Nighttime versus daytime TIA and stroke: a prospective study of 110 consecutive patients

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Background: Ischemic stroke occurs most frequently after awakening and only in 20–40% of patients at night. Sleep and stroke characteristics of patients with daytime and nighttime onset of acute cerebrovascular events are unknown.

Methods: A consecutive series of 110 patients with TIA (n = 45) or acute ischemic stroke (n = 65) was studied by means of a standard protocol which included assessment of time of onset of symptoms, sleep and stroke characteristics. An overnight polysomnography was performed after the onset of TIA/stroke in 71 patients.

Results: In 23 (21%) of 110 patients TIA or stroke occurred at night (between midnight and 6 a.m.). Patients with and without nighttime onset of TIA/stroke were similar in demographics; risk factors; associated vascular diseases; clinical and polysomnographic sleep characteristics (including severity of sleep apnea); and stroke severity, etiology, and outcome. Only the diastolic blood pressure at admission was significantly lower in patients with nighttime events (74 vs 82 mmHg, p = 0.01).

Conclusions: Nighttime and daytime TIA/Stroke are similar in sleep and stroke characteristics. Our study suggest that diastolic hypotension may predispose to nighttime cerebrovascular events. Factors not assessed in this study probably account for the circadian variation in the frequency of TIA and acute ischemic stroke.

Charcot-Wilbrand syndrome after bilateral posterior cerebral artery stroke

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Background: Patients with cessation of dreaming following stroke (Charcot-Wilbrand syndrome) were rarely reported and only exceptionally assessed by polysomnography.

Case report: This 73-year old patient presented with left homonymous hemianopsia, right quadrantanopsia, and achronatopsia. Detailed neuropsychological examination revealed only reading difficulties but no amnesia, topographic disorientation, prosopagnosia, reviualization or emotional disturbances. Brain MRI showed bilateral inferior lingual gyrus and left posteroverentral thalamic infarctions. Sleep history Before stroke the patient experienced dreaming several times/week. The 3rd night after stroke the patient had a single episode of vivid dreaming (dwarf-like figures moving over a colourful carpet. The patient denied any dream experience for the following five months Poly{-20}{somnographic (PSG) studies: PSG 1 (5 days after stroke) showed slightly abnormal sleep architecture (sleep latency = 30 min, NREM stage 1 = 19% of total sleep time, stage 2 = 28%, stage 3–4 = 23%) but normal REM sleep (REM-latency = 60 min, REM = 16%, REM-density) and sleep breathing. PSG 2 (at 3 weeks) and PSG 3 (at 4 weeks) showed similar findings. During PSG 4 (at 6 weeks) the patient had 5 REM-periods: after 4 awakenings from REM sleep she denied any dream experience.

Conclusions: We demonstrate that bilateral PCA-stroke can cause persisting loss of dreaming in the absence of (other) neuropsychological deficits and REM sleep abnormalities.
Sleep apnea in acute stroke: diagnosis and treatment with an intelligent CPAP

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Background: Obstructive sleep apnea (OSA) is found by conventional polysomnography in >50% of patients (pts) with acute stroke. The diagnostic/therapeutic value of intelligent CPAP devices in acute stroke pts with OSA is unknown.

Patients and methods: We prospectively studied 94 patients (mean age 55 ± 11 years) with acute stroke. Sleep breathing was assessed by an intelligent CPAP machine (Res Med AutoSet). The Apnea-Hypopnea Index (AHI) was determined. CPAP titration was tried in all pts with obstructive sleep apnea (OSA, AHI >15/h or with AHI >10 and hypersomnia). Treatment with conventional CPAP was started at a fixed pressure determined from the results of the AutoSet night.

Results: Diagnostic studies were performed a mean of 3 days (range 0–9 days) after stroke onset. The mean AHI was 17 ± 14 (range 0–56). OSA was found in 38 (40%) of 94 pts. Patients with OSA had significantly (p <0.05) more often a positive history for habitual snoring (58% vs 28%), hypertension (63% vs 33%), and diabetes (34% vs 5%) than pts without OSA. CPAP titration was successfully completed in 30 (79%) of 38 pts. At hospital discharge 20 (53%) of 38 pts were still on CPAP.

Conclusions: We confirm that OSA is frequently found in acute stroke pts. Diagnosis of OSA and CPAP titration with an intelligent CPAP machine are feasible in this clinical setting but CPAP compliance appears to be low.

Symptomatic and asymptomatic carotid artery occlusion (CAO): aetiologies, clinical and vascular findings in 174 patients

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Background: Detailed descriptions of clinical aspects in CAO in the past were usually based on findings in patients who had undergone conventional angiography. With widespread use of advanced ultrasound technology, more asymptomatic forms are detected. This study aimed at identifying factors associated with symptomatic or asymptomatic CAO.

Method: We looked retrospectively at 174 consecutive patients with ultrasound diagnosis of common or internal CAO regarding clinical manifestations at time of carotid occlusion, previous cerebrovascular events, ultrasound specific findings, aetiology and outcome. 69% of the patients were male, 31% were female. Mean age was 66 years.

Results: 69% had symptomatic occlusion, in 31% occlusion was asymptomatic. 78% of the symptomatic patients had infarctions, 22% had transient ischaemic attacks (TIA). 82% of the symptomatic patients had hemispheric manifestations, 17% had retinal symptoms. 69% were left with no or slight disability, 30% with moderate or severe disability. The aetiology was in 78% atheromatosis, in 5% dissection, in 2% thromboembolism and in 14% not determinable. In symptomatic CAO, TIA of the homolateral hemisphere prior to manifestation of occlusion was more common than in asymptomatic cases (18% vs. 43%, p = 0.004). Atherosclerosis was related to asymptomatic occlusion (98% vs. 85% in symptomatic occlusion, p = 0.034).

Conclusion: The occurrence of asymptomatic CAO is a common finding in patients sent for neurovascular ultrasound investigation. Patients with asymptomatic CAO usually have atherosclerosis, while in those with symptomatic CAO further aetiologies like dissection and embolism are observed.
A mural thrombus in the common carotid artery: an uncommon finding in a stroke patient with fibrin strands

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Background and purpose: The occurrence of a mural thrombus in the common carotid artery (CCA) is an exceptional angiographic finding. We would like to discuss clinical, radiological, ultrasonographic features and etiology of a stroke patient with a CCA's mural thrombus.

Results: A 44-year old woman without medical history presented a right sensitivo-motor deficit associated with a right hemineglect, dysarthria, apraxia and a right ataxia. Brain-CT showed recent multiple cortical ischemic lesions in the left ACA and left MCA territories while an old ischemic lesion was found in the right ACA territory. CTA and MRA revealed a mural thrombus of 38 × 5 mm in size in the left CCA. Color and Power Duplex Imaging noticed the following characteristics: 1) a mural thrombus in the left CCA without hemodynamically significant stenosis; 2) a variable detection of the mural thrombus according to the insonation angle; 3) the respect of the intima-media complex. The only cause of stroke in this patient was the evidence of fibrin strands on the aortic valve at transesophageal echocardiography.

Conclusions: A mural thrombus in the CCA is a rare cause of embolic strokes with a specific pattern at color/power Duplex ultrasonography and may be associated with fibrin strands.

Cerebral infarction of a 38-year-old woman with a rare cause of cardiac emboli origin: the isolated ventricular noncompaction

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Background: Diagnostic approaches to the sources of cardiac emboli is especially important in young people because of relevant therapeutic and prognostic consequences. Since the transthoracic (TTE) and transesophageal echocardiography (TEE) was established as an important diagnostic step, a lot of new pathophysiological mechanisms and diseases could be identified noninvasively. One of these diseases is the entity of isolated ventricular non-compaction (IVNC), which we describe in this lecture.

Case description: A 38 year old female patient had a cerebral infarction in the middle cerebral artery region with the manifestation of two recidivous transient ischemic attacks (TIA). The diagnosis of the IVNC was done after the second TIA. As origin of the cardiac emboli the TTE and TEE showed a “localized” hypertrophy of the left ventricle apex with excessive trabeculation with deep perfused recesses. The left ventricle systolic (LVSF) and diastolic function (LVDF) was normal. Since the patient was on adequate oral anticoagulation she has been stable for 3,5 years.

Conclusions: When the disease of IVNC is known and the diagnostic criteria are fullfilled, the diagnosis of the IVNC is relatively easy to make. The consequences of the IVNC are a lifelong oral anticoagulation to prevent further cardiac emboli manifestations and a yearly TTE control to evaluate the prognostic important factor of the LVSF and LVDF. If this is reduced, the prognosis of this disease is very bad with a mortality of 60% in 6 years. The IVNC is a relatively new accepted entity of a cardiac disorder, which is an important differential diagnosis of cardiac embolic cause of cerebrovascular events with relevant therapeutic and prognostic consequences.
The Lausanne Emotion in Stroke Study: emotional behavior in acute stroke

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Objective: To assess early patterns of emotional behavior in stroke and correlate them with stroke features and evolution.

Background: Depression, anxiety, apathy and mania have occurred after stroke, but better clinico-topographic correlates of emotional behavior in the acute phase of stroke and definition of risk factors ask for a prospective study.

Methods: Data concerning all patients with first-ever stroke admitted within 48 hours to our population-based center were collected prospectively, including neurologic and neuropsychological examination, CT/MRI. Personal/familial psychiatric history and medication. A Behavioral index form specifically designed and validated for its inter-examiner fidelity on 35 patient, was filled out during the first 4 days by the team continuously present in our acute care unit. It included a quantified rating reactions: overt sadness, passiveness, aggressiveness, indifference, disinhibition, denial, adaptation, abnormal sleep/feeding. At days 7 and 90 evaluations were performed with mood scales (Hamilton), functional scores (Barthel/Rankin/ADL) and semistructured psychiatric interview.

Results: 66 patients have completed the protocol: 38 men, 28 women, age 62 ± 20 years, 45 stroke in the MCA territory and 21 in the posterior circulation (24 right, 40 left and 2 bilateral). During the first 4 days, patients showed reactions of disinhibition (52), denial (43), indifference (46), overt sadness (50), aggressiveness (44), or abnormal sleep/feeding (54). On day 7, 35 (53%) patients had adequate memory of the acute event, whereas recall was partial in 23 (34%) and impossible in 8 (12%). On the 3rd month, 32 patients (48%) were anxious (6), anxio-depressive (11), depressed (9), or sub-manic (2). Preliminary statistical analysis suggested that specific early behavioral features such as denial, may be related to post-stroke depression.

Conclusions: Early emotional behavior can be quantified in acute stroke using the Behavioral Index Form, a new scale validated for its inter-examiner fidelity. This may allow us to delineate the best markers of subsequent mood disorder and to perform detailed clinico-topographical correlations.
A new non-invasive method to estimate cerebral hemodynamics and oxygenation pattern in patients with cerebral vasospasm

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**Background:** Cerebral vasospasm (CVS) leading to delayed ischemic neurological deficit is the most significant cause of morbidity and mortality in patients surviving SAH long enough to reach medical care. Radiographic vasospasm do not reflect cerebral hemodynamics and oxygenation patterns. Radiographic CVS may occur in the absence of clinical deficit, and vice-versa. The established methods for bedside measurement of cerebral blood flow (CBF) with inert tracers such as the nitrous oxide dilution method, or the 133Xenon dilution technique are technically difficult, time consuming or involve radioactive radiation. Stable Xenon-enhanced computed tomography (sXe-CT), positron emission tomography (PET), single-photon emission computed tomography (SPECT), or MR spectroscopy are powerful research tools but require that the patient be transported, which carries a potentially high risk. Transcranial doppler (TCD) and jugular bulb oximetry using optical fibers give indices that can be related to changes in cerebral blood flow (CBF) but do not measure true flows. Therefore to find a suitable method for bedside monitoring of cerebral oxygenation and perfusion to detect and treat cerebral vasospasms is still a matter of investigation.

**Methods:** 2 pairs of near infrared-(NIRS)-optodes are placed bilaterally on the forehead, emitter and detector 4cm apart. The spectrophotometer (Hamamatsu, NIRO 300) uses four light-emitting diodes at different wavelengths (913, 850, 810 and 775 nm). OD changes and changes of Hb oxy and Hb desoxy were recorded by the NIRS-system with a sampling rate of 2 s⁻¹ for a two minutes baseline analysis. The instrument measures transmitted light in a series of separate detectors with a fixed spacing, which allows to estimate an absolute value of tissue oxygen saturation (TOI). Peripher venous injections of 0.5mg/kgKG ICG (5mg/ml aqua dest.) were performed. The appearance of ICG in the optical field and dye dilution curves were recorded. Measurements were performed in a 50 years old female patient with symptomatic MCA- and ACA-vasospasm. Transcranial doppler sonography, angiography and NIRS-measurements were obtained 1 hour before and after superselective papaverin instillation into the right MCA and ACA and initiation of hypertensive hypervolemic hemodilution (triple-h-therapy).

**Results:** Before papaverin instillation and triple-h-therapy TOI obtained above the right hemisphere was lower (49.2 ± 1.4) than TOI obtained...
above the left hemisphere (60.3 ± 1.1). After papa-
verin instillation and initiation of triple-h-thera-
py TOI from both hemispheres increased and in-
terhemispheric TOI-differences disappeared
(right 71 ± 0.7; left 68.5 ± 1.3). ICG-dye-dilution
curves from both hemispheres before and after
papaverin and triple-h-therapy are shown in the
figures.

The amplitudes of ICG dilution curves increased
in both hemispheres after initiation of triple-h-
therapy. After superselective papaverin instillation
into the vasospastic right MCA and ACA the ICG
dilution curve from the right hemisphere increased
more pronounced (24.5% right hemisphere; 15.5%
left hemisphere).

Conclusions: Shown by superselective papaverin
instillation in the right MCA and ACA, measure-
ments by the NIRS-ICG-dilution-method seem to
reflect changes from the intracerebral vessels. The
new methodology could be a powerful tool in
detection and treatment of CVS.
Coexisting causes of stroke

Background: The coexistence of multiple potential causes of cerebral infarct (MPCI) has been poorly studied.

Methods: Using a standard protocol of investigation, we studied the patients who had at least 2 of the following potential causes of first cerebral infarct among 3909 patients from the Lausanne Stroke Registry. Large artery disease LAD (narrowing of >50% of the lumen diameter in the appropriate large artery; small artery disease SAD (patients with small (<1.5 cm) deep infarct SDI and hypertension or diabetes); and cardiac source of embolism (CSE).

Results: There were 250 patients (6.3%); mean age 69.9 years (SD 8.8), who had at least two MPCI, with the following subgroups: 1. LAD + CSE 43% (108/250), 2. SAD + CSE 34% (84/250); 3. LAD + SAD 18% (45/250); 4. LAD + SAD + CSE 5% (12/250). Hypertension predominated in all groups, but only in 47% (51/108) of patients in the LAD + CSE group (p <0.001). Cigarette smoking was prevalent in the LAD + SAD group (18/45; 40%) p <0.05. Previous TIAs predominated in the LAD + CSE group (40/108; 37%) p = 0.06. A decreased level of consciousness and speech disorders were more common in LAD + CSE patients (26/108; 24% and 59/108; 55% respectively) p <0.001. Classic lacunar syndromes (LS) predominated in the LAD + SAD group (42/45; 93%) p >0.05. Pure motor stroke was the most frequent LS in the SAD + CSE (36/85; 42%) and in the LAD + SAD (30/45; 67%) groups p >0.05, but in the LAD + SAD + CSE group ataxic hemiparesis predominated. Infarcts involving the carotid circulation were more common in patients in the LAD + CSE group (87/108; 81%) p <0.05. The outcome at one-month was better in patients in the LAD + SAD + CSE and LAD + SAD groups p <0.001. Other stroke characteristics and clinical features did not differ greatly between the 4 groups.

Conclusion: These findings suggest that MPCI are uncommon. When present, the most frequent association is the LAD+CSE. Stroke patterns and clinical characteristics only rarely allow to emphasize a preeminent etiology.

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Malformation artério-veineuse et phénomène de moyamoya: une hypothèse angiogénique

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L’association d’un phénomène de moyamoya et d’une malformation artério-veineuse cérébrale (MAV) est rare.

Nous rapportons le cas d’une patiente de 50 ans admise pour l’apparition subite d’une dysarthrie et d’une extinction auditive gauche secondaire à un ramollissement du gyrus temporal supérieur droit démontré à la résonance magnétique. L’angiographie cérébrale a mis en évidence une MAV pariéto-temporale droite ainsi qu’un phénomène de moyamoya avec occlusion de l’artère sylvienne droite, sténose de l’artère cérébrale antérieure gauche, sténose de l’artère communicante postérieure droite, sténose de l’artère cérébrale postérieure associées à un réseau collatéral moyamoya par les artères perforantes et leptomeningées. La patiente a bénéficié de la résection de la MAV et l’angiographie de contrôle à 6 mois a démontré une nette régression du phénomène de moyamoya.

Intrigués par la régression du réseau moyamoya après la résection de la MAV chez cette patiente, nous avons identifié rétrospectivement 11 patients présentant la même association d’une MAV et d’un phénomène de moyamoya.

Tous ces patients présentaient des occlusions ou sténoses artérielles se situant en amont de la MAV et sur le tronc artériel nourricier principal. Les vaisseaux moyamoya dilatés représentaient dans tous les cas des connexions artério-artériolaires, ne montraient pas de shunt artério-veineux et s’étaient développés dans les territoires jonctionnels superficiels ou profonds. La circulation dans ces vaisseaux moyamoya étaient lente et ils suppléaient la MAV. Une diminution du réseau collatéral était visible angiographiquement après traitement de la MAV.

Les changements observés dans le réseaux moyamoya après traitement de la MAV sont intrigants et suggèrent que l’association d’une MAV et d’un réseau moyamoya représente un phénomène angiogénique adaptatif et n’est pas une coïncidence. Ceci supporte aussi l’hypothèse nouvelle que les vaisseaux moyamoya représentent un territoire jonctionnel induit par la MAV. Ces aspects hémodynamiques et angiogéniques ont des implications physiopathologiques et thérapeutiques importantes qui seront discutés.
Bilateral vertebral artery occlusion: 5 cases and review

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Background: Bilateral vertebral artery occlusion (BVAO) is a very rare cerebrovascular disorder (CM, responsible for ca. 0.1–0.2% of all strokes. Only three small series with a total of 31 cases exist in the literature. Adding all the anecdotal cases of bilateral vertebral artery dissection depicted in journals, there would be published about 40 cases of BVAO.

Giant-cell arteritis (GCA) is a common vasculitic disease with a prevalence of 18/100'000, 30 of patients having neurological signs or symptoms. Stroke rate assumes only 1–3 %, but strokes originate 2.5-fold more often in the vertebrobasilar territory than in arteriosclerotic disease. This fact reflects the frequent involvement of the extracranial part of the vertebral arteries. Only 4 cases of BVAO due to GCA are found in the literature. In the following we report on 5 own cases of BVAO, emerging all in the last year, with respect to symptoms, the neurovascular findings, outcome and etiology.

Case reports: As in the literature, male sex is prominent (80%) and mean age (60 years) far younger than in carotideal disease. The clinical course began insidiously, progressing to a sudden outbreak of severe symptoms and signs of vertebrobasilar ischemia, which disappeared after adequate treatment. Three cases are due to arteriosclerotic vessel disease, whilst in the one fatal case necropsy revealed GCA as the etiology of BVAO. In the resting case, progressive disease stopped only after administration of i/v high-dose methylprednisolon, supposing a inflammatory (eg. vasculitic) cause. The four surviving patients improved slowly to actually respectable disability.

Conclusions: BVAO is an infrequent cerebrovascular disease of atherothrombotic-embolic etiology in 5 out of 6 patients which are 7 years younger as the patients with carotideal disease. BVAO evolves subacutely to a sudden outbreak of serious symptoms and signs, but the former bad (lethal) outcome turns actually to a better prognosis with survival of about 70% of patients (70% of them with full recovery/slight disability, 30% with severe handicap).

Together with our 2 cases of GCA-related BVAO with typically sparing of the intracranial part of the vertebral arteries, the literature mentions solely 6 cases of older patients (mean 71 years) with 4 of them with fatal outcomes stressing the serious prognosis of this combination of diseases. In 3 cases, surprisingly, vertebrobasilar signs and symptoms represented the first manifestation of GCA. To our opinion, in cases with otherwise (under anticoagulation) progressive vertebrobasilar infarction and in suspicion of a vasculitic disease mechanism aggressive antiinflammatory treatment with high-dose steroids is by far justified as proved in one of our cases.
AVC, foramen ovale perméable et migraine

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**Introduction:** Diverses pathologies vasculaires peuvent être à l’origine de migraines dites symptomatiques: une athéromatose sévère des artères cervicales ou une dissection. Plus rarement les migraines sont associées à une pathologie cardioembolique. Une étude récente a montré une prévalence accrue de foramen ovale perméable (FOP) chez des patients migraineux avec aura et il nous a paru important d’étudier la fréquence de ces deux mécanismes dans un groupe de patients ayant présenté un AVC.

**Patients et résultats:** Nous avons revu 35 patients hospitalisés dans notre service pour un AVC. Vingt et un des patients présentent un FOP détecté au moyen d’un Doppler transcrânien avec injection de produit de contraste, une échographie thoracique et/ou une échographie transoesophagienne. Une fréquence augmentée de patients migraineux avec aura a pu être observée dans le groupe de patients avec FOP. Les caractéristiques du FOP chez des patients migraineux et non-migraineux sont les mêmes. Le diagnostic d’infarctus migraineux a été évoqué initialement chez 3 patients, et la découverte d’un FOP entraîna chez l’un d’entre eux une fermeture chirurgicale.

**Observation d’un cas:** Patiente de 41 ans, souffrant de migraines avec aura depuis une vingtaine d’années, hospitalisée dans notre service pour un AVC ischémique frontal gauche. Cinq ans auparavant, elle a présenté un hémisyndrome droit considéré comme un infarctus migraineux (lésion ischémique thalamique gauche). C’est à la suite de la découverte d’un FOP que la patiente nous est transférée. Durant l’examen Doppler transcrânien, quelques secondes après l’injection du produit de contraste, la patiente signale une aura visuelle typique qui va durer environ 20 min., puis elle notera l’apparition de céphalées pulsatiles habituelles. Une fermeture chirurgicale du FOP sera réalisée ultérieurement.

**Conclusion:** Les migraines avec aura semblent fréquentes chez des patients ayant eu un AVC et qui sont porteurs d’un FOP. Dans certains cas, le diagnostic initial d’infarctus migraineux peut être erroné et la découverte d’un FOP doit inciter à considérer la possibilité d’une migraine induite par une embolie paradoxale.
Time-resolved projection magnetic resonance angiography of the cerebral vasculature after bolus injection of contrast agent

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Purpose: To evaluate the feasibility of a time-resolved MR Projection Angiography to show the cerebral vasculature and to acquire hemodynamic information in patients with high grade stenosis of the carotid artery.

Methods: A RF-spoiled-FLASH sequence optimized for projection imaging was used (TE 1.4 ms, TR 3.4 ms) on a 1.5 T system (Siemens Magnetom Vision; gradient strength 25 mT/m, rise time 40T/ms). Images were acquired as projections through thick slabs (60–200 mm thickness) in the coronal, sagittal and axial plane. A matrix of 256 phase encoding steps was used, one image was obtained every 900 ms. Simultaneously to the injection of a clinical dose (0.1 mmol/kg) of Gd-DTPA the measurement was started with 50 images acquired consecutively. Images were calculated as complex subtractions from the baseline images.

Results: In 5 healthy volunteers and in 10 patients with stenoocclusive disease of the carotid artery images of consistent high quality were obtained. The passage of the contrast media bolus was reliably shown from the early arterial phase in the internal carotid artery to the arterial, capillary and venous phase intracranially up to the late venous phase in the jugular vein. In patients with a high grade stenosis of the carotid artery a delayed arrival time of the contrast medium bolus on the obstructed side was observed.

Conclusion: Subsecond Projection MR angiography of the intracranial vasculature is a robust technique to depict time resolved distribution of contrast agent. No timing between contrast agent application and image acquisition is necessary. The technique offers a fast, dynamic overview about the cerebral perfusion and hemodynamic information in patients with stenoocclusive disease not obtainable by “conventional” MRA techniques.

Recent experience of revascularisation on patients with Moyamoya syndrome and Moyamoya disease

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Moyamoya disease or Moyamoya syndrome are still little known in Switzerland and elsewhere in Europe. There are, however, an increasing number of published reports originating from countries other than Japan. We recently performed surgical revascularization in seven cases of Moyamoya disease or syndrome. Our experience confirms that this entity occurs in Europe, though with a lesser incidence than in Japan.

The following points relating to surgical management will be discussed:

Diagnostic criteria – The clinical manifestations of the Moyamoya disease or syndrome in Europe

Measurement of CBF and hemodynamic reserve with positron emission tomography to optimize surgical planning, including the selection of a revascularization procedure.

The optimal timing of the surgical procedure, and the selection of surgical revascularization.

Postoperative hemodynamic assessment

Long term follow-up

Further clinical and basic research