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ORIGINAL COMMUNICATION

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Recanalization of acute symptomatic occlusions of the internal carotid artery

Abstract *Background* Little is known about the natural course of internal carotid artery (ICA) occlusion and its possible recanalization. The present study was designed to evaluate recanalization rates of extracranial ICA occlusions in acute stroke patients by means of color-coded duplex sonography (CCDS). *Methods* 305 patients with acute ischemia in the territory of the middle cerebral artery were included in this study. All patients had a neurological examination on admission and on discharge and were rated by means of the European Stroke Scale (ESS). Extracranial color-coded duplexsonography, transcranial Doppler sonography and cranial computed tomography were immediately performed after admission and within 7 days. *Results* 254 patients showed no sign of hemodynamic relevant stenosis greater than 70 % of the ICA. 21 patients had symptomatic high grade ICA stenosis. 20 patients had an acute occlusion and 10 patients an old ICA occlusion as judged by duplex sonographic criteria. Six patients (5 male, 1 female; age range 57 to 77 years) with an acute atherothrombotic or cardioembolic occlusion showed a recanalization of the ICA in the follow-up ultrasonography. Two patients with cardiogenic embolic occlusion of the ICA had the most favorable outcome and these patients showed no residual stenosis. 4 patients who had ultrasound findings consistent with atherosclerosis on follow-up examination (2 high-grade stenosis, 2 with carotid plaques) did not show a notable improvement of their ESS-score. Patients with carotid plaques developed complete MCA infarctions; the other 4 patients had partial anterior circulation infarction on follow-up CT. *Conclusions* The present study showed that recanalization of the occluded ICA in acute stroke patients is more frequent than generally presumed. CCDS should be routinely performed in the follow-up of stroke patients as spontaneous recanalization may influence clinical outcome.

Key words duplex sonography · internal carotid artery occlusion · recanalization · stroke

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Introduction

Prognosis and outcome of patients with an acute internal carotid artery (ICA) occlusion is poor. Acute ICA occlusions are associated with profound disability in 40 to 69 % of the cases and with a death rate of 16 to 55 % [17]. Little is known about the natural course of a proximal internal carotid artery (ICA) occlusion and its possible recanalization.

The present study was designed to evaluate recanalization rates of the occluded extracranial ICA in acute stroke patients by means of color-coded duplex sonography (CCDS).

Methods

786 patients were admitted to our department over a period of 1,5 years with signs of an acute stroke in the anterior or posterior circu-

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lation. 305 consecutive patients of this population fulfilled the inclusion criteria of acute ischemia in the territory of the middle cerebral artery with onset 24 hours prior to admission and were enrolled in this study. All patients had a neurological examination on admission and on discharge and were evaluated by means of the German version of the European Stroke Scale (ESS) [3] and stroke classification was done according to the TOAST criteria [15]. Extracranial color-coded duplex sonography (CCDS), continuous-wave (cw) Doppler sonography of the periorbital arteries and transcranial pulsed-wave (pw) Doppler sonography were immediately performed on admission and again within 7 days. CCDS examinations were carried out by using an Ultramark 9HDI, ATL, Bothel WA, USA, which was equipped with a 7.5 MHz linear array scanner. Pulse repetition frequencies were set between 500 and 4500 Hz and the wall filter at standard 100 Hz or reduced to 50 Hz to increase sensivity to detect low flow. Extracranial cw-Doppler and transcranial pw-Doppler were performed with a Companion (Nicolet-EME GmbH, Kleinostheim, Germany), with 2- and 8-MHz probes. An occlusion of the ICA was diagnosed according to previously suggested criteria. In brief, these criteria are absent flow in the lumen of the ICA for at least 1.5 cm, diminished flow velocity in the ipsilateral common carotid artery with increased pulsatility and pathological Doppler signal in the ipsilateral periorbital arteries [1, 9]. The following criteria were used in order to differentiate between an acute and an old occlusion. An old occlusion was assumed when the vessel wall was demarcated only vaguely from the surrounding tissue, as transformation of the vessel wall into connective tissue has occurred in contrast to an acute occlusion where the vessel wall can be clearly visualized. Hyperechogenic structures within the vessel lumen indicate organization of thrombus in old occlusions, whereas hypoechogenic structures, that are hardly distinguishable from normal blood suggest an acute occlusion. In order to avoid confusion of different pathophysiological causes of occlusions, special attention was paid to characteristic duplex sonographic features of ICA dissections [23, 24] such as tapering of the ICA lumen, crossing of an irregular membrane in the ICA lumen dividing it into a true and a false lumen, mural hematoma, absence of relevant atherosclerotic plaques, patent proximal ICA or bidirectional flow in the proximal ICA. Cranial computed tomography (CCT) was performed on all patients on admission and again within 7 days in order to determine infarct size and localization. CCT was performed with a Somatom Plus 4A Scanner (Siemens, Erlangen, Germany). Scanning direction was caudocranial with a slice thickness of 4mm and parallel to the orbitomeatal line. CCT findings were analysed according to standard templates [5] as complete MCA infarction, cortical involvement of the superficial branch territories and subcortical, with additional differentiation between non-lacunar and lacunar infarctions.

Results

254 of the 305 patients had no sign of hemodynamic relevant stenosis of the ICA. 21 (6.9 %) patients revealed symptomatic high grade ICA stenosis of greater than 70 %. Of the 30 (9.9 %) patients with ICA occlusions, ten patients demonstrated an old occlusion and twenty patients an acute occlusion. Of these acute occlusions, two were due to carotid dissection and 18 due to atherosclerosis and cardioembolism. In follow-up CCDS, two male patients (one 43 years old, ESS-score on admission 73 and on discharge 92, superficial MCA infarction in CCT; the other 54 years old, ESS-score on admission 82 and on discharge 100, no infarct signs in CCT) with an ICA occlusion due to arterial dissection developed recanalization within 3 months. They were left out of consideration and systematic evaluation within the scope of the study in order to avoid confusion of different pathomechanisms. Six patients (5 male, 1 female; age range 57 to 77 years) of the group of atherosclerotic and cardioembolic acute occlusions showed a recanalization of the ICA in the follow-up CCDS. Clinical, CCT and ultrasound findings of these patients are summarized in Table 1. Even though patient 2, 3, 4 and 6 were hospitalized within the first three hours after the onset of the symptoms, thrombolysis was not indicated in these patients. All patients with ICA occlusion received intravenous heparin. According to the TOAST classification [15], stroke originated in two patients from cardioembolic disease and in four patients it was due to local thrombosis. The two patients with cardiogenic embolic occlusion of the ICA had the most favorable outcome (see table). The initial ultrasonic examination in these two individuals revealed hypoechogenic occlusions, and in the follow-up there was no residual stenosis in either patient (see figure 1 a and b). In four patients, atherosclerotic changes were demonstrated. In the follow-up examination, patient 3 showed an ICA stenosis of 90 %

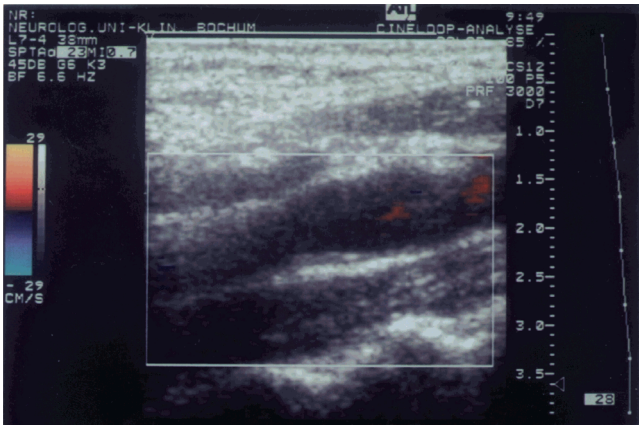

Fig. 1a

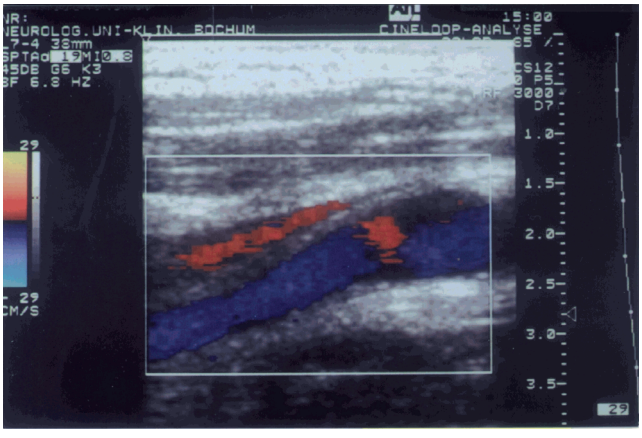

Fig. 1b

Table 1 Clinical, ultrasound and CCT findings of 6 patients with a recanalization of an ICA occlusion due to cardioembolic or atherothrombotic causes

n	Age/ years	ESS on admission	ESS on discharge	Symptom onset prior to admission for hours	Vascular Risk factors	Classification (TOAST criteria)	Morphology of occlusion	Flow in periorbital arteries	Collaterals	Morphology after recanalization	Infarct morphology in CCT
1	64	32	77	7	atrial fibrillation mitral stenosis	cardio-embolism	hypoechogen	absent	no bone window	complete recanalization	subcortical
2	77	29	91	3	atrial fibrillation	cardio-embolism	hypoechogen	retrograde	collateral flow through anterior cerebral artery	complete recanalization	superficial
3	75	81	95	1	hypertension nicotinism	large-artery atherosclerosis	hypo- & hyperechogen	retrograde	no bone window	ICA stenosis of 90 % (hypo-& hyperechogen)	superficial
4	59	75	75	1	hypertension hypercholes-teremia	large-artery atherosclerosis	hypoechogen	retrograde	collateral flow through anterior cerebral artery	ICA stenosis of 80 % (hypoechogen)	superficial
5	74	6	18	8	hypertension hypercholes-teremia	large-artery atherosclerosis	hypo- & hyperechogen	retrograde	collateral flow through anterior cerebral artery	plaques	complete
6	57	24	43	2	hypertension nicotinism	large-artery atherosclerosis	hypoechogen	retrograde	collateral flow through anterior cerebral artery	plaques	complete

consisting of an irregular mixture of hyperechogenic and hypoechogenic material and patient 4 a hypoechogenic proximal ICA stenosis of 80 %. Even though complete recanalization was established in patients 5 and 6, both showed extensive atherosclerotic disease in the form of multiple hyper- and hypoechogenic plaques. The four patients who had ultrasound findings consistent with large-artery atherosclerosis did not show a noteworthy improvement of their ESS-scores (see table). Only patient 5 and 6 developed complete MCA infarctions, the other 4 patients had partial anterior circulation infarction on follow up CT.

Discussion

Emergent use of non-invasive carotid duplex imaging as a bed-side testing in the initial evaluation of acute stroke patients is not well established [2]. However, it has been shown that CCDS allows accurate diagnosis of extracranial ICA stenosis and occlusion in comparison with other techniques such as angiography [1, 9, 12, 14]. For this reason this technique is well suited as a reliable and practicable tool to identify extracranial occlusive diseases in acute stroke, as has been demonstrated in the present study. Out of 1041 patients subjected to initial carotid duplex sonography in a study of antithrombotic treatment in acute cerebral ischemia, 95 (9.1 %) patients had a carotid occlusion and 85 (8.2 %) patients a stenosis of 70 % or greater [2]. Even though our cohort was smaller, it revealed similiar prevalences of carotid artery disease.

Reperfusion of a former occluded ICA has been presented mostly in single case reports [16, 20–22]. In ultrasound studies, spontaneous recanalization of the ICA has been described as a common phenomenon in ICA dissections in about 57 to 68 % of the cases [4, 23, 24], but in patients with an underlying atherosclerotic disease or embolic cause it was rarely seen [20]. Dannenmaier et al. [7] could identify 19 patients with a recanalized occlusion of the ICA, but the underlying cause was a dissection in 57.9 % of the cases and an atherosclerotic lesion in 26.3 %. Six (30 %) of our 18 patients with an acute occlusion due to cardioembolic or atherothrombotic disorders showed a recanalization of the primarily occluded ICA. Typical duplex sonographic morphology of atherosclerotic or cardioembolic carotid artery occlusion [11], clinical findings and medical history were in concordance with atherosclerotic or cardioembolic origin of the carotid artery occlusion.

The majority of occlusions of the ICA is due to atherosclerosis, where preexisting high grade stenotic lesions of the sinus generate local thrombosis due to rupture of an unstable atherosclerotic plaque [13]. Cardiac embolism is another cause of acute occlusions of the ICA whose frequency should not be underestimated [6]. Discrimination of cardioembolic and atherothrombotic ICA occlusion is possible by means of duplex carotid

sonography and might help to come to a decision about the subsequent diagnosis and therapy [11], as, for example, investigation for intermittent tachyarrhythmias and the commencement of anticoagulant therapy. Ultrasonography can detect and monitor arterial sources of embolism and early diagnosis of carotid artery disease might modify the therapy [2, 15].

Because of intravascular lysis and fragmentation of the thrombus, recanalization can occur in days to weeks. Spontaneous recanalization depends on thrombus composition (fibrin or platelet thrombus). In different studies proximal ICA occlusion seemed to be less successfully recanalized by thrombolytic therapy. A relative resistance of strokes with proximal ICA thrombosis to fibrinolyis has been related to the unfavorable volume of clot to rTPA [25]. Recanalization rates with thrombolytic therapy are dependent on the size of the occluded vessel and the presence of collateral blood flow, as the rates are higher in smaller arteries and in the presence of good collateral blood flow [19]. The benefits of acute embolectomy, intraarterial thrombolysis, the combination of both or angioplasty in this life threatening condition of ICA occlusion are still under investigation [8, 26]. Our study shows that CCDS is an appropriate non-invasive tool to identify and monitor those individuals that may benefit from these therapies.

Duplex sonography has already been established as a diagnostic screening and monitoring tool for acute MCA occlusions [10, 18] and in future its potential value might show its benefit in acute ICA occlusions as well. As diagnostic procedures of stroke patients are completed much more quickly these days, reports on acute ICA occlusions might increase and repeated duplexsonography examinations might reveal a higher rate of recanalization than generally supposed at present. Acute ICA occlusions have so far been associated with a poor prognosis. The detection of spontaneous recanalization might help to predict clinical outcome.

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