AJNR

Applicability of Tableside Flat Panel Detector CT Parenchymal Cerebral Blood Volume Measurement in Neurovascular Interventions: Preliminary Clinical Experience

P. Mordasini, M. El-Koussy, C. Brekenfeld, G. Schroth, U. Fischer, J. Beck and J. Gralla

This information is current as of June 18, 2025.

AJNR Am J Neuroradiol published online 29 September 2011
http://www.ajnr.org/content/early/2011/10/27/ajnr.A2715

Published October 27, 2011 as 10.3174/ajnr.A2715

ORIGINAL RESEARCH

Applicability of Tableside Flat Panel Detector CT Parenchymal Cerebral Blood Volume Measurement in Neurovascular Interventions: Preliminary Clinical Experience

P. Mordasini
M. El-Koussy
C. Brekenfeld
G. Schroth
U. Fischer
J. Beck
J. Gralla

BACKGROUND AND PURPOSE: CBV is a vital perfusion parameter in estimating the viability of brain parenchyma (eg, in cases of ischemic stroke or after interventional vessel occlusion). Recent technologic advances allow parenchymal CBV imaging tableside in the angiography suite just before, during, or after an interventional procedure. The aim of this work was to analyze our preliminary clinical experience with this new imaging tool in different neurovascular interventions.

MATERIALS AND METHODS: FPD-CBV measurement was performed on a biplane FPD angiographic system. Eighteen patients (11 women, 7 men) were examined (age range, 18–86 years; median, 58.7 years). In the 10 patients with stroke, the extent of intracranial hypoperfusion was evaluated. The remaining 8 patients had an intracranial hemorrhage; periprocedural CBV was evaluated during the course of interventional treatment.

RESULTS: In the 18 cases studied, 23 CBV measurements were performed. Twenty acquisitions were of sufficient diagnostic quality. The remaining 3 acquisitions failed technically, 1 due to motion artifacts and 2 due to injection technique and/or hardware failure.

CONCLUSIONS: FPD-CBV measurement in the angiography suite provides a feasible and helpful tool for peri-interventional neuroimaging. It extends the intraprocedural imaging modalities to the level of tissue perfusion. However, the technique has technical limitations and shows room for improvement in the future.

ABBREVIATIONS ACA = anterior cerebral artery; CBF = cerebral blood flow; CTP = CT perfusion; FPD = flat panel detector; MRP = MR perfusion imaging; TIMI = Thrombolysis in Myocardial Infarction

Today, FPD-mounted C-arm angiographic systems have been widely introduced into neurointerventional suites. FPD imaging techniques not only allow the acquisition of high-quality 3D vascular imaging (3D rotational angiography) but also obtain CT-like cross-sectional soft-tissue imaging (FPD-CT). Applications include assessment of the extent of SAH or intracerebral hemorrhage and the width of the ventricles,[1-4] and immediate evaluation of coil and stent placement in the treatment of intracranial aneurysms.[5,6] FPD-CT has also been shown to be capable of visualizing the struts of a stent during intracranial placement[6-8] and extracranial carotid artery stent placement.[9] FPD technology allows fast imaging without the need for time-consuming transfer to a CT facility and, therefore, has become a helpful tool for immediate, "on the table" evaluation of treatment results and intraprocedural complications.

CBV is an important parameter for assessing the viability of brain tissue. A significant drop of CBV in the clinical setting of acute ischemic stroke signifies failure of local parenchymal compensatory mechanisms and the irreversibility of the ischemic damage. The CBF and the temporal perfusion maps help to delineate the potentially reversible ischemic penumbra. Recently, the possibility of performing whole-brain parenchymal CBV measurements has been added to the spectrum of FPD-CT imaging. Feasibility studies in canines[10,11] and preliminary clinical studies[12,13] have shown that CBV mapping by using FPD-CT after intravenous contrast media injection is feasible, safe, and capable of depicting CBV values comparable with standard multisection CT perfusion. Furthermore, FPD-CBV imaging offers the advantage of whole-brain coverage not always available by conventional CT perfusion measurements.

However, despite the current limitation in temporal resolution being unable to provide additional dynamic perfusion maps like CBF or TTP measurements, tableside FPD-CBV may offer a further adjunctive on-line tool to evaluate and monitor cerebral perfusion as a physiologic parameter to guide treatment decisions and to evaluate treatment effect. Particularly, patients undergoing revascularization procedures for acute or chronic stroke may benefit from advanced image-guided management. Only a few clinical data on the impact on clinical decision-making and peri-interventional monitoring of neurovascular procedures by using FPD-CBV have been published so far, to our knowledge.

The purpose of this study was to review our preliminary clinical experience evaluating the applicability and usability of

Received January 24, 2011; accepted after revision May 1.

From the Departments of Interventional and Diagnostic Neuroradiology (P.M., M.E.-K., C.B., G.S., J.G.), Neurology (U.F.), and Neurosurgery (J.B.), Inselspital, University of Bern, Switzerland.

Please address correspondence to Jan Gralla, MD, MSc, Department of Interventional and Diagnostic Neuroradiology, University of Bern, Inselspital, Freiburgstr 4, CH-3010 Bern, Switzerland; e-mail: jan.gralla@insel.ch

Indicates article with a supplemental on-line table.

http://dx.doi.org/10.3174/ajnr.A2715

Copyright 2011 by American Society of Neuroradiology.

tableside peri-interventional FPD-CBV mapping as an additional imaging tool in different neurovascular interventions.

Materials and Methods

Patient Characteristics

Between August and November 2010, 18 patients (11 women, 7 men; age range, 18–86 years; median, 58.7 years) with different cerebrovascular pathologies referred for cerebral angiography were examined. This Health Insurance Portability and Accountability Act–compliant study was performed according to the guidelines of our institution, and informed consent was waived. Presenting symptoms included acute stroke or stroke-like symptoms in 6 patients, subacute stroke in 4 patients, headache and nausea in 6 patients, and impairment/loss of consciousness in 2 patients. In the 10 patients with stroke, the causative arterial stenosis or occlusion was confirmed. The remaining 8 patients had an intracranial hemorrhage, 3 had an SAH due to aneurysmal rupture and 1, due to a posttraumatic dissecting aneurysm. The FPD-CBV acquisitions were performed in these cases to exclude hypoperfusion complicating the endovascular intervention (eg, stent placement, coiling, and/or embolization). Patient clinical data and characteristics are summarized in the On-line Table.

FPD-CBV Measurement

FPD-CBV measurement was performed on a biplane FPD angiographic system (Axiom Artis Zee; Siemens, Erlangen, Germany). As previously described,[12,13] data acquisition consisted of 2 rotations: an initial mask run followed by a second fill run. Data acquisition was performed by using the following imaging parameters: acquisition time, 8 seconds; 70 kV; 616 × 480 matrix; projection on a 30 × 40 cm flat panel size; 200° total angle, 0.5°/frame; 400 frames total; dose, 1.20 μGy/frame.

To obtain the necessary steady-state contrast medium opacification of the brain parenchyma for CBV data acquisition during the fill run, the technique of "bolus watching" was applied as previously described.[12,13] In brief, contrast medium injection was started simultaneously with the mask run. After return of the C-arm to the starting position, conventional DSA acquisitions at a rate of 1 image per second were obtained until opacification of the transverse sinus was seen by the interventionalist as a surrogate marker for steady-state parenchymal contrast medium filling. At this point, the fill run for CBV data acquisition was manually started.

Intravenous and intra-arterial injection protocols according to the interventionalist's discretion were used. Contrast media injections were performed by using 50 mL of iodinated contrast material (iopamidol, Iopamiro 300; Bracco, Milan, Italy) either through a peripheral cubital venous access (20-ga) in 15 patients or intra-arterially in 3 patients through a pigtail catheter (6F, Torcon NB Advantage Catheter; Cook, Bloomington, Indiana) placed in the ascending aorta at a rate of 5 mL/s by using a power injector (Angiomat Illumena; Liebel-Flarsheim, Cincinnati, Ohio). However, during the study, the route of pre- and postprocedural contrast application was consistent in all cases, allowing a comparison of datasets within the case. The details of the injection protocol for each patient are described in the On-line Table.

Postprocessing of FPD-CBV Data

Postprocessing of FPD-CBV data was performed by using commercially available imaging software (syngo Neuro PBV IR; Siemens) installed on the imaging workstation (Leonardo; Siemens). Multiplanar reconstructions (section thickness, 5 mm) were performed covering the whole-brain parenchyma in axial, coronal, and sagittal planes. CBV images were stored on a workstation for analysis. Images were visually assessed together by 2 neuroradiologists (P.M., M.E.-K.) in consensus, unaware of patient histories and pathology for asymmetry in parenchymal CBV.

Results

In the 18 cases studied, 23 CBV measurements were performed. Twenty acquisitions were of proper diagnostic quality. The remaining 3 acquisitions had technical failure (1 due to motion artifacts, 2 due to injection technique and/or hardware failure). The technical failures decreased as further patients were examined, probably representing a learning-curve effect.

Illustrative Cases

Case 1. A 53-year-old patient (patient 1) was referred for stroke with acute right hemiparesis and aphasia, 3.5 hours after the onset of symptoms. The National Institutes of Health Stroke Scale score at presentation was 19. Emergency MR imaging revealed a diffusion restriction of the left MCA territory and a wide diffusion-perfusion mismatch including the whole left MCA territory and partial ACA territory due to an ICA and M1 occlusion (Fig 1*A*–*C*). The patient was immediately transferred to the neurointerventional suite for endovascular stroke treatment. Diagnostic DSA confirmed an occlusion of the left ICA from the bifurcation. Preinterventional FPD-CBV by using an intra-arterial injection protocol with a pigtail catheter placed in the descending aorta was performed, showing decrease in CBV values consisting of the whole MCA and parts of the ACA territory (Fig 1*D*). TIMI 3 recanalization of the ICA and M1 could be achieved by stent placement in the ICA and intra-arterial thrombolysis by using 1 million IU of urokinase. Immediate postinterventional control FPD-CBV measurement depicted normalization of CBV values in the left MCA and ACA territories with signs of hyperperfusion in the parietal lobe (Fig 1*E*). Control MR imaging 4 days after the intervention showed cerebral infarction restricted to the initial area of diffusion restriction in the left MCA territory without diffusion-perfusion mismatch (Fig 1*F*–*H*).

Case 2. A 47-year-old patient (patient 11) presented to the emergency department with an episode of sudden headache and nausea. CT evaluation showed an SAH and a suspected PICA aneurysm on the right. DSA depicted a partially saccular multilobulated aneurysm of the PICA with fusiform dilation incorporating the adjacent vessel segment (Fig 2*A*). Because of its partially fusiform appearance and the extent of the lesion, a dissecting aneurysm was suspected and segment occlusion intended. Pre- and postinterventional FPD-CT was performed to evaluate the extent of the CBV deficit to anticipate the necessity of decompressive craniotomy in this sedated and intubated patient. Vessel sacrifice by embolization of the PICA by using *N*-butyl-2-cyanoacrylate (Histoacryl) (Tissue Seal, Ann Arbor, Michigan) was performed, and complete vessel occlusion could be achieved (Fig 2*B*).

Immediately after the termination of the embolization, an FPD-CBV measurement was performed depicting a CBV decrease in the right PICA territory (Fig 2*C*). A control CT scan confirmed the postinterventional PICA infarction (Fig 2*D*), and decompressive craniotomy was performed.

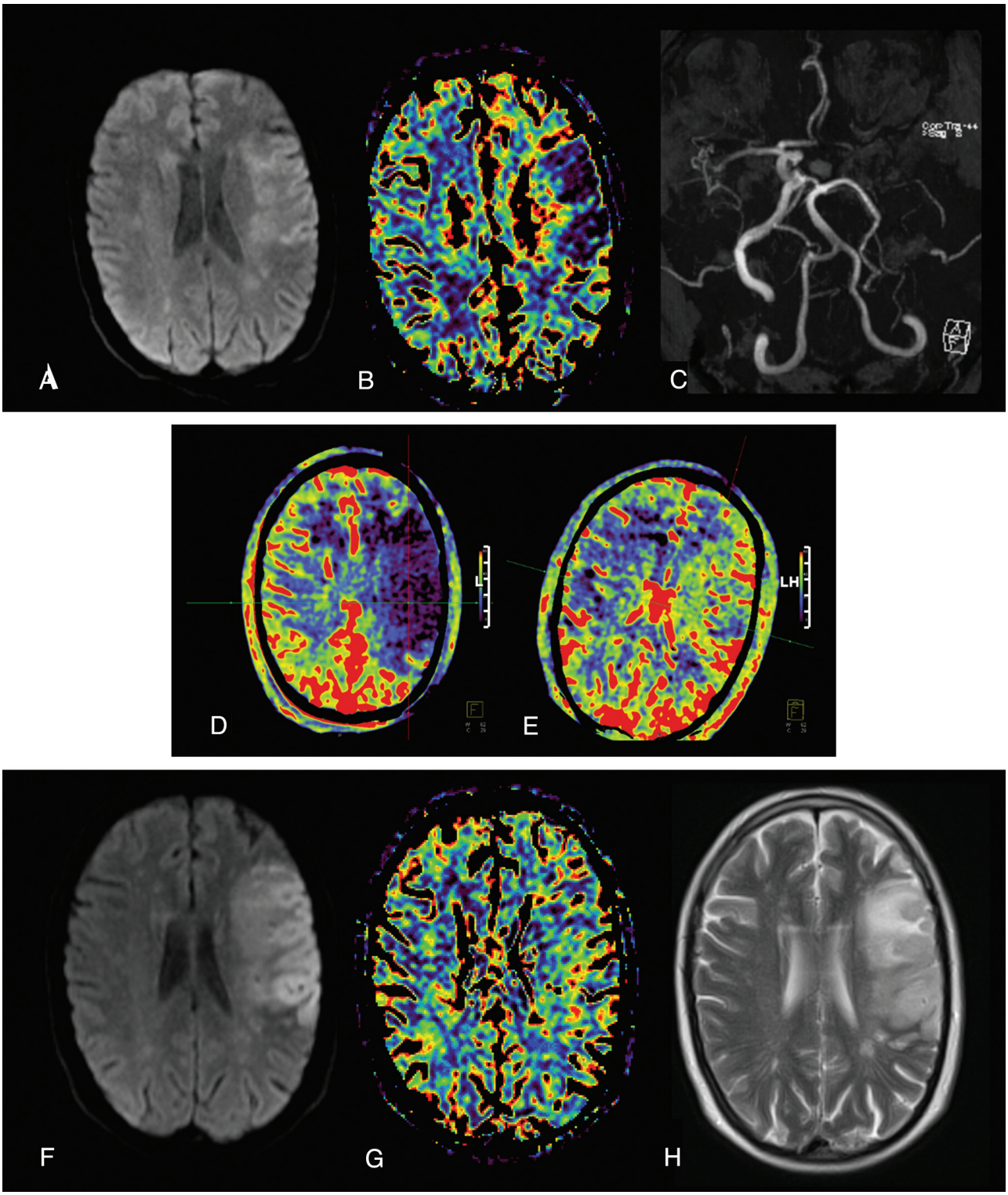

Fig 1. A 53-year-old patient presenting with acute right hemiparesis and aphasia. *A*–*E*, Emergency MR images by using diffusion-weighted imaging (*A*) and MRP (CBV, *B*) depict a significant diffusion-perfusion mismatch due to an ICA and MCA occlusion (time-of-flight, *C*). Preinterventional FPD-CBV measurement (*D*) and postinterventional FPD-CBV measurement (*E*) after complete recanalization (TIMI 3). *F*–*H*, Control MR image shows cerebral infarction restricted to the initial area of diffusion restriction without diffusion-perfusion mismatch depicted by the CBV map.

Discussion

Imaging techniques for assessment of cerebral perfusion are traditionally indicated in hypoperfusion (eg, arterial occlusions or stenosis) as well as in hyperperfusion states (eg, after carotid stent placement or endarterectomy) and in cases of seizure. In the past 2 decades, CTP and MRP have been introduced as robust and more widely available alternatives to positron-emission tomography and single-photon emission CT. The most commonly used CTP and MRP parameters are CBV, CBF, and temporal parameters including TTP and mean tran-

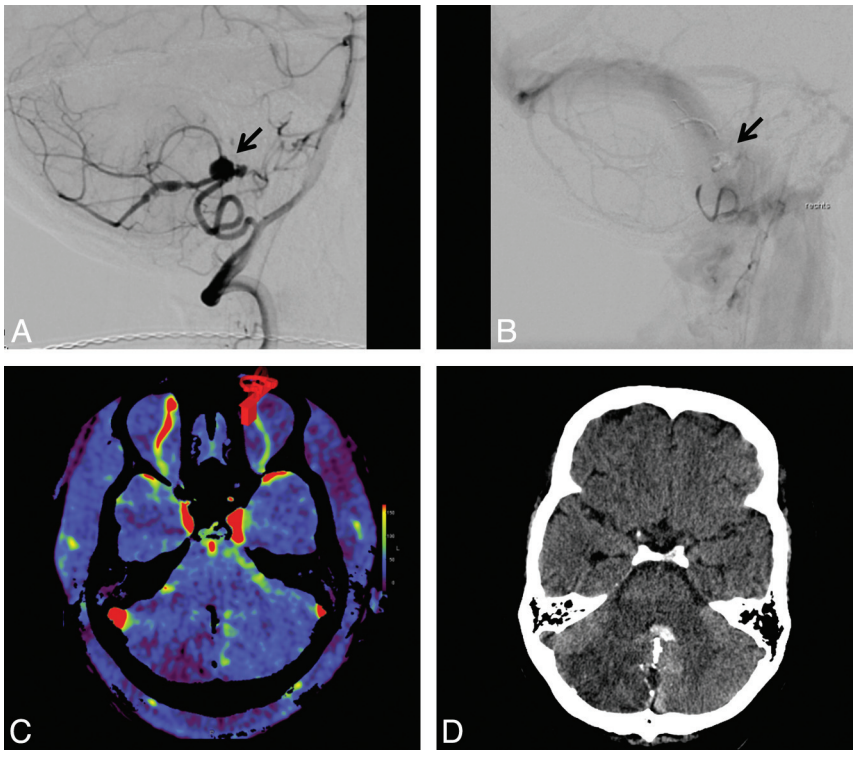

Fig 2. *A,* A 47-year-old patient presented with SAH due to dissecting PICA aneurysm (*arrow*). *B,* Complete vessel occlusion after superselective Histoacryl embolization (*arrow*). *C,* Immediate postinterventional FPD-CBV measurement shows decreased CBV in the right PICA territory. *D,* Postinterventional control CT scan confirms the similar extension of PICA infarction.

sit time. Furthermore, a recent publication showed that CT angiographic source images correlate more closely with CBF anomalies, whereas postcontrast CT correlates more with CBV defects.[14] A significant drop of CBV in the clinical setting of acute ischemic stroke signifies failure of local parenchymal compensatory mechanisms and the irreversibility of the ischemic damage. The CBF and the temporal perfusion maps help to delineate the potentially reversible ischemic penumbra.

From our experience, FPD-CT has various possible indications in the future for perfusion assessment before and after neurovascular interventions: 1) patients with ischemic stroke and patients with symptomatic and/or high-grade stenosis indicated for an endovascular revascularization procedure, 2) before and after spasmolysis after SAH, 3) intracranial and head and neck tumors before and after embolization (eg, preoperative devascularization of a meningioma or other vascular neoplasms), and 4) after interventional vessel sacrifice (eg, during treatment of dissections) to determine the extent of infarction and to tailor postinterventional monitoring or decompressive surgery.

In such cases, a tableside technique integrated into the neuroangiography suite represents an extremely appealing method for on-line peri-interventional assessment of perfusion. This provides the advantage of rapid on-line decision-making and obviates tedious transport to and from an MR imaging or CT scanner.

Furthermore, to our knowledge, few publications on FPD-CT have focused on the imaging of intraprocedural complications, (eg, hemorrhage, vessel rupture, or depiction of the installed endovascular treatment armamentarium, including stents and coils). Perfusion imaging with FPD-CT has been recently introduced to the neuroradiologic arena. The first studies documented results comparable with CBV values acquired by multisection CTP technology.

However, the FPD-CBV technique still has some limitations. In our preliminary experience, a few technical and hardware failures occurred. In 1 case, the motion artifacts significantly degraded the perfusion images. In 2 other cases, a hardware/injector failure was responsible for the low quality of the images. Our suggestions for improving the quality and reproducibility of the technique include the following: 1) a uniform protocol of injection, and 2) intravenous injection protocol. Intra-arterial injection protocols are feasible but need the introduction of a pigtail catheter into the aortic arch, which is time-consuming, especially in acute stroke treatment. On the other hand, intravenous contrast injection seems to be a straightforward and reliable method of contrast administration to achieve reproducible FPD-CBV measurements. Furthermore, this technique currently yields only CBV maps. CBF and temporal maps are not available yet. However, other perfusion techniques have this limitation of providing only 1 perfusion parameter (eg, arterial spin-labeling, which only provides CBF data). CBU maps obtained with FPD-CBV can provide absolute quantification if post-processing on the imaging work station is performed.

Limitations

A limited study of patients with various cerebrovascular pathologies was reported. The injection protocol was not uniform in all cases.

Conclusions

FPD-CBV measurement in the angiography suite provides an attractive and feasible tool for peri-interventional neuroimag-

ing. It extends the periprocedural imaging modalities to the level of tissue perfusion. However, the technique still has some technical limitations and shows room for improvement.

Disclosures: Jan Gralla, *Consultant*: ev3, Details: principal investigator of the Star Trial (Solitaire FR in Stroke); no connection to this study.

References

1. Doelken M, Struffert T, Richter G, et al. **Flat-panel detector volumetric CT for visualization of subarachnoid hemorrhage and ventricles: preliminary results compared to conventional CT.** *Neuroradiology* 2008;50:517–23
2. Struffert T, Richter G, Engelhorn T, et al. **Visualisation of intracerebral haemorrhage with flat-detector CT compared to multislice CT: results in 44 cases.** *Eur Radiol* 2009;19:619–25
3. Struffert T, Eyupoglu IY, Huttner HB, et al. **Clinical evaluation of flat-panel detector compared with multislice computed tomography in 65 patients with acute intracranial hemorrhage: initial results: clinical article**. *J Neurosurg* 2010;113:901–07
4. Engelhorn T, Struffert T, Richter G, et al. **Flat panel detector angiographic CT in the management of aneurysmal rupture during coil embolization.** *AJNR Am J Neuroradiol* 2008;29:1581–84
5. White PM, Gilmour JN, Weir NW, et al. **AngioCT in the management of neurointerventional patients: a prospective, consecutive series with associated dosimetry and resolution data.** *Neuroradiology* 2008;50:321–30
6. Richter G, Engelhorn T, Struffert T, et al. **Flat panel detector angiographic CT for stent-assisted coil embolization of broad-based cerebral aneurysms.** *AJNR Am J Neuroradiol* 2007;28:1902–08
7. Benndorf G, Claus B, Strother CM, et al. **Increased cell opening and prolapse of struts of a Neuroform stent in curved vasculature: value of angiographic computed tomography—technical case report.** *Neurosurgery* 2006;58(suppl 2): ONS-E380
8. Psychogios MN, Schramm P, Buhk JH, et al. **Angiographic CT after intravenous contrast agent application: a noninvasive follow-up tool after intracranial angioplasty and stenting.** *AJNR Am J Neuroradiol* 2010;31:1886–91. Epub 2010 Jul 15
9. Mordasini P, Al Senani F, Gralla J, et al. **The use of flat panel angioCT (DynaCT) for navigation through a deformed and fractured carotid stent.** *Neuroradiology* 2010;52:629–32
10. Ahmed AS, Zellerhoff M, Strother CM, et al. **C-arm CT measurement of cerebral blood volume: an experimental study in canines.** *AJNR Am J Neuroradiol* 2009;30:917–22
11. Bley T, Strother CM, Pulfer K, et al. **C-arm CT measurement of cerebral blood volume in ischemic stroke: an experimental study in canines.** *AJNR Am J Neuroradiol* 2010;31:536–40
12. Struffert T, Deuerling-Zheng Y, Kloska S, et al. **Flat detector CT in the evaluation of brain parenchyma, intracranial vasculature, and cerebral blood volume: a pilot study in patients with acute symptoms of cerebral ischemia.** *AJNR Am J Neuroradiol* 2010;31:1462–69
13. Struffert T, Deuerling-Zheng Y, Kloska S, et al. **Cerebral blood volume imaging by flat detector computed tomography in comparison to conventional multislice perfusion CT.** *Eur Radiol* 2010;21:882–89. Epub 2010 Sep 21
14. Sharma M, Fox AJ, Symons S, et al. **CT angiographic source images: flow- or volume-weighted?** *AJNR Am J Neuroradiol* 2011;32:359–64