Learning objectives

The aim of the study is to present an overview of the currently used radiologic methods in the evaluation of delayed cerebral ischemia and vasospasm with a special focus on CTP and CTA.

Background

Vasospasm related delayed cerebral ischemia (DCI) constitutes the main cause for death and morbidity for patients surviving the initial event of subarachnoid hemorrhage (SAH). DCI is defined as the delayed development (typically 4-12 days post-SAH) of a focal neurological deficit, and/or cerebral infarction that is unrelated to aneurysm treatment and other causes of neurological deficits (Vergouwen, Vermeulen et al. 2010). The clinical evaluation of new neurological deficits due to DCI is often challenging due to the poor neurological condition of many SAH patients.

The early diagnosis of DCI is of high importance, because early treatment seems to maximise the chances of averting ischaemia. Intensified therapy consists of haemodynamic augmentation as the mainstay of medical treatment as well as transluminal balloon angioplasty and super-selective intra-arterial infusion of vasodilators (Rabinstein, Lanzino et al. 2010).

Imaging findings OR Procedure details

1. Doppler Ultrasound

In 2004, a consensus statement by the Therapeutics and Technology Assessment Subcommittee of the American Academy of Neurology concluded, that transcranial doppler reliably predicts the absence or presence of angiographic vasospasm of the middle cerebral artery, but not other cerebral vessels. The following criteria for vasospasm diagnosis were advocated for identifying vasospasm: flow velocities <120 or >200 cm/s, a rapid rise in flow velocities, or a higher Lindegaard ratio (velocity of MCA/velocity of ICA) (Sloan, Alexandrov et al. 2004).

2. Value of CTA and CTP in the evaluation of vasospasm: comparison to gold standard digital subtraction angiography
Compared to DSA, CTA constitutes the method with highest specificity for vasospasm (0.9) whereas a prolongation of the CTP derived mean transit time (MTT) over 6.4 seconds constitutes the single value with the highest sensitivity (0.95). The combination of both methods achieves a positive predictive value of 89.9% and a negative predictive value of 93.6% (Wintermark, Ko et al. 2006). However, some patients suffer from DCI despite inconspicuous DSA.

3. Value of CTP in the evaluation of acute DCI

A relative difference of MTT between both hemispheres over 1.1 seconds is the most sensitive marker for DCI (sensitivity 0.8, specificity 0.6). A prolongation of MTT over 5.9 seconds has the highest predictive value (sensitivity 0.7, specificity 0.8) of all single, absolute values (Dankbaar, de Rooij et al. 2009).

4. Value of early CTP for risk stratification and selection for intensified therapy

Patients that develop DCI in the course of SAH related hospitalization exhibit altered cerebral perfusion values at admission with a threshold for CBF of 24-25 mL/100 g/min (sensitivity 0.5, specificity 0.9) and for MTT of 5.5 s (sensitivity 0.6, specificity 0.7). CBF is lower and MTT higher in DCI patients compared to no-DCI patients up to 3 days before, during, and after DCI, with the largest difference between the groups at the time of DCI, while CBV remains relatively constant in both groups. Furthermore, MTT asymmetry develops in DCI patients at the time of DCI and decreases after DCI (Dankbaar, de Rooij et al. 2011).

5. Value of baseline NECT for risk stratification and selection for intensified therapy

Early NECT scans offer valuable information to estimate the risk of delayed vasospasm; the presence of not only cisternal but also intraventricular blood increases the risk of vasospasm. This is incorporated in the modified Fisher scale. Minimum or thin SAH, with the exclusion of intraventricular hemorrhage is classified as modified Fisher grade 1, minimum or thin SAH with IVH in both lateral ventricles is classified as modified Fisher grade 2, thick SAH with the exclusion of IVH is defined as modified Fisher grade 3 and thick SAH with IVH in both lateral ventricles is defined as modified Fisher grade 4 (Kramer, Hehir et al. 2008). Hijdra et al. have proposed a more accurate grading scale, that is used less often, because the amount of blood in 10 basal cisterns/fissures and in 4 ventricles is graded separately (Hijdra, Brouwers et al. 1990).

Images for this section:
Fig. 2: CBF is reduced in patients with vasospasm as an indicator for endovascular therapy.
Fig. 3: regional CBV is mainly preserved.
**Fig. 4:** Vasospasm: Significantly abnormal brain perfusion in the distribution of the right MCA branches is seen primarily on MTT maps. Note the difference between both hemispheres of over 1.1 seconds in the MTT maps as the most accurate sign of acute DCI.
Fig. 5: Vasospasm: absolute perfusion values in the indicated regions of interest. Significantly abnormal brain perfusion in the distribution of the right MCA branches is seen primarily on MTT maps. Note the difference between both hemispheres of over 1.1 seconds in the MTT maps as the most accurate sign of acute DCI. CBF is reduced as an indicator for endovascular therapy while regional CBV is mainly preserved.
**Fig. 6:** Gold standard DSA confirms severe vasospasm of the horizontal segment of the middle cerebral artery.
Fig. 7: CTP Study after intraarterial treatment. Note the higher cerebral blood flow in the treated hemisphere.
Fig. 8: CTP Study after intraarterial treatment. Regional CBV is slightly elevated.
Fig. 9: CTP Study after intraarterial treatment. After intraarterial administration of 2 mg Nimodipin in the right internal carotid artery a normalization of the MTT differences between both hemispheres and absolute values below 6.4 sec are documented.
Fig. 10: Absolute perfusion values in the indicated regions of interest after treatment. 2 mg Nimodipin was administered in the right internal carotid artery and a normalization of the MTT differences between both hemispheres and absolute values below 6.4 sec were documented. Note the higher cerebral blood flow in the treated hemisphere.
**Fig. 11:** A normal diameter of the horizontal branch of the horizontal segment of the middle cerebral artery indicates the cessation of the severe vasospasm after intraarterial therapy.
Conclusion

The value of CTP and CTA in the risk stratification and selection of patients for intensified therapy is subject of ongoing research. CTP derived MTT is the most sensitive parameter in the evaluation of SAH related DCI that occurs even without angiographic evidence for vasospasm in CTA and DSA. The broad application of CT based methods in the evaluation of DCI and vasospasms in patients with SAH is increasingly feasible due to drastically lowered radiation doses achievable with latest available CTP protocols and modern CT scanners.

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References


