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Angiographic computed tomography and computed tomographic angiography techniques: actual interventional and diagnostic possibilities of their use in patients with cerebral aneurysms

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Abstract

Since the introduction of radiological examination techniques, such as an angiographic computed tomography (ACT) and a computed tomographic angiography (CTA), the diagnosis and treatment planning for cerebral aneurysms became quicker and safer. Unfortunately, the state of development of these techniques, and their possible indications and benefits are still today restricted to specialized centers. The objective of this update was to analyze the current scientific evidence about their actual interventional and diagnostic use and identify the individual advantages of each through a literature review and personal experience-based data.

Introduction

Aneurysms of the intracranial vessels are relatively common, with a reported prevalence of 3-6% in the general population, predominantly in women.[1] These aneurysms may rupture, causing subarachnoid hemorrhage. A subarachnoid hemorrhage is a neurological emergency characterized by the extravasation of blood into the spaces covering the central nervous system that are filled with cerebrospinal fluid.[2]

This disorder is also associated with a substantial burden on health care resources. The average case fatality rate for subarachnoid hemorrhage is 51%, with approximately one third of survivors needing lifelong care.[3] Most deaths occur within two weeks after the ictus, with 10% occurring before the patient receives medical attention and 25% within 24 hours after the event.[4]

Due to the high mortality rate among patients with this condition, prompt localization of the aneurysm is critical for determining the appropriate neurosurgical or endovascular intervention. This can be extremely important for patients in poor condition with increased intracranial pressure.[5,6] Digital subtraction angiography (DSA) is currently considered the imaging modality of choice for the evaluation of suspected aneurysms. DSA is an invasive test, however, and data from studies of patients who had subarachnoid hemorrhage or cerebral aneurysms and who underwent cerebral DSA indicate a 0.07% risk of permanent neurological complications.[7,8]

Taking into account all these data, the employment of additional techniques can be justified if they allow a reduction of possible complications, the acceleration of the diagnostic process or improve the interventional possibilities.

Since magnetic resonance angiography can be technically challenging to perform in the acutely ill patient, this update will be focused on other alternative or complementary angiographic examinations techniques used on patient admission.

Actual interventional possibilities

Several aneurysms and particularly large aneurysms may demonstrate unclear relationships to nearby structures and the parent vessel in DSA and magnetic resonance angiographic scans, which limits the usefulness of these methods for treatment planning.[9] In the last four years, a new novel technique for obtaining cranial CT-like images using a biplane angiographic system has been developed. Angiographic computed tomography (ACT) is a new technique that provides cross-sectional CT-like images based on rotational radiography performed with a rotating C-arm-mounted flat-panel detector. This commercially available system combines a flat-detector biplane angiographic system (Axiom Artis dBA; Siemens Medical Solutions, Erlangen, German), with rotational radiography, as well as a new commercially available software (Dyna-CT). Siemens Medical Solutions introduced Dyna-CT for the first time in Europe at the European Congress of Radiology in March, 2005. This new application enables users of angiographic C-arm systems to create soft tissue images based on the principles of CT.

ACT allows the clear visualization of stents in both intracranial and extracranial arteries and is an even superior technique to conventional digital subtraction angiography and digital radiography in visualizing both the stent struts and their relationships with the arterial walls and aneurysmal lumen. Image post-processing corrects scattered radiation, beam hardening, and ring artefacts on a workstation. The display of imaged stents can be obtained by using multiplanar reconstructions.[10] ACT allows determination of the correct stent position, which may be very helpful in complex stent-assisted aneurysm coiling procedures.

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The relationship between arterial wall and stent struts is well visualized even with diluted contrast medium. In cases with aneurysms larger than 10 mm in diameter, beam hardening artifacts caused by the endoaneurysmal coil package can impair the visibility of the stent.[11,12]

In particular, the early recognition of any complication during endovascular procedures, whether these are followed or not by a neurosurgical intervention, has been demonstrated to be critical in improving the outcome of patients with aneurysmatic subarachnoid hemorrhage.[13,14] In such cases, the prompt recognition of a developing intracranial mass effect caused by a hematoma, helps to optimize patient management. The results from Struffert *et al.* indicate that a flat-detector computed tomography is a helpful tool in the daily emergency management of ICH patients. The accuracy of this device for the detection of intracerebral hemorrhage was found to be nearly as reliable as that obtained by using multislice CTs.[15]

As a matter of fact, in anesthetized patients, significant ICP changes may become apparent only by elevations in systemic arterial blood pressure or signs of oculomotor nerve compression. In such patients, mobilization and transportation to a CT scanner cause significant loss of time and also compromise patient care during transportation. Therefore, not only the early development of intracranial bleedings, but also the progression of an acute hydrozephalus during the radiological procedure can be detected faster with ACT.

This technology can be also added to the surgical armamentarium in the operating theatre, not only because it allows the simultaneous visualization from blood vessels and surrounding parenchyma structures, but also because this produces real time images of the involved surgical fields. These easily obtained real time images will even probably mean that the use of other image guided devices such as a navigator becomes unnecessary. Intra-operatively obtained real time images are more useful for operator's decision making than pre-operatively loaded pictures. In this way, the operators are able to confirm not only the aneurysm occlusion and the patency of the vessels involved by the procedure, as well as the development of possible extravascular complications, but also the positioning from other soft tissue surgically implanted materials. The advantages of its use should be further examined, analyzing the accuracy of this new equipment for detecting some residual intracranial tumors as well as the positioning from some other implanted devices during complexes spinal surgeries.

Limitations of this technology are motion and beam-hardening artefacts that may mask small hematomas located in the posterior fossa or the skull base.

Improved diagnostic and post-interventional controls

In pre-selected difficult cases, intraoperative DSA angiography provides a high percentage of visualized angiographic abnormalities as well as an increased impact on corrective treatment.[16] Nevertheless, in several hospitals today, a multislice computed tomographic angiography (CTA) is the preferred investigation for underlying causes of spontaneous subarachnoid hemorrhage because of its speed, tolerability, convenience, and the ability to provide three dimensional reconstructions.[17,18] The sensitivity of the procedure for identifying aneurysms greater than 3 mm diameter is about 96% but poorer for smaller aneurysms.[19,20]

The clinical usefulness of CTA scanning in cerebral aneurysms has been reported by several authors in the last 15 years.[21-29] As a matter of fact, some authors have detected some peripherally located aneurysms of the posterior fossa only with CTA scanning.[28,30] In DSA scans, the presence of vasospasm, the length and tortuosity of the parent arteries and the arterial cross-flow pattern within communicating arterial segments probably reduce aneurysm filling. Particularly in regions of vascular cross-flow, DSA and CTA scanning can be successfully combined, as demonstrated for anterior communicating artery aneurysms and aneurysms in the posterior circulation.[21,31] In a previous study, we detected only 16 of the 25 posterior fosse ruptured aneurysms (64%) on the first DSA scans and, even with repeated examinations, 6 aneurysms were not clearly identified with this technique. CTA scanning revealed the ruptured aneurysms in 25 cases, and demonstrated increased vascular filling and improved optical definition of the aneurysms, compared with DSA scanning in 12 cases (48%). The information obtained from the CTA scans allowed the selection of 5 patients for endovascular treatment and facilitated the surgical procedures in 5 cases.[21]

Villablanca *et al*. reported that CTA scanning can provide complete aneurysm quantitation and characterization of both large and small aneurysms giving the incorrect impression that the use of DSA assessments should be reduced in the future.[32] However, DSA scanning should be the initial method of evaluation for aneurysms since several anatomical vascular variations, small perforators, collateral circulation and flow dynamics are not well enough represented in CTA studies. In contrast, peripherally located aneurysms of the posterior circulation, which often exhibit reduced filling flow, and basilar artery aneurysms, which can be masked by cross-flow phenomena, are often overlooked on the first angiograms.

Lourenco *et al.* reported that 16-detector CTA did not improve detection of non-traumatic subarachnoid hemorrhage when compared with studies using single-detector CT.[33] However, in another recent study, the sensitivities of 16-slice CT angiography for aneurysms smaller than 5 mm, between 5 and 10 mm, and larger than 10 mm were 94.8, 100, and 100%, respectively, on a per-aneurysm basis.[34] Multi-detector row CT (MDCT) scanners provided today increased spatial resolution and decreased scanning time, which increased the sensitivity of the technique in depicting small aneurysms.[7] A recent review of the literature that compared 16-slice or 64-slice MDCT with catheter-based coronary angiography for the detection of coronary artery disease in non-revascularized, post-stent and post-coronary artery bypass graft patients showed several improvements in spatial and temporal resolution with 64-slice technology.[35] This improved accuracy and safety of MDCT may reduce future needs for different catheter-based angiography procedures.

On the other hand, experiences with this technique have shown how observer findings can differ.[17] Particularly in the evaluation of patients with intracranial aneurysms who had undergone clip occlusion, the positive predictive value from multislice CTA on a per-patient basis is 86%, for aneurysms at the clip site 83%, and for aneurysms at different locations 91%.[36] On the other hand, cobalt clips produce much more artifact on CT scans than titanium clips making image evaluation difficult.

Finally, the combination of three-dimensional CTA and two-dimensional CT images may today help to improve the surgical outcome by indicating aneurysmal rupture points, leading to the prevention of rupture as reported by Wada *et al.*[37]

More recently, the employment of four-dimensional CT angiography also gives additional valuable information determining aneurysmal wall dynamics, such as the motions of the aneurysm-wall blebs.[38] Four-dimensional CT angiography is a novel technology that includes the dimension of time, which is repeated within a cardiac cycle. Four-dimensional CT angiography entails multislice computed tomography with a retrospective electrocardiography-gated reconstruction algorithm. The system uses high-resolution three-dimensional imaging with temporal resolution in a beating heart to deliver clinically useful images of cerebral arteries. Visualization of a pulsating aneurysm in a gated acquisition will allow physicians to obtain novel and highly useful information regarding individual aneurysm features, such as dome pulsations, blebs and perhaps to predict their future hemodynamic behavior and chances of rupture.

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