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Clinical evaluation of flat-panel detector compared with multislice computed tomography in 65 patients with acute intracranial hemorrhage: initial results

Clinical article

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Object. The goal in this study was to compare flat-panel detector (FD) CT with multislice (MS) CT in the visualization of intracerebral hemorrhage (ICH), subarachnoid hemorrhage (SAH), intraventricular hemorrhage, and external ventricular drains (EVDs) to evaluate the diagnostic quality and limitations of the new FD CT imaging modality.

Methods. Neuroimages obtained in 65 patients, including 24 with EVDs, were reviewed by 2 independent, experienced clinicians. Lesions in all patients were investigated with FD CT and MS CT. The numbers of slices positive for ICH and SAH were counted, and for ICH the diameter and area of the lesion was measured. The positioning of drains was assessed. The presence of ventricular blood was noted. Statistical analysis was performed by calculating the Pearson correlation coefficient (r) to evaluate the level of inter- and intraobserver agreement, and linear regression analysis was done to visualize the results of the numbers of ICH- and SAH-positive slices.

Results. The authors found high interobserver agreement regarding the number of slices with evidence of ICH (r = 0.89 for MS CT, r = 0.78 for FD CT) and SAH (r = 0.88 for MS CT, r = 0.9 for FD CT). Thin layers of blood in the ventricles were not detected on FD CT in 36.4% of cases. Six of 7 perimesencephalic SAHs were not seen on FD CT scans. The EVDs could be assessed with both modalities in 83.3% of cases, but the position of the drain could not be determined with FD CT in 16.7% (4 of 24 cases).

Conclusions. In some respects, FD CT is of limited use for the visualization of intracranial hemorrhage. However, despite limited contrast resolution, ICH and EVDs can be reliably demonstrated. Perimesencephalic SAH and thin layers of blood in the occipital horns may not be detected using FD CT. Further evaluation and improvement of the image quality is necessary before FD CT will provide identical quality in comparison with MS CT.
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Key Words • **flat-panel detector computed tomography** • **multislice computed tomography** • **intracranial hemorrhage** • **external ventricular drain**

The emergency management of intracranial hemorrhage warrants fast and effective treatment strategies. An increase in hematoma volume with ICH and rebleeding in SAH are the principal causes of early neurological deterioration.[2,7,15] Moreover, during endovascular procedures, rebleeding and the rupture of an aneurysm or arteriovenous malformation have continued to be some of the most feared complications, even though the incidence in high-volume centers is low (2–5%).[1,13] In these patients, secondary IVH is seen quite often either as thin layers of blood in the occipital horns or as a blood clot occupying the whole ventricle, and may lead to obstructive hydrocephalus with poor outcome.[5] Almost all of these patients receive EVDs to control increased intracranial pressure. Imaging is required to confirm the correct position of the drain. Computed tomography scanning is the most effective method of diagnosing and monitoring ICH, SAH, IVH, and the position of EVDs.[7] Ideally, a CT

Abbreviations used in this paper: EVD = external ventricular drain; FD = flat-panel detector; ICH = intracerebral hemorrhage; IVH = intraventricular hemorrhage; MS = multislice; r = Pearson correlation coefficient; REV 1, 2 = Reviewer 1, 2; SAH = subarachnoid hemorrhage.

option should be available within the angiography suite without having to transport or reposition the patient, to rule out early rebleeding or to confirm the correct positioning of an EVD. For this purpose, some manufacturers offer the combination of an angiography/CT suite by using FD technology for conventional angiography and the option of FD CT interchangeably with the C-arm of the angiography machine.[10] This new technology offers the possibility of generating CT-like cross-sectional images without patient transfer. The FD CT scan and postprocessing of raw data are performed within a few minutes. This possibility could avoid transport to the CT unit and save time if the image quality of FD CT is equivalent to MS CT.

The FD CT technique was initially developed for high-contrast vascular imaging.[16] Although the contrast resolution of the latest angiographic devices equipped with FDs is not yet achieving the performance of CT scanners, these FDs provide an almost CT-like contrast resolution, allowing the differentiation of lesions with a density difference as small as 10 HU.[9,12] There is little information available on the use of FD CT for visualization of ICH, SAH, IVH, or EVDs. However, preliminary results suggest good visibility of ICH and SAH.[4,17] The aim of this study was therefore to compare FD CT with MS CT in the visualization of ICH, SAH, IVH, and EVDs, and to evaluate the diagnostic quality and limitations of FD CT. Our hypothesis was that FD CT scanning has the ability to show hemorrhages with MS CT–like image quality. Because not only neuroradiologists but also clinicians will have to evaluate the images to make further decisions on the management of hemorrhage in a patient admitted to the emergency department, we wanted to evaluate the diagnostic value of FD CT for clinicians.

Methods

Between March 2007 and May 2008, 351 patients with intracranial hemorrhage were scheduled for angiography in our department. In this retrospective analysis we reviewed the images of 65 of the patients examined with both modalities and showing no change in the hemorrhage. In the same time range, 25 patients with a diagnosis other than hemorrhage were examined. Five of these patients served as controls because CT and FD CT images obtained within 3 hours of each other were available. These patients had acute ischemic stroke, and they underwent CT scanning as part of their treatment with intraarterial thrombolysis and mechanical devices. Follow-up imaging ruled out hemorrhage in all 5 cases.

All patients underwent conventional angiography within 3 hours of MS CT. The FD CT was the first procedure of the angiography session if the clinician had the impression that the patient's condition might have changed. All FD CT investigations were therefore clinically indicated. We obtain informed consent from all our patients as a regular procedure so that their data may be used for retrospective analysis.

Two experienced clinicians—a neurosurgeon (REV 1) and a neurologist (REV 2)—both blinded to the clinical findings, independently evaluated the MS CT and FD CT images with respect to image quality (good, affected by motion artifacts, or inappropriate for evaluation). The reviewers had to determine the total number of slices with ICH or SAH visible in each patient. In patients with ICH, the largest diameter, the vertical diameter (in centimeters), and the area (in square centimeters) had to be measured using standard software tools that are part of the Leonardo workstation (Siemens Medical Solutions). The reviewers had to decide if blood was visible in the ventricles. Thin layers of blood in the occipital horns were defined as a trace of blood, whereas a blood clot occupying the whole ventricle was defined as complete filling of one or both ventricles. Evaluation of EVDs involved deciding whether they were correctly positioned (within the frontal horn, tip at the foramen of Monro, or within the third ventricle), displaced (tip within the parenchyma, catheter not in contact with the frontal horn), or the image was not suitable for evaluation. The FD CT technology has not yet been standardized like MS CT, so window placement is not as reproducible. Optimum window values may differ, and the reviewers were subsequently allowed to change the window placement. Appropriate values were approximately W 220–280 HU (width) and C 80–100 HU (center).

Protocol for MS CT Scanning

The MS CT study was performed by acquiring spiral data (SOMATOM Volume Zoom 4 CT system, Siemens Medical Solutions). The following parameters were used: for the skull base—collimation 4 × 1 mm, pitch 0.75, 120 kV, 300 effective mAs, reconstructed slice width 4 mm, kernel soft brain; for the cerebrum—collimation 4 × 2.5 mm, pitch 0.75, 120 kV, 300 effective mAs, reconstructed slice width 8 mm, kernel soft brain.

Protocol for FD CT Scanning

The FD CT study was performed on a biplanar, FD angiography system (AXIOM Artis dBA, Siemens Medical Solutions) with commercially available software (Syngo DynaCT, Siemens Medical Solutions). The FD CT data acquisition was performed using the following parameters (20sDR-H program): 20-second rotation, projection on 30 × 40–cm detector size, 217° angular range, increment 0.4°/image. Postprocessing was performed with a commercially available dedicated workstation (Leonardo DynaCT, InSpace 3D software; Siemens Medical Solutions). The software includes application of system-specific filter algorithms to correct for beam hardening, scattered radiation, truncated projections, and ring artifacts. Postprocessing resulted in a volume data set with a batch of approximately 400 slices in a 512 × 512 matrix. Single-slice thickness was 0.3 mm. The data set was further processed as multiplanar reconstructed slices adjusted to MS CT with respect to similar angulation, slice thickness (reconstructed slice widths 4 and 8 mm), and slice number. The MS CT and FD CT multiplanar reconstructed slices were anonymized and transferred in mixed order to a Leonardo workstation for evaluation.

Statistical Analysis

Statistical analysis was performed using GraphPad Prism 4 and SPSS 14.0, calculating the Pearson correla-

tion coefficient to evaluate the level of inter- and intraobserver agreement. Linear regression analysis was done to visualize the results of the numbers of ICH- and SAH-positive slices. Agreement was considered good if the Pearson coefficient was between 0.6 and 0.8, and excellent if the coefficient was greater than 0.8.

Results

Sixty-five patients with hemorrhages (38 female and 27 male patients, median age [± SD] 58 ± 16 years) and 5 patients without intracranial bleeding acting as controls were included in the study. Although ICH, SAH, and IVH all appeared together in a single case, we found 29 ICHs, 44 SAHs, 22 thin layers of blood in the occipital horns, 7 blood clots occupying the whole ventricle, and 24 patients with EVDs.

Retrospective analysis showed the causes of the hemorrhage to be aneurysms (25 patients; see Fig. 1A), arteriovenous malformations (5 patients), atypical hematomas without any vascular pathological entity (19 patients; see Fig. 1B), typical hypertensive hematomas (14 patients; see Fig. 1C), trauma (1 patient), and venous sinus thrombosis (1 patient). All the ICHs were supratentorial. The ICH diameter was 1–7 cm. Seven of the patients with SAH showed typical perimesencephalic hemorrhages. Two MS CT and 11 FD CT scans showed obvious motion artifacts (Fig. 1C), but all images were considered to be suitable for evaluation.

All 29 intraparenchymal hemorrhages were detected by both reviewers. Figure 2A shows the total number of FD CT and MS CT slices with visible ICH as found by REVs 1 and 2. The linear regression curves for REV 1 and REV 2 are almost identical. The ICH is demonstrated equally in MS CT and FD CT, as shown by the same numbers of ICH-positive slices on MS CT compared with FD CT scans. The r value indicating interobserver agreement for the number of ICH-positive slices was 0.89 for MS CT and 0.78 for FD CT scans (29 cases). The r values comparing the number of ICH-positive slices between MS CT and FD CT images (intraobserver agreement) were 0.89 for REV 1 and 0.74 for REV 2.

Measurements of the area are shown in Fig. 2B. The linear regression curves are nearly parallel, and cut the MS CT axis at approximately 1 cm^2, indicating that small lesions may be underestimated in FD CT images. In the range of 3–4 cm^2, the impression of the area seems to be identical. The r value for interobserver agreement was 0.77 for MS CT and 0.95 for FD CT scans (29 cases). Intraobserver agreement was 0.97 for REV 1 and 0.97 for REV 2.

Of the 44 cases of SAH, 6 were not detected by either reviewer on FD CT images. Three of these cases were overlooked on MS CT images; these were all perimesencephalic SAHs (Fig. 3A). In all of these patients, SAH was confirmed by lumbar puncture. Among the remaining 38 cases, 1 additional perimesencephalic SAH was found by both reviewers on MS CT and FD CT images (Fig. 3B). No false-positive SAHs were reported by the reviewers on MS CT or FD CT scans. Figure 2C gives the results reported by REV 1 and REV 2 in detecting the total number of image slices with visible SAH on FD CT compared with MS CT scans. Linear regression curves of the reviewers' results are almost similar, and cut the y axis (MS CT axis) at approximately 4 slices, meaning

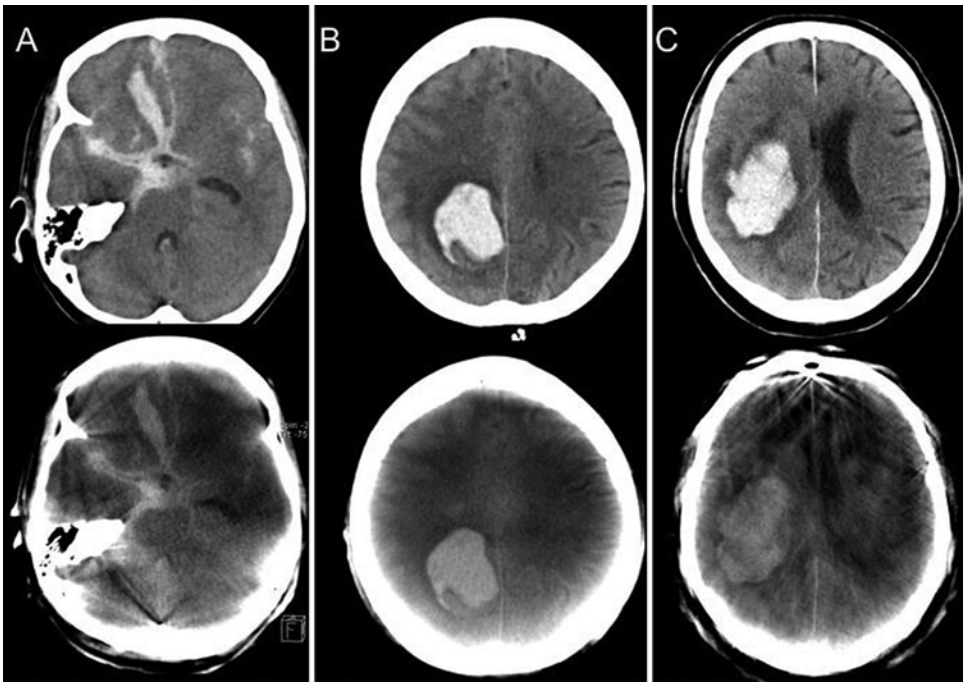

Fig. 1. Hemorrhages visualized using different CT methods (*upper row*, MS CT; *lower row*, FD CT throughout all figures). **A:** Typical SAH with intraparenchymal bleeding (anterior communicating artery aneurysm). The SAH is easy to see; note beam-hardening artifact due to the temporal bone and sphenoid wing. **B:** The ICH can be seen, and the margins are sharp and clearly delineated. **C:** The ICH is still visible, but the FD CT image quality is reduced because of obvious motion artifacts.

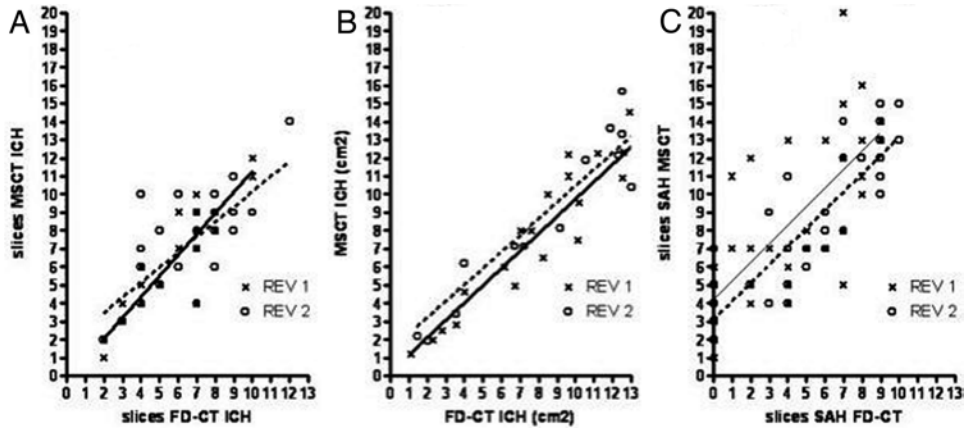

Fig. 2. Scatterplots. **A:** Linear regression of the number of slices with visible ICH. **B:** Linear regression of the area of visible ICH. **C:** Linear regression of the number of slices with visible SAH.

that if 1 SAH-positive slice was found on FD CT, 4 slices were found on MS CT scans. The r value in interobserver agreement for the number of slices with visible SAH was 0.88 for MS CT and 0.9 for FD CT scans (38 cases). The r values for the number of image slices with visible SAH (intraobserver agreement) on MS CT compared with FD CT images were 0.7 (REV 1) and 0.88 (REV 2).

Of the 22 thin layers of blood in the occipital horns, 8 (36.4%) were not visible on FD CT, but were visible on MS CT scans (Fig. 4A and B). All 7 blood clots occupying the whole ventricle were detected (Fig. 4C).

All 24 EVDs were seen on both FD CT and MS CT scans. In 20 cases (83.3%), evaluation of their position was identical in both modalities (Fig. 5A and B). Evaluation was possible on all CT images; in 4 cases (16.7%), the precise position was not seen on FD CT because of motion artifact and insufficient visibility of the ventricle margins (Fig. 5C).

All scans in the control group were identified as negative for hemorrhage on MS CT and FD CT scans. The control group consisted of 5 patients undergoing endovascular treatment for ischemic stroke, who were evaluated with FD CT scanning postintervention to rule out complications.

Discussion

Flat-panel detector CT scanning is a promising new method that can provide cross-sectional CT–like images

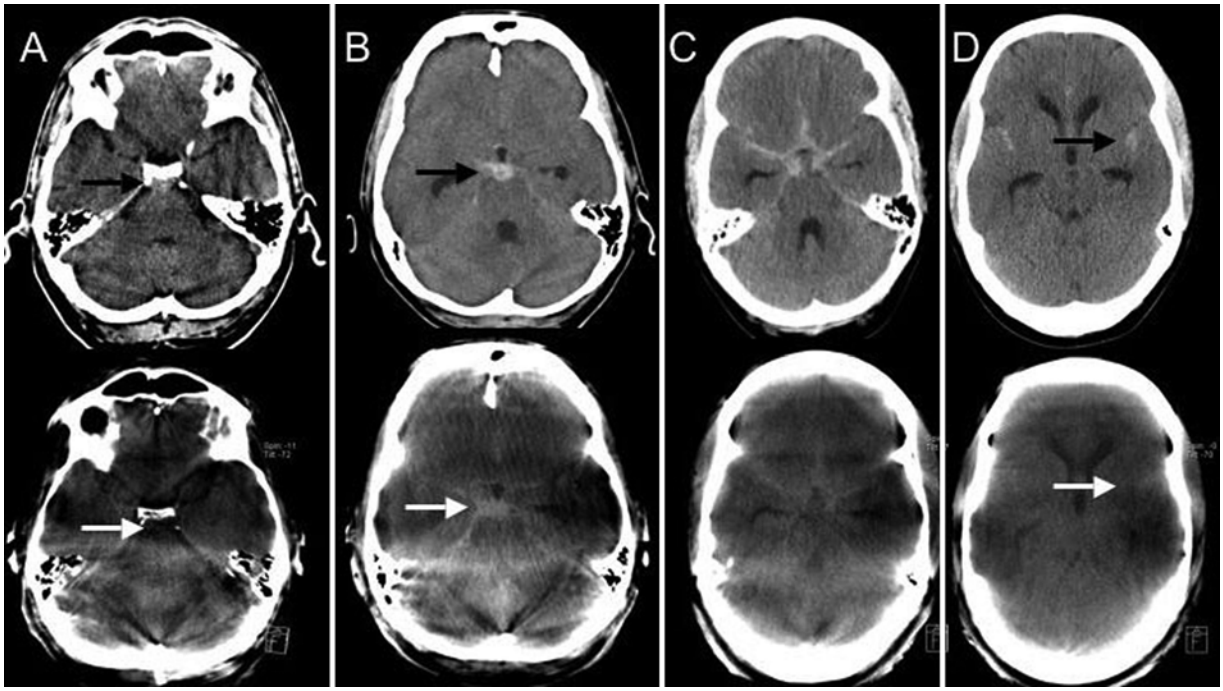

Fig. 3. A: Obvious perimesencephalic SAH *(black arrow)* on MS CT, which is not visible on the FD CT scan *(white arrow)*. **B:** Our only case of visible perimesencephalic SAH on both imaging types (*black arrow*, MS CT; *white arrow*, FD CT). **C and D:** In the same patient, images show that despite the clear basal SAH seen in **C**, small amounts of SAH may not be visible due to limited contrast resolution (**D**, *black arrow* in MS CT and *white arrow* in FD CT; the small amount of blood in the sylvian fissure was not visible).

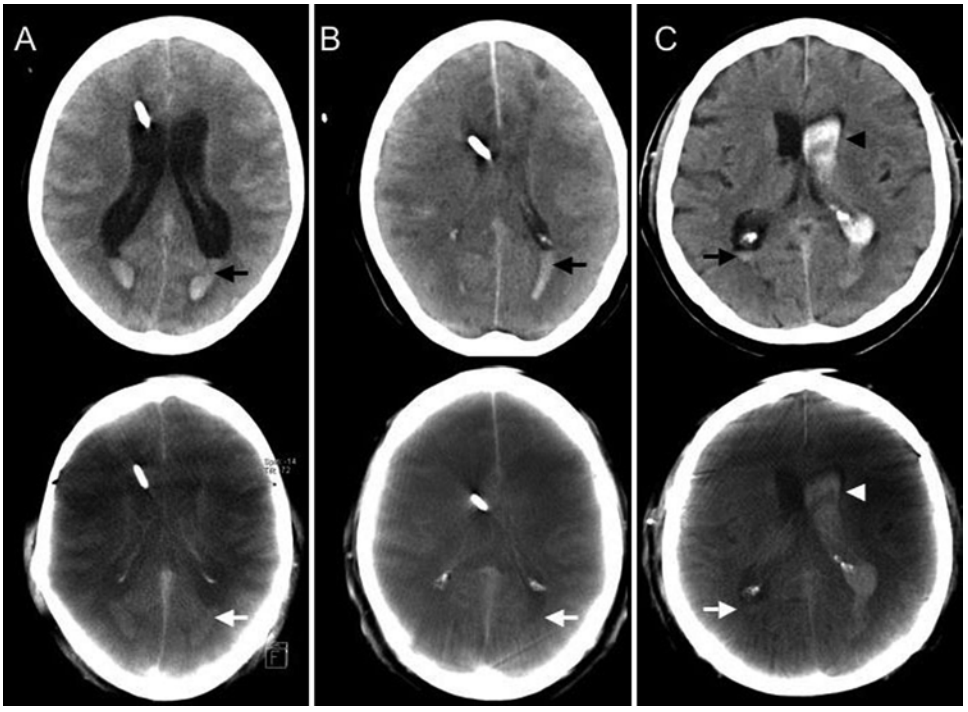

Fig. 4. **A:** Note the correct positioning of the EVD. A small blood clot in the occipital horns (*black arrow*, MS CT; *white arrow*, FD CT) is clearly visible. **B:** The blood clot is not visible on FD CT *(arrows)*. **C:** Easily recognizable, complete filling of the left ventricle *(arrowheads)*. Here also, a small blood clot demonstrated in the right ventricle by MS CT *(black arrow)* is hard to see on the FD CT scan *(white arrow)*.

within minutes, by using the C-arm of the angiography suite without the necessity of transporting the patient to the nearest conventional CT unit. This procedure saves time and helps to avoid additional, potentially dangerous transport. Recent studies have shown good results using FD CT technology to visualize stents or low-contrast structures, such as in myelography.[6,14] However, data regarding the image quality and limitations of FD CT scans in the visualization of important details in comparison with MS CT are rare.[4,17]

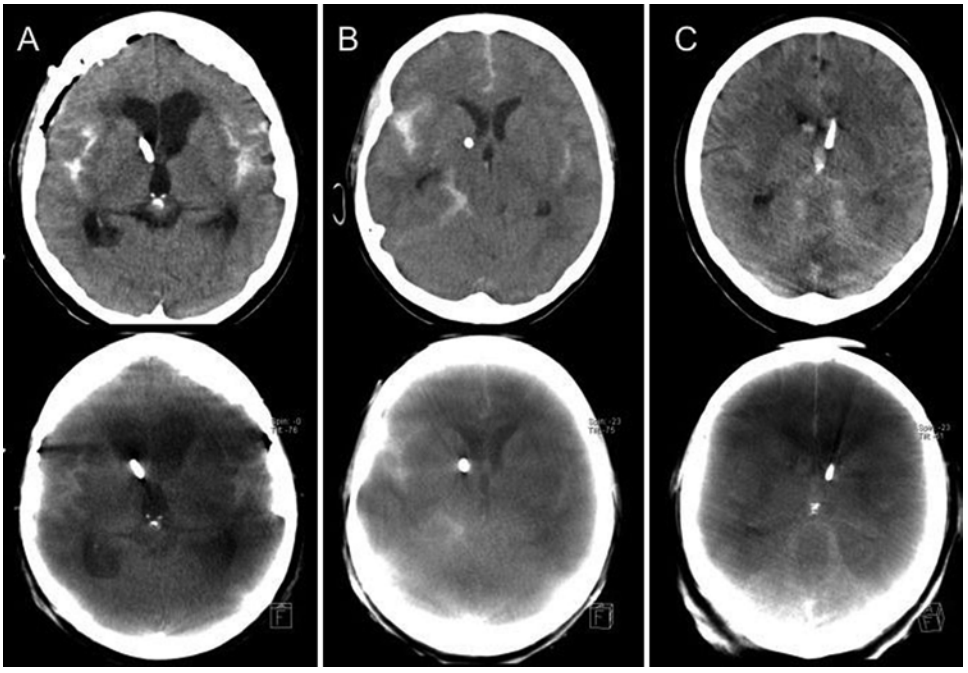

Fig. 5. **A:** Correct positioning of an EVD (tip at foramen of Monro). **B:** Incorrect placement, with the tip of the catheter in the apex of the thalamus. Note identical visualization on MS CT and FD CT scans. **C:** Position of the EVD not clearly visible on FD CT in this case because of motion and low contrast.

We counted the numbers of ICH-positive slices and found them to be equal. We found good inter- and intraobserver agreement. The areas were measured because the limited contrast resolution of FD CT scans may give a different impression of the extent of the hematoma, and these measurements were also equal. We found good inter- and intraobserver agreement, with r values showing a high correlation.

The numbers of SAH-positive slices were different; SAH was seen in fewer slices on FD CT scans (Fig. 3C and D). The regression curves of both reviewers cut the MS CT axis at approximately 4 slices, meaning that if 1 SAH-positive slice was found on FD CT, 4 such slices were found on MS CT scans. The curves are nearly parallel, and we observed high inter- and intraobserver correlations for this finding. Our results may be explained by the lower FD CT contrast resolution, making it impossible to detect small amounts of blood within the subarachnoid space. Evaluation of EVDs was not possible in only 4 of 24 cases. However, in the other 20 cases visualization was adequate for evaluation and equal to MS CT images.

Our study has its limitations. We were able to review only patients with obvious hemorrhage who were scheduled for angiography. So far, there are no data available concerning the FD CT visualization of brain structures in healthy people. Because the lesions investigated in this study are well known in both modalities, no statement can be made about the possibility of detecting other pathological conditions with FD CT. There are no reports on the visualization of tumors, stroke, or inflammatory lesions. Sixty-five patients is a limited number, but reflects the fact that FD CT was performed in selected patients. In all of these patients we assume that the hemorrhage did not change within the 3 hours between MS CT and FD CT scanning. The control group was small, but more patients were not available.

Our results indicate that FD CT has the potential to visualize ICH and EVDs as reliably as MS CT. Because all our intracerebral hematomas were supratentorial in location, we cannot comment with respect to the posterior fossa. The posterior fossa seems to be a problematic region, and we recognize that beam hardening decreases image quality. Additionally, motion artifacts seem to affect FD CT more than MS CT images. Once movement occurs during acquisition of FD CT images, the entire data set and all slices will show artifacts, whereas MS CT will be affected in only 1 or 2 slices.

The FD CT technique may change workflow in the future. Loss of valuable time may be avoided by simultaneously performing digital subtraction angiography and FD CT scanning. Our results are in agreement with the few results published so far.[4,8,17] In addition, complications during endovascular procedures may be detected with FD CT studies.[8] Because a favorable outcome can be expected if treatment is initiated within 30 minutes of iatrogenic bleeding during endovascular procedures, FD CT seems to provide the necessary sensitivity to detect clinically relevant hematomas and to accelerate the workflow in these situations.[3] At the moment, we see indications for use of FD CT to check EVDs and ventricular width to rule out major complications in cases of spontaneous deterioration in the angiography room, and after endovascular procedures if complications are suspected. The FD CT technique should not be used in all patients, because there are publications indicating that the radiation dose may even be higher than with regular MS CT.[11]

Conclusions

Visualization of ICH by FD CT is reliable in comparison with MS CT, but visualization of SAH is limited. Visualization of EVDs is reliable. The MS CT technique will continue to serve as the diagnostic tool of choice. However, because FD CT seems to provide useful information, it may improve workflow in the management of bleeding in patients with intracranial hemorrhage. Future work should be directed at improving soft-tissue resolution, and eliminating motion and other artifacts such as beam hardening.

Disclosure

The authors report no conflict of interest concerning the materials or methods used in this study or the findings specified in this paper.

Author contributions to the study and manuscript preparation include the following. Conception and design: T Struffert, O Ganslandt, A Doerfler. Acquisition of data: T Engelhorn, M Doelken, M Saake, O Ganslandt. Analysis and interpretation of data: IY Eyupoglu, HB Huttner. Drafting the article: T Struffert. Critically revising the article: O Ganslandt. Reviewed final version of the manuscript and approved it for submission: T Struffert, IY Eyupoglu, HB Huttner, T Engelhorn, M Doelken, M Saake, O Ganslandt, A Doerfler. Statistical analysis: M Doelken.

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