ORIGINAL RESEARCH

Latest generation of flat detector CT as a peri-interventional diagnostic tool: a comparative study with multidetector CT

Johanna Rosemarie Leyhe, Ioannis Tsogkas, Amélie Carolina Hesse, Daniel Behme, Katharina Schregel, Ismini Papageorgiou, Jan Liman, Michael Knauth, Marios-Nikos Psychogios

ABSTRACT

Background and purpose Flat detector CT (FDCT) has been used as a peri-interventional diagnostic tool in numerous studies with mixed results regarding image quality and detection of intracranial lesions. We compared the diagnostic aspects of the latest generation FDCT with standard multidetector CT (MDCT).

Materials and methods 102 patients were included in our retrospective study. All patients had undergone interventional procedures. FDCT was acquired peri-interventionally and compared with postinterventional MDCT regarding depiction of ventricular/subarachnoidal spaces, detection of intracranial hemorrhage, and delineation of ischemic lesions using an ordinal scale. Ischemic lesions were quantified with the Alberta Stroke Program Early CT Scale (ASPECTS) on both examinations. Two neuroradiologists with varying grades of experience independently screened the anonymized images separately, blinded to the clinical history.

Results The two methods were of equal diagnostic value regarding evaluation of the ventricular system and the subarachnoidal spaces. Subarachnoidal, intraventricular, and parenchymal hemorrhages were detected with a sensitivity of 95%, 97%, and 100%, and specificity of 97%, 100%, and 99%, respectively, using FDCT. Gray–white differentiation was feasible in the majority of FDCT scans, and ischemic lesions were detected with a sensitivity of 71% on FDCT, compared with MDCT scans. The mean difference in ASPECTS values on FDCT and MDCT was 0.5 points (95% CI 0.12 to 0.88).

Conclusions The latest generation of FDCT is a reliable and accurate tool for the detection of intracranial hemorrhage. Gray–white differentiation is feasible in the supratentorial region.

INTRODUCTION

In the past decade, non-contrast flat detector CT (FDCT), acquired with angiography systems, has been used primarily for postinterventional detection of complications, such as subarachnoidal or parenchymal hemorrhage (PH).1 Multiple studies comparing the diagnostic features of FDCT with multidetector CT (MDCT) have shown good image quality in the supratentorial region, with reliable detection of large hemorrhages, albeit limited image quality in the infratentorial region due to diverse image artifacts.2–4 Detection of ischemic lesions with FDCT has been inconsistent to date, due to the inferior contrast resolution and diverse artifacts of the cone beam acquisition. The latest generation of FDCT promises improved image quality.

The new high dynamic range flat detector with a 16 bit analog–digital conversion in combination with an entire image processing pipeline as well as a reconstruction algorithm chain running on 16 bit allows for enhanced soft tissue resolution. This technology package results in four times more gray value differentiation compared with conventional systems. Improved FDCT fidelity in the detection of hemorrhagic and ischemic lesions could expand the role of FDCT in acute stroke diagnostics (so called ‘one stop management’) with a possible impact on door to groin times.

In this study, we tested and compared latest generation FDCT images with standard MDCT scans regarding depiction of ventricular/subarachnoidal spaces, detection of ischemic/hemorrhagic lesions, and the presence of artifacts.

METHODS

We retrospectively screened all angiographic procedures in our department after installation of the latest generation angiography suite (Artis Q Angiography System; Siemens Healthcare GmbH, Forchheim, Germany) from September 2014 to April 2016 for acquisition of FDCT. Patients with FDCT scans were then screened for postinterventional MDCT scans. Only patients with complete FDCT and MDCT scans were included in our analysis. Three scans with marked motion artifacts were excluded. The ethics committee of our hospital waived the need for a formal application or informed patient consent due to the retrospective design of this study.

FDCT was acquired with a biplane flat detector angiography system using the following parameters: 20 s of rotation; 200° total angle with approximately 500 projections; 2×2 binning; 109 kV; 1.8 μGy/frame; weighted CT dose index (CTDIw) ~60 mGy, effective dose ~2.5 mSv. Initial FDCT projections were then reconstructed on a postprocessing workstation (Syngo X Workplace; Siemens Healthcare GmbH) with a ‘HU smooth’ kernel and ‘DynaCT Clear’ algorithm to images with a 512×512 matrix. MDCT was acquired on a 128...
slice CT scanner (Somatom Definition AS+; Siemens Healthcare GmbH) using a standard brain scan protocol. Raw FDCT and MDCT data were extracted from the department's picture archiving and communication system, anonymized, reconstituted parallel to the orbitomeatal plane with a slice thickness of 5 mm and slice distance of 3 mm, and imported for evaluation into the aforementioned postprocessing workstation.

Two neuroradiologists (M-NP, >5 years of experience; IT, <5 years of experience) and a medical student (ACH), analyzed all of the images using a 3 point ordinal scale (0=not identifiable; 1=identifiable, but not diagnostic; 2=diagnostic) for the following structures/entities: supratentorial ventricular system, infratentorial ventricular system, supratentorial subarachnoidal space, infratentorial subarachnoidal space, and gray–white differentiation of the basal ganglia, insula, central region, and cerebellum. Raters were asked to identify subarachnoidal hemorrhage (SAH), intraventricular hemorrhage (IVH), PH, and cerebellum. Raters were blinded to all clinical information.

Scores for the infratentorial ventricular system and infratentorial subarachnoidal spaces on FDCT were slightly worse, with 92 (90%) and 98 (96%) ‘diagnostic’ values, respectively (table 1). Scores for the infratentorial ventricular system and infratentorial subarachnoidal spaces on FDCT were significantly different compared with MDCT scans. Additionally, ASPECTS ratings on FDCT (figure 2C) showed a mean difference of 0.5 points (95% CI 0.12 to 0.88) in the Bland–Altman plot (see online supplementary figure S1A) compared with ratings of MDCT images. When asked about their opinion on ischemic lesion detectability, raters stated that in 98% and 99% of cases

### Table 1: Rating of Cerebral Structures

<table>
<thead>
<tr>
<th>Variable</th>
<th>Diagnostic n (%)</th>
<th>Identifiable but not diagnostic n (%)</th>
<th>Not identifiable n (%)</th>
<th>Total n (%)</th>
<th>Wilcoxon p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supratentorial ventricular system</td>
<td>FDCT 102 (100)</td>
<td>0 (0)</td>
<td>0 (0.0)</td>
<td>102 (100)</td>
<td>–</td>
</tr>
<tr>
<td></td>
<td>MDCT 102 (100)</td>
<td>0 (0)</td>
<td>0 (0.0)</td>
<td>102 (100)</td>
<td>–</td>
</tr>
<tr>
<td>Infratentorial ventricular system</td>
<td>FDCT 92 (90)</td>
<td>9 (9)</td>
<td>1 (1)</td>
<td>102 (100)</td>
<td>0.106</td>
</tr>
<tr>
<td></td>
<td>MDCT 98 (96)</td>
<td>3 (3)</td>
<td>1 (1)</td>
<td>102 (100)</td>
<td></td>
</tr>
<tr>
<td>Supratentorial subarachnoidal space</td>
<td>FDCT 98 (96)</td>
<td>4 (4)</td>
<td>0 (0)</td>
<td>102 (100)</td>
<td>0.813</td>
</tr>
<tr>
<td></td>
<td>MDCT 99 (97)</td>
<td>3 (3)</td>
<td>0 (0)</td>
<td>102 (100)</td>
<td></td>
</tr>
<tr>
<td>Infratentorial subarachnoidal space</td>
<td>FDCT 75 (74)</td>
<td>25 (25)</td>
<td>2 (2)</td>
<td>102 (100)</td>
<td>0.177</td>
</tr>
<tr>
<td></td>
<td>MDCT 85 (83)</td>
<td>14 (14)</td>
<td>3 (3)</td>
<td>102 (100)</td>
<td></td>
</tr>
<tr>
<td>Gray–white differentiation of basal ganglia</td>
<td>FDCT 97 (95)</td>
<td>5 (5)</td>
<td>0 (0)</td>
<td>102 (100)</td>
<td>0.563</td>
</tr>
<tr>
<td></td>
<td>MDCT 99 (97)</td>
<td>3 (3)</td>
<td>0 (0)</td>
<td>102 (100)</td>
<td></td>
</tr>
<tr>
<td>Gray–white differentiation of insular cortex</td>
<td>FDCT 94 (92)</td>
<td>8 (8)</td>
<td>0 (0)</td>
<td>102 (100)</td>
<td>0.625</td>
</tr>
<tr>
<td></td>
<td>MDCT 96 (94)</td>
<td>6 (6)</td>
<td>0 (0)</td>
<td>102 (100)</td>
<td></td>
</tr>
<tr>
<td>Gray–white differentiation of central cortex</td>
<td>FDCT 98 (96)</td>
<td>4 (4)</td>
<td>0 (0)</td>
<td>102 (100)</td>
<td>0.813</td>
</tr>
<tr>
<td></td>
<td>MDCT 99 (97)</td>
<td>3 (3)</td>
<td>0 (0)</td>
<td>102 (100)</td>
<td></td>
</tr>
<tr>
<td>Gray–white differentiation of cerebellum</td>
<td>FDCT 57 (56)</td>
<td>37 (36)</td>
<td>8 (8)</td>
<td>102 (100)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>MDCT 88 (86)</td>
<td>13 (13)</td>
<td>1 (1)</td>
<td>102 (100)</td>
<td></td>
</tr>
</tbody>
</table>

FDCT, flat detector CT; MDCT, multidetector CT.
they were sure about the detection/exclusion of extended (ASPECTS <5) ischemic lesions on FDCT and MDCT, respectively (p=0.019).

SAH was diagnosed in 39 cases with FDCT; 37 were true positives, resulting in a sensitivity of 95% and a specificity of 97% (see online supplementary table S1; p<0.001; AUC 0.96, 95% CI 0.89 to 0.98) (figure 3). One false negative FDCT scan included an SAH seen on a few slices (group with 2–12) on MDCT and one seen on several MDCT slices (group with 12–33). Thirty-three of the 34 IVH cases were detected on FDCT (p<0.001; AUC 0.98; 95% CI 0.93 to 0.99). The one false negative FDCT scan included an IVH seen on a few slices (group with 2–4) on MDCT. All cases diagnosed with PH on MDCT were also depicted and scored similarly on FDCT, resulting in 100% sensitivity and 99% specificity of FDCT for the detection of PH (p<0.001; AUC 0.99; 95% CI 0.95 to 1.00). The median slice count of PH on MDCT was 10 (IQR 8–13). The mean difference between PH measurements on FDCT and MDCT was −35.13 mm² (95% CI −88.67 to 18.39 mm², see online supplementary figure S1B). In the supratentorial region, raters found ‘very good’ image quality for hemorrhage detection in 87% of FDCT scans compared with 93% of MDCT examinations (p=0.266). A statistically significant difference was shown in the same category of scores in the infratentorial region, with 58% of ‘very good’ scores on FDCT compared with 78% on MDCT (p=0.002). When asked about their subjective judgement on hemorrhagic lesion detectability, raters stated that in 98% and 99% of cases they were sure about the detection/exclusion of hemorrhagic lesions on FDCT and MDCT, respectively (p=1).

Metal artifacts were delineated in 22% of FDCT scans, with only one case with significant degradation of image quality. Motion, ring, and burn-in artifacts were visible on 26%, 23%, and 24% of FDCT scans, respectively. Streak artifacts were present on the majority of FDCT scans (72%). However, most artifacts only slightly affected the image quality of FDCT scans. The highest correlation coefficient between overall raters’ scores was documented between the two physicians (r=0.80; 95% CI 0.79 to 0.81) while lower values were documented between the experienced physician and the medical student (r=0.71; 95% CI 0.69 to 0.73) as well as the inexperienced physician and the medical student (r=0.69; 95% CI 0.68 to 0.71).

**DISCUSSION**

The primary use of FDCT to date has been limited to detection of peri-interventional complications, such as SAH after coiling.
much improved compared with previous generations of FDCT, there was no statistically significant region was feasible with the latest generation of FDCT, as diagnosed on FDCT. Gray regardless of size or intracranial location, were depicted and FDCT and were visible on only a few MDCT slices. All PH, specifically smaller focal spot sizes, thus enhancing image sharpness in all viewing directions. As in previous studies, delineation of supratentorial ventricles was excellent with FDCT. Compared with past generations of FDCT, a significant improvement was observed in the infratentorial region, as we found 74% and 90% of FDCT scans to be of ‘diagnostic’ quality regarding depiction of subarachnoidal spaces and of the fourth ventricle, respectively (29% and 61% in a previous study). However, with limited diagnostic quality in 26% of FDCT scans, detection of small infratentorial SAH can be challenging. This fact should be taken into consideration in future studies evaluating the use of FDCT as a primary triage tool in stroke. The radiation dose of the FDCT scan used in our study is comparable with incremental MDCT examinations with an effective dose of approximately 2.5 mSv.

The primary limitation of our study is its retrospective character. As FDCT and MDCT scans were acquired with a time delay, we cannot exclude false negative results due to new hemorrhage or demarcation of ischemic lesions. Two false positive SAH cases on FDCT were a result of contrast media extravasation after a long intervention which was falsely rated as an SAH on FDCT but resolved after a few hours on MDCT. Lastly, FDCT detectability of ischemic lesions and gray–white differentiation may have been enhanced by the presence of contrast media, in cases where FDCT was performed postinterventionally.

Our results may impact the management of acute stroke patients. After publication of the ‘unhappy triad’ of negative trials in 2013, time from hospital admission to reperfusion was identified as a reason for the negative results, in addition to the use of older devices and low reperfusion rates. The authors of the ‘unhappy triad’ trials reported significant delays to initiation of endovascular treatment, with up to 120 min from imaging to groin puncture. Inhospital times were much improved in the five positive randomized trials published in 2015, with a median door to groin time of 104 min. However, only 13% and 4% of the randomized patients were treated within the ‘ideal’ SNIS 2015 intervals of ≤60 min for door to groin time and ≤30 min for imaging to groin time. Even with a streamlined process, Frei et al. recently reported a median door to groin time of 71 min for direct admission patients undergoing triage with MDCT.

Implementation of a one stop management for stroke patients could lead to a reduction in inhospital times. In our department, we estimated a time gain of approximately 30 min if we bypass MDCT and transport patients with suspected large vessel occlusions directly to the angi suite (Psychogios MN, unpublished data, 51th Meeting of the German Society of Neuroradiology, http://dgmr.conference2web.com/content/748/details?from_view=all, 2016). The addition of flat detector CT perfusion or multiphase flat detector CT angiography allows the acquisition of multimodal CT within the angi suite as a complete stroke.
imaging battery without relevant limitations compared with MDCT multimodal imaging.15 16

CONCLUSIONS
The latest generation of FDCT is a reliable and accurate tool for the detection of intracranial hemorrhage. Gray–white differentiation is feasible in the supratentorial region but seems limited for the infratentorial brain.

Contributors Guarantor of the integrity of the entire study: M-NP. Study concepts: MK and M-NP. Study design: M-NP, JRL, IT, and ACH. Definition of intellectual content: M-NP, IT, and JRL. Literature research: M-NP, JRL, DB, and KS. Clinical studies: IT, JRL, DB, KS, and ACH. Data acquisition: IT, JRL, DB, and KS. Data analysis: M-NP, MK, IP, and ACH. Statistical analysis: M-NP, JRL, and IP. Manuscript preparation: M-NP, JRL, and JRL. Manuscript editing: M-NP and DB. Manuscript review: M-NP, MK, JRL, and IP.

Competing interests The Department of Neuroradiology, University Medicine Goettingen, has a research agreement with Siemens Healthcare GmbH, Forchheim, Germany.

Ethics approval The study was approved by the ethics committee of University Medicine Goettingen, has a research agreement with Siemens Healthcare GmbH, Forchheim, Germany.

Provenance and peer review Not commissioned; externally peer reviewed.

Previous or future presentations DGNR, October 2016, German Neuroradiology Society Meeting, Cologne, Germany; International Stroke Conference, February 2017, Houston, Texas, USA.

Open Access This is an Open Access article distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited and the use is non-commercial. See: http://creativecommons.org/licenses/by-nc/4.0/

REFERENCES
Latest generation of flat detector CT as a peri-interventional diagnostic tool: a comparative study with multidetector CT

Johanna Rosemarie Leyhe, Ioannis Tsogkas, Amélie Carolina Hesse, Daniel Behme, Katharina Schregel, Ismini Papageorgiou, Jan Liman, Michael Knauth and Marios-Nikos Psychogios

doi: 10.1136/neurintsurg-2016-012866

Updated information and services can be found at:
http://jnis.bmj.com/content/9/12/1253

These include:

References
This article cites 14 articles, 6 of which you can access for free at:
http://jnis.bmj.com/content/9/12/1253#BIBL

Open Access
This is an Open Access article distributed in accordance with the Creative Commons Attribution Non Commercial (CC BY-NC 4.0) license, which permits others to distribute, remix, adapt, build upon this work non-commercially, and license their derivative works on different terms, provided the original work is properly cited and the use is non-commercial. See: http://creativecommons.org/licenses/by-nc/4.0/

Email alerting service
Receive free email alerts when new articles cite this article. Sign up in the box at the top right corner of the online article.

Topic Collections
Articles on similar topics can be found in the following collections

- Neuroimaging (158)
- Open access (74)

Notes

To request permissions go to:
http://group.bmj.com/group/rights-licensing/permissions

To order reprints go to:
http://journals.bmj.com/cgi/reprintform

To subscribe to BMJ go to:
http://group.bmj.com/subscribe/