kg/m^2, were examined at 100 kVp [30 on GE and 26 on Siemens systems], and 251 patients (82%) were examined at 120 kVp (158 (63%) had BMI #25 kg/m^2). Overweight patients (BMI #25 kg/m^2) accounted for almost two thirds of the study population and were equally distributed between the two kVp groups. Almost one out of five patients was obese (BMI #30 kg/m^2).

Hundred and twenty nine patients (42%) with vascular prosthetic material were included with a relatively balanced proportion of patients examined at 100 kVp and at 120 kVp (19 in the 100 kVp group (33.9%) versus 110 in the 120 kVp group (43.8%)).

Hundred and fifty four patients received an injection of iomeprol 400 mgI/mL (51.8% at 100 kVp / 49.8% at 120 kVp) and 153 received an injection of iobitridol 350 mgI/mL (48.2% at 100 kVp / 50.2% at 120 kVp).
Exposure parameters and dose reports

As shown in Figure 1, the mean mAs was significantly higher in the 120 kVp group (342.1 ±192.3) compared to the 100 kVp group (215.3 ±111.9) (p<0.001).

The DLP and CTDI\textsubscript{vol} were obtained retrospectively for the angiographic part of the MDCT in 188 patients (34 in the 100 kVp group and 154 in the 120 kVp group). The mean DLP in the 100 kVp group was 382.6 ±128.4 mGy.cm vs 1031.5±558.5 mGy.cm in the 120 kVp group (p<0.001). By applying a conversion coefficient of 0.015 mSv.mGy\textsuperscript{-1}.cm\textsuperscript{-1} [6],
the effective dose was 5.7±1.9 mSv in the 100 kVp group vs 15.5±8.4 mSv in the 120 kVp group. The CTDI$_{vol}$ was 6.5±2.9 mGy in the 100 kVp group vs 17.2±8.6 mGy in the 120 kVp group (p<0.001). A threefold reduction of the radiation dose was therefore demonstrated for both CTDI$_{vol}$ and DLP.

Fig.

References: Hôpital Charles Nicolle, Radiologie Centrale - Rouen/FR

Diagnostic efficacy results

As shown in Table 2, the diagnostic contribution was equivalent for the two x-ray tube voltages, with no impact of BMI, endoprosthesis and iodinated contrast agent concentration. The examinations were deemed suboptimal in 2 of the 307 patients. Grade 0 was attributed in one patient (120 kVp), grade 1 in 1 patient (120 kVp), grade 2 in 5 patients (one patient studied at 100 kVp and 4 patients studied at 120 kVp).
### Table 2. Diagnostic contribution according to X-ray power and confounding factors

<table>
<thead>
<tr>
<th></th>
<th>kVp 100</th>
<th>kVp 120</th>
<th>all</th>
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<tbody>
<tr>
<td></td>
<td>N=56</td>
<td>N=251</td>
<td>N=307</td>
</tr>
<tr>
<td><strong>Diagnostic contribution overall</strong></td>
<td></td>
<td></td>
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<tr>
<td>Not satisfactory</td>
<td>0 (0.0%)</td>
<td>2 (0.8%)</td>
<td>2 (0.7%)</td>
</tr>
<tr>
<td>Totally satisfactory / satisfactory</td>
<td>56 (100.0%)</td>
<td>249 (99.2%)</td>
<td>305 (99.3%)</td>
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<tr>
<td><strong>Patients without endoprosthesis</strong></td>
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<tr>
<td>Not satisfactory</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
<td>0 (0.0%)</td>
</tr>
<tr>
<td>Totally satisfactory / satisfactory</td>
<td>37 (100%)</td>
<td>141 (100%)</td>
<td>178 (100%)</td>
</tr>
<tr>
<td><strong>Patients with endoprosthesis</strong></td>
<td></td>
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<tr>
<td>Not satisfactory</td>
<td>19 (0.0%)</td>
<td>110 (18.8%)</td>
<td>129 (14.1%)</td>
</tr>
<tr>
<td>Totally satisfactory / satisfactory</td>
<td>19 (100.0%)</td>
<td>108 (99.2%)</td>
<td>127 (99.4%)</td>
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<tr>
<td><strong>Patients with BMI &lt; 25 kg/m²</strong></td>
<td></td>
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<tr>
<td>Not satisfactory</td>
<td>22 (0.0%)</td>
<td>93 (100%)</td>
<td>115 (100%)</td>
</tr>
<tr>
<td>Totally satisfactory / satisfactory</td>
<td>22 (100.0%)</td>
<td>93 (100.0%)</td>
<td>115 (100.0%)</td>
</tr>
<tr>
<td><strong>Patients with BMI ≥ 25 kg/m²</strong></td>
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<tr>
<td>Not satisfactory</td>
<td>34 (0.0%)</td>
<td>156 (98.7%)</td>
<td>190 (99.0%)</td>
</tr>
<tr>
<td>Totally satisfactory / satisfactory</td>
<td>34 (100.0%)</td>
<td>156 (98.7%)</td>
<td>190 (99.0%)</td>
</tr>
<tr>
<td><strong>Patients with lioptrol 400</strong></td>
<td></td>
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<tr>
<td>Not satisfactory</td>
<td>27 (0.0%)</td>
<td>126 (100%)</td>
<td>153 (100%)</td>
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<tr>
<td>Totally satisfactory / satisfactory</td>
<td>27 (100.0%)</td>
<td>125 (99.2%)</td>
<td>152 (99.3%)</td>
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<tr>
<td><strong>Patients with lioptrol 350</strong></td>
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<tr>
<td>Not satisfactory</td>
<td>29 (0.0%)</td>
<td>125 (100%)</td>
<td>154 (100%)</td>
</tr>
<tr>
<td>Totally satisfactory / satisfactory</td>
<td>29 (100.0%)</td>
<td>124 (99.2%)</td>
<td>153 (99.4%)</td>
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</table>

**Fig.:** Table 2  
**References:** Hôpital Charles Nicolle, Radiologie Centrale - Rouen/FR  
**Vessel image quality**

The per segment distribution of good or excellent vessel image quality according to kVps demonstrated significantly better image quality in the 120 kVp group (87.6 vs 96.4%). No impact on image quality was observed for any of the three confounding factors.

**Vessel lumen enhancement**

As expected, vessel lumen enhancement was significantly better in the 100 kVp group. The mean Hounsfield Unit value of the 419 segments assessed at 100 kVp in 56 patients
was 378.5±86.6 vs 328.2±95.5 in the 1,974 segments assessed at 120 kVp in 251 patients (p=0.0001). In contrast, vessel lumen enhancement was not influenced by BMI, endoprosthesis, or concentration of iodinated contrast agent injected.

**Iodine dose**

The iodine dose was 31.5 ± 6.9 g in the 100 kVp group versus 39.5 ± 6.1 g in the 120 kVp group (p<0.001).
Fig. 0

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Conclusion

Using 100 kVp instead of 120 kVp for MDCT abdominal angiography has no impact on diagnostic contribution, even in patient with a BMI greater than 25 kg/m$^2$, and/or vascular prosthetic material and/or when using an iodine concentration as low as 350 mgI/mL. Although setting the x-ray tube at 100 kVp does not impact the diagnostic efficacy of abdominal 64-slice MDCT angiography, it negatively impacts the image quality; but this drawback does not prevent accurate diagnosis. Scanning patients at 100 kVp is compatible with a two-third reduction of the radiation dose.
References


Personal Information

Jean-Nicolas Dacher, MD, PhD is a Professor of Radiology and Diagnostic Imaging at University Hospital of Rouen.

This retrospective study was partially based on the data from a previously published multicenter trial (6) with Prof. Dr. Christian Loewe, Vienna, Austria as principal investigator.

Guerbet SA, Roissy, France, sponsored the multicenter trial and allowed this additional study.

Acknowledgements

The authors are grateful to Farid Khalfi, Joelle El Khoury, Philippe Zamia and Corinne Dubourdieu (Guerbet SA, Roissy, France) for their very helpful support.