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REVIEW

Hyperperfusion and intracranial haemorrhage after carotid angioplasty with stenting – latest review

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ABSTRACT

The number of endovascular procedures is constantly increasing. As far as the carotid artery is concerned, carotid angioplasty with stenting (CAS) is an alternative to surgical treatment (carotid endarterectomy; CEA).

Two major devastating complications can occur after both procedures – cerebral hyperperfusion syndrome (CHS) and intracranial haemorrhage (ICH).

The incidence of CHS and ICH in CAS is fortunately low but overall morbidity and mortality remains high.

This latest review re-evaluates the pathogenesis, clinical features, risk factors and diagnostic procedures as well as management of these two complications.

Key words: carotid artery stenting, complications, hyperperfusion syndrome, intracranial haemorrhage

Introduction

Stroke is the third leading cause of death and the leading cause of adult disability in North America, Europe and Asia. Intracranial cerebral atherosclerosis accounts for approximately 8-10% of all ischaemic strokes. Possible causes include hypoperfusion, thrombosis at the site of stenosis, thromboembolic events and direct occlusion of small penetrating vessels. (1)

As carotid artery atherosclerosis is an important cause of ischaemic stroke, correcting the stenosis at the level of the carotid vessels is the treatment of choice. It can be surgical (carotid endarterectomy; CEA) or endovascular (carotid angioplasty with stenting; CAS). (1,2)

The latter has several benefits such as shorter hospitalisation, avoidance of open neck surgery as well as the ability to treat a technically difficult stenosis. Whether carotid stenting is superior to the classical surgical approach remains unclear. Studies have shown that the risk of the composite primary outcome of stroke, myocardial infarction or death, did not differ significantly, however there was a higher risk of stroke with the endovascular approach and a higher risk of myocardial infarction after endarterectomy. (1,3)

Late outcomes with CAS are comparable to those of CEA. (2)

Complications of both procedures include cerebral embolism, arterial dissection, focal hyperperfusion as well as cerebral hyperperfusion syndrome (CHS) and intracranial haemorrhage (ICH). (1,3,4)

CHS was primarily described as a combination of increased blood pressure together with clinical signs – ipsilateral migraine - like headache, seizure and transient focal neurological deficits in the absence of cerebral ischaemia after successful carotid endarterectomy. (5,6) A similar phenomenon is described in the analogue endovascular procedure. (6,7)

Another complication of the procedure is also well known – ICH. This may be a consequence of CHS (6,8) or a completely different entity as some authors propose. (9)

Pathophysiology of cerebral hyperperfusion syndrome

The exact mechanism is still unknown but seems to be multifactorial in origin. (4,6)

However, there are two main mechanisms which contribute to the development of CHS – impaired cerebral autoregulation as well as postoperatively elevated systemic blood pressure.

The main mechanism in normal cerebral autoregulation is cerebrovascular reactivity defined as the ability of the arterioles to constrict or to dilate in response to specific stimuli such as alteration of blood flow or change of partial pressure of carbon dioxide.

Figure 1. Patient with hyperacute intracranial haemorrhage (ICH) (an hour after carotid angioplasty with stenting (CAS)).
The right internal cerebral artery (ACI) stenosis was symptomatic - the patient suffered right medium cerebral artery (ACM) territory stroke more than a year before the CAS. Risk factors included diabetes mellitus and high degree of stenosis. A Tight stenosis of the right ACI with very slow flow to right cerebral hemisphere is seen on digital subtraction angiography (DSA). B Magnification view shows near occlusion of the ACI caused by calcified plaque. C Stenosis was resolved with two self-expandable stents. D Significantly improved flow to the right cerebral hemisphere is seen at the end of the procedure when the patient was without clinical signs of hyperperfusion. F Less than an hour after the CAS (refractory hypertension as risk factor). E Dramatic neurological deterioration of the patient was caused by a massive ICH that resulted in a fatal outcome.

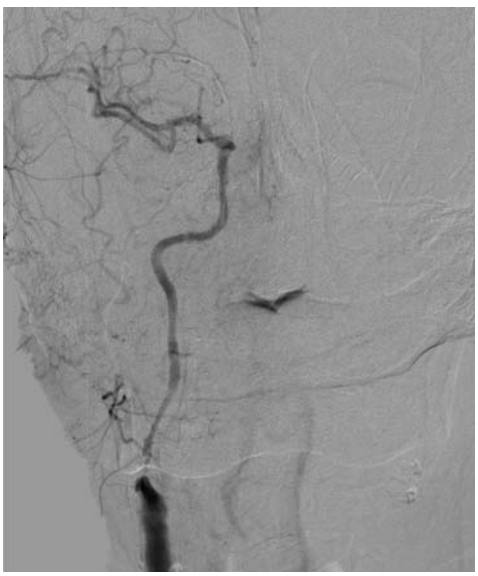
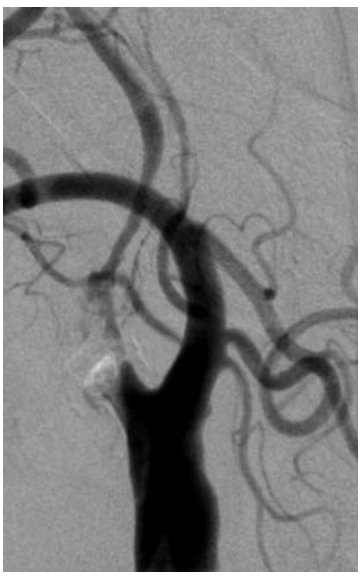


Figure 1A.



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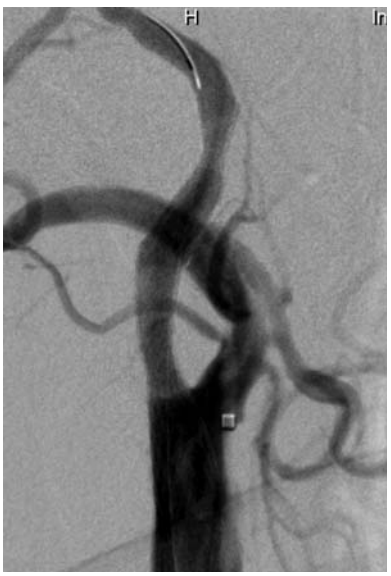

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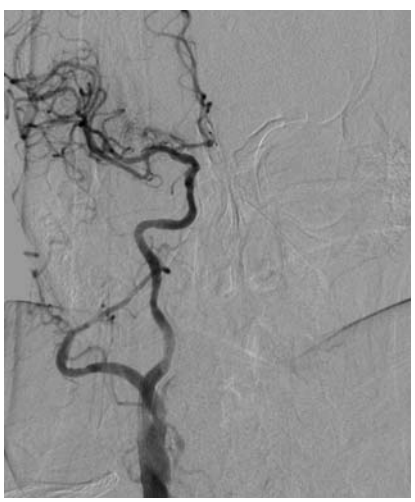

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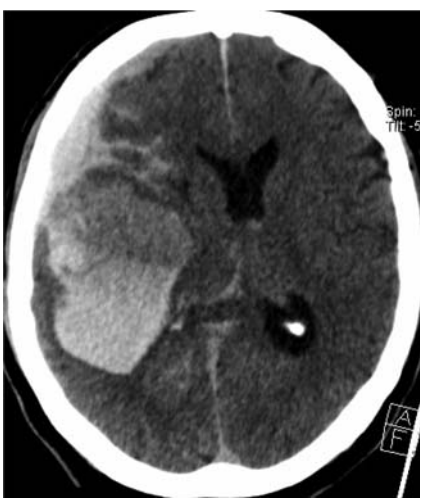

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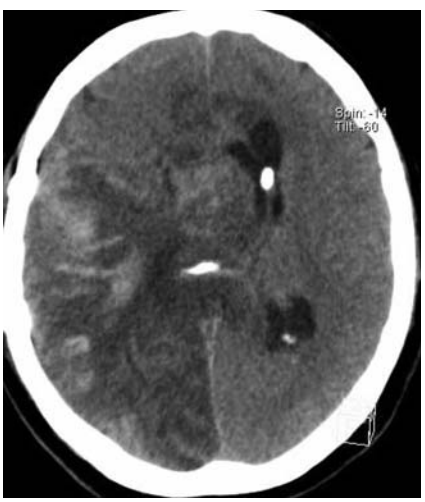


Figure 1F.

Patients, who suffer from carotid stenosis, have maximally vasodilatated cerebral arterioles in order to maintain adequate blood supply to brain tissue. The severity of autoregulation impairment depends on several factors such as the duration and the intensity of cerebral hypoperfusion. The latter depends on the grade of ipsilateral carotid stenosis, the presence of contralateral carotid occlusion as well as the collateral flow. (6)

The loss of ability to dilate in order to maintain adequate perfusion is the main problem in the pathogenesis of CHS. After revascularization, cerebral arterioles fail to constrict as a normal response to elevated blood pressure.

Figure 2. Patient with chronic left sided internal cerebral artery (ACI) occlusion and asymptomatic high grade right sided ACI stenosis treated with carotid angioplasty with stenting (CAS) in whom signs of hyperperfusion occurred 5 days after the procedure. Computer tomography angiography of the right ACI before (A) and after (B) the procedure. The patient was urgently readmitted to the hospital 5 days after the CAS due to a sudden early morning migraine - like headache localized frontally (non responsive to non steroid analgesics), nausea and vomiting. An hour after the first symptoms hemiparesis with bursts of epileptic seizures predominantly in the left arm occurred. The only risk factor was poorly controlled long standing hypertension. White matter oedema in confined region of the right fronto-parietal region was noticed on computer tomography (CT) (C) and magnetic resonance imaging (MRI) (D). E Hyperperfusion in the same confined region was confirmed with MR perfusion imaging, as shown on cerebral blood flow map. After admission to the intensive care unit for epileptic status, the patient underwent a full neurological recovery. F Follow-up CT one month later revealed complete reversibility of changes in brain tissue.

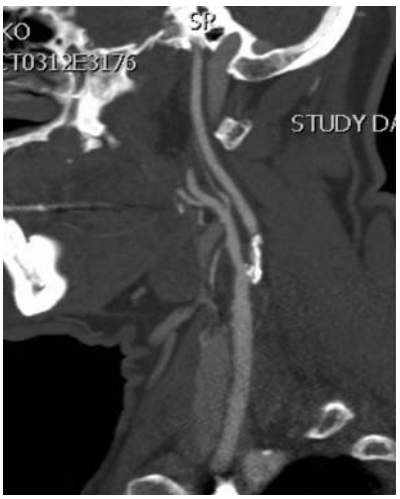
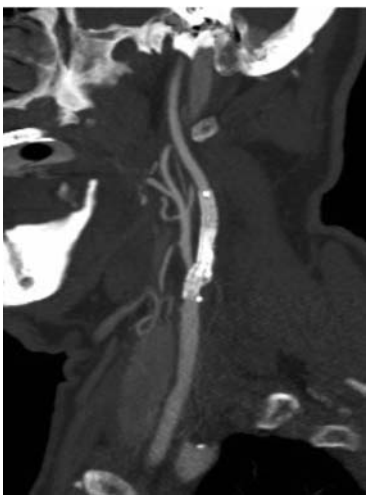


Figure 2A.



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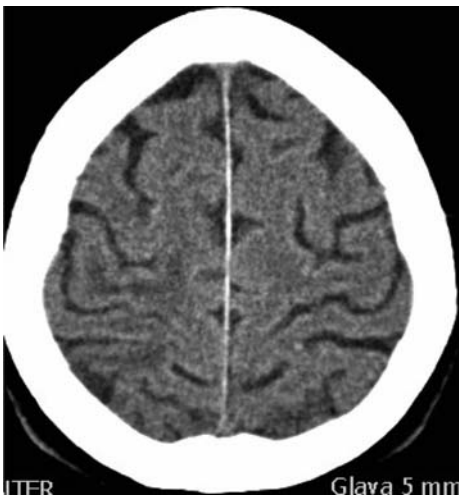

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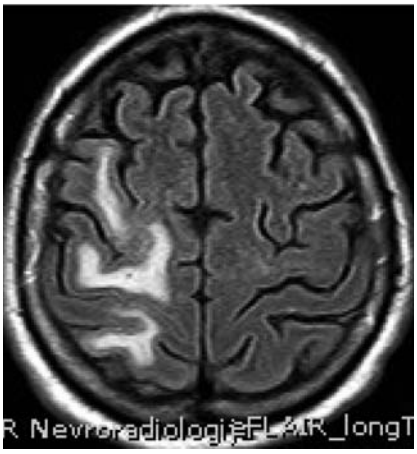

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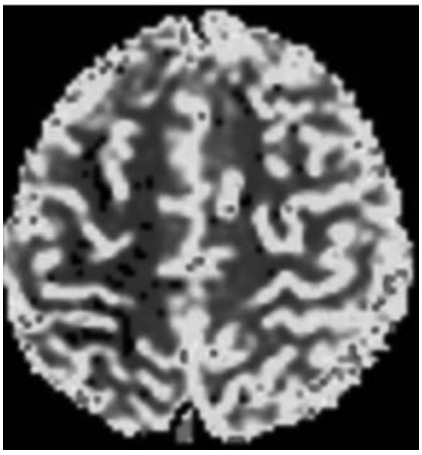

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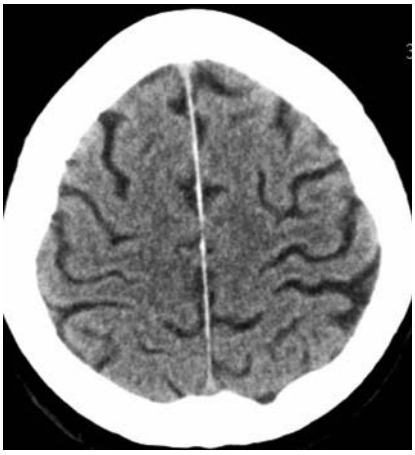

Figure 2F.

The latter reaches the capillary bed and causes cerebral oedema and/or haemorrhage. (3)

The second mechanism, encountered in the pathogenesis of CHS, is postoperatively elevated systemic blood pressure. Hypertension is especially well known after CEA and it is due to receptor denervation. It leads to increased cerebral blood flow and consequently to hyperperfusion of previously hypoperfused brain tissue. This leads to cerebral oedema and elevated intracranial pressure as well as to increased levels of norepinephrine which additionally contribute to elevated blood pressure.

Other possible causes include elevated cranial levels of norepinephrine due to central nervous system sympathomimetic mechanism, perioperative stress and usage of specific anaesthetics during the procedure.

The incidence of CHS and ICH after CAS

Hyperperfusion occurs among 10-13% of patients. (4,6,10) However, the inci-

dence of clinical manifestations such as CHS and ICH is estimated on the basis of retrospective reviews and is still uncertain – the incidence of CHS and ICH after CAS was from 1. 1% and as high as 5% (3,6,11) and from 0. 2% to 3.8%. (3,6,9,12)

A comparison of incidence of CHS and ICH between CAS and CEA is not known to be comparable since anticoagulants and potent antiplatelet drugs are used before and during CAS. (11) Recent studies however implicate that recipients of CAS are more likely to experience ICH. Patients who are younger than 70 years of age and are symptomatic, are especially prone to this devastating complication. (13) The comparison of simultaneous bilateral CAS and unilateral CAS has not shown a statistical difference in CHS and ICH incidence. (14) CAS in patients with symptomatic carotid near occlusion is also not associated with a higher risk for CHS/ICH. (15)

Clinical presentation

Symptoms of CHS and ICH can occur immediately after the procedure or up to several weeks later. Peak onset of CHS after CAS is within 12 hours of surgery; although it can develop later on. (6,9)

Symptoms of CHS are the consequences of brain oedema and include pulsatile migraine like headache (moderate to severe) ipsilateral to revascularised artery (typically localised frontotemporal or retro orbital), altered consciousness and confusion as well as ipsilateral focal seizures or focal neurological deficit without radiographic evidence of infarction. (6,9,11) The majority of patients experience headache only or a minor and transient neurological deficit. (3) Manifestations include hemiparesis, hemiplegia, hemianopsia, obtundation as well as aphasia and epileptic disturbances. Some authors also described cognitive impairment and psychotic disorders. (6)

ICH is usually associated with CHS and early manifestations include the symptoms of raised intracranial pressure such as alterations in sensorium and vomiting. The outcome is associated with high morbidity and mortality (figure 1). (6,11)

A special entity, hyperacute ICH, is described after CAS. It usually occurs within hours (a delay from 8 minutes to 8 hours after the procedure) and without prodromata; it is very unpredictable with high mortality. Bleeding is typically localised in the basal ganglia and the majority of patients present with high – grade stenosis before the procedure as well as microvascular changes of the vessel. (6,9)

Risk factors

Risk factors for development of CHS/ICH can be classified into three groups and include preoperative (hypertensive microangiopathy due to long standing hypertension, diabetes mellitus, advanced age, recent procedure on contralateral vessel (< 3 months), high degree of stenosis with poor collateral flow, severe contralateral carotid occlusion, recent stroke and/or ischaemia, incomplete circle of Willis, attenuated cerebrovascular reactivity after acetazolamide), perioperative (intraoperative distal carotid pressure below 40 mmHg, high doses of volatile anaesthetics, intraoperative cerebral infarction/ischaemia) and postoperative (refractory postoperative cerebral hyperperfusion, postoperative hypertension, administration of anticoagulants/antiplatelet agents). (3,6,15,16)

A recent prospective study performed on a large cohort of CEA cases (841 patients) identified a brief interval between ischaemic symptoms and endarterectomy as the clearest risk factor for CHS. (17)

Diagnostic methods in patients at risk

In order to identify patients at risk several methods have been implicated such as the usage of transcranial Doppler (TCD), computer tomography (CT), magnetic resonance imaging (MRI) and single-photon emission computed tomography (SPECT). (6,16,18) It has been proved recently that preoperative MRI detection of cerebral microbleeds (latent vascular damage) and preoperative 123I-iomazenil SPECT imaging predicts cerebral hyperperfusion. (19)

Perioperative monitoring includes the usage of electroencephalography, ocular pneumopletismography, transcranial colour-coded real-time ultrasonography with echo contrast agents, cerebral circulation time, (3) near infrared spectroscopy (NIRS) and intraoperative internal carotid artery pressure measurement. (3,6,10,20,21)

It has recently been observed that intraoperative TCD may not precisely predict the onset of CHS. The influence of anaesthetic agents on TCD measurements was proposed as a possible cause of inaccuracy. (21) Near infrared spectroscopy has been reported to be a promising noninvasive intraoperative method. However, additional studies are needed to clearly define regional oxygen saturation (rSO_2) cut off values in NIRS measurements. (20)

Additional methods can be used in the postoperative period. Some authors propose postoperative CT perfusion imaging to detect CHS. (22,23) Postoperative MRI and magnetic resonance perfusion imaging can also be used as shown in our case (figure 2). Novel MRI methods include diffusion tensor imaging (DTI) for identifying white matter damage caused by CHS. (24)

Management of hyperperfusion syndrome

A critical point is identification of patients with high risk and prevention of development of the syndrome. (6)

Intraprocedural modifications include the cautious use of anticoagulation therapy as well as employment of embolli-prevention devices and limiting the duration of balloon inflation. The latter two minimize the risk of intraoperative brain ischaemia, which potentiates the risk of CHS and ICH.

The role of anticoagulants and/or antiplatelet agents raises a dramatic safety concern in the pathogenesis of ICH. Excessive anticoagulation during the procedure should be avoided as well as the usage of anticoagulants postoperatively. (11)

The anaesthetist plays a key role in the endovascular management of patients with cerebrovascular atherosclerosis. Optimization of comorbidities, meticulous control of systemic physiologic variables and aggressive management of complications contribute to enhanced patient outcome. (25)

Patients should be admitted to the high dependency or intensive care unit after the procedure. (3)

Intensive blood pressure monitoring is essential; some authors also propose the usage of TCD postoperatively. (26)

Postoperative blood pressure should be maintained at normal or slightly subnormal levels. It has been suggested that blood pressures in the normal range may be deleterious in high risk patients. Antihypertensive therapy should be started as soon as possible in cases of elevated blood pressure. (6,11)

The choice of antihypertensive agent remains unclear, however rapid lowering of blood pressure leads to hypoperfusion of end-organ as well as ischaemia. The usage of agents with a short onset is highly recommended. (27)

Cerebral vasodilator agents such as calcium channel blockers or nitrate should be avoided. (6,27)

The usage of beta blockers is also limited due to potential bradycardia after revascularization. (6)

Prophylactic anticonvulsant therapy is not recommended. However, in cases of convulsions, adequate therapy is indicated. (6)

Cerebral oedema, which can develop after the procedure, should be aggressively treated with adequate sedation, administration of mannitol and/or hyperventilation. Corticosteroids and barbiturates have also been used in this field.

Due to early discharge after the procedure patients and general practitioners should be aware of the complications.

Monitoring of blood pressure and treatment of hypertension is therefore strongly recommended for at least two weeks after the procedure.

Patients should return to hospital in case of severe headache and/or if systolic blood pressure exceeds 160 mmHg. (6,11,27,28)

Conclusions

The number of endovascular procedures in increasing and so are the complications.

The role of the interventional neuroradiologist as well as the rest of the team is to prevent, identify and to treat the complications as soon as possible.

Therefore we recommend a multidisciplinary approach to patients, especially the ones with increased risk.

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