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Diagnostics of Extra-Cranial Carotid Stenoses

Comparison of CW-Doppler Sonography and Intravenous Digital Subtraction Angiography

R. Puzich[1], E. Becker[1], U. Hegerl[1], R. Roßdeutscher[2], D. Banzer[2], and W. Hepp[3]

[1] Abteilung Neurologie (Direktor: Prof. Dr. W. Girke),
[2] Abteilung Radiologie (Direktor: Prof. Dr. R. Felix),
[3] Abteilung für Chirurgie (Direktor: Prof. Dr. E. S. Bücherl), Klinikum Charlottenburg, Freie Universität Berlin, Eschenallee 3, D-1000 Berlin 19

Summary. In 98 internal carotid arteries, continuous-wave ultrasound Doppler sonography (USD) and i.v. digital subtraction angiography (DSA) of the internal carotid arteries were performed. The findings were compared with each other prospectively and on the basis of conventional angiography findings. The aim of this investigation was to clarify, whether DSA would show stenoses with lumen restriction of less than 50% more precisely than USD, or whether it would enable clearer localization of any vascular lesions.

The results revealed that in cases of haemodynamic effective stenoses and occlusions both procedures correlated well with each other and also with catheter angiography. However, USD and DSA showed increasing discrepancies of findings with decreasing degree of severity of the stenosis. The accuracy for localization of stenoses also decreased markedly for both methods with increasing distance from the carotid bifurcation.

In the case of congruent findings of USD and DSA in haemodynamic effective stenoses (degree of stenosis more than 75%) or occlusions conventional angiography did not increase the diagnostic information, and it seems therefore dispensable for vascular surgical decisions. However, in cases with existing clinical symptoms with contradictory or negative USD and DSA findings angiography is still indicated.

Key words: Doppler sonography – Intravenous digital subtraction angiography – Carotid stenoses

Introduction

Reconstructive measures on the extra-cranial sections of the cerebral arteries can reduce the frequency of cerebral insults. This requires the recognition of corresponding vascular lesions prior to the incidence of irreversible damage to the brain, if possible by non-invasive diagnostic procedures.

In this context, continuous-wave ultrasound Doppler sonography (CW-USD) has recently been proved to be a suitable procedure. Meanwhile, new possibilities have been presented by the introduction of i.v. digital subtraction angiography (DSA). Contrast application and radiation exposure do not justify the term "non-invasive", but the complication risk in view of "conventional" angiography (catheter technique, direct puncture, or counter-current principle) seems to be considerably lower, and allows outpatient application. From the neurological, radiological and vascular surgery point of view, the question of a comparison of both methods in the diagnosis of extra-cranial vascular changes does arise, particularly as to whether or not stenoses with less than 50% lumen restriction would be shown more precisely by DSA than by USD (or whether DSA might give a clearer localization of vascular changes).

Offprint requests to: R. Puzich at the above address

Methodology

Independent investigators rated a total of 98 internal carotid arteries in 49 unselected consecutive patients (age: 39–79 years) with cerebrovascular symptomatology not only by means of USD but also by DSA. Subsequently, USD and DSA findings were compared directly and on the basis of conventional angiographical findings. Because of the prospective character of this study, the indication for conventional angiography was given under strictly clinical aspects. Thus, only 52 carotids were additionally assessed by intra-arterial catheter angiography. All examinations took place within 14 days at the most.

In the USD examination, the common carotid artery, external carotid artery, and the extra-cranial section of the internal carotid artery as well as the supra-trochlear artery were screened by means of a directional Doppler device (Kranzbühler BV762, frequency of 4 MHz).

The acoustic phenomena and graphically registered blood flow signals were evaluated according to the criteria suggested by Büdingen et al. [3].

For DSA we used the "Angiotron" unit (Siemens). By doing 4–7 series in different projections, it was possible to show all supra-aortal branches. The quantity of contrast medium (Omnipaque, Schering) was 30 ml, injected at a flow rate of 18 ml/s mainly via the cubital vein, very rarely via the femoral vein.

According to the usual international procedure, we carried out "conventional" catheter angiography by a two-plane angiography unit with AOT-film changer via femoral puncture (Seldinger technique) with aortic arch-survey and common carotid artery catheterisation.

In order to compare the individual findings with each other, we graduated the lumen restriction into 5 degrees of severity: normal findings, 1%–49%, 50%–74%, 75%–99% degree of stenosis, and vascular occlusions. The localization of

stenoses/occlusions was classified into: close to the origin (up to 1 cm distal of the bifurcation), distal extra-cranial and intra-cranial. Corresponding quota tables served to compare the results of the applied methods.

Results

Degree of Stenoses

The direct comparison of CW-USD and conventional angiography (Table 1) in 46 internal vessels showed a high conformity in cases of occlusions and haemodynamically effective stenoses (more than 75% lumen restriction). Stenoses in the critical range of 50% were mainly diagnosed by CW-USD, but not always classified correctly with regard to the severity. For methodological reasons, stenoses without haemodynamic relevance (below 50%) cannot be shown [19]. No fundamentally different view resulted from the comparison of DSA and conventional angiography in the 46 examined internal vessels (Table 2). A high correlation in significant stenoses and occlusions also existed; a greater number of haemodynamically non-effective stenoses could not be clearly identified. The comparison of CW-USD and DSA findings in all 98 vessels examined (Table 3) showed that severe stenoses and occlusions were identically diagnosed, and that discrepancies of findings were significantly increased with a decreasing degree of severity. In this quota table, the DSA seemed to be superior to the USD with regard to revealing stenoses with a lumen restriction of less than 50%; however, this was not true for the direct comparison between DSA and conventional angiography.

Localisation of Stenoses

In comparison with the angiographical findings (Table 4), CW-USD-realized stenoses in the origin region of the internal carotid artery were exactly localized, but insignificant lesions overlooked. The numbers were too low for a conclusive assessment of the distal extra-cranial as well as the intra-cranial stenoses; however, the discrepancy increased as expected. In this case as well, DSA was unable to show better consistency than conventional angiography (Table 5). Insignificant stenoses in the bifurcation area were overlooked with the same frequency. The discrepancies in findings also increased with increasing distance from the vessel origin. Therefore, the highest conformity of findings in comparison of CW-USD and DSA (Table 6) was with stenoses localized in the bifurcation area.

Furthermore, how many of the stenoses/occlusions assessed identically by USD and DSA had been confirmed by conventional angiography was determined (Table 7). In all angiographically controlled cases, there were no contradictory results in lumen restrictions over 75% including the occlusions. Remark-

Table 1. Degree of stenosis – CW-USD versus angiography ($n = 46$)

Angio \ cw-Doppler	0%	1-49%	50-74%	75-99%	Occlusion
0 %	12	1			
1-49 %	6		2	1	
50-74 %	3	1	3		
75-99 %	2		1	10	
Occlusion					4

Table 2. Degree of stenosis – DSA versus angiography (5 arteries in DSA not evaluable) $n = 46$

Angio \ DSA	0%	1-49%	50-74%	75-99%	Occlusion
0 %	9	1			
1-49 %	7	1	1		
50-74 %	2	1	1	1	
75-99%	3	1	2	7	
Occlusion					4

Table 3. Degree of stenosis – CW-USD versus DSA (5 arteries in DSA not evaluable) $n = 98$

DSA \ cw-Doppler	0%	1-49 %	50-74%	75-99%	Occlusion
0 %	46	2	4		
1-49 %	10	1	4		
50-74 %	1		2	4	
75-99 %	1		4	8	
Occlusion					6

Table 4. Localization – CW-USD versus angiography ($n = 46$)

Angio \ cw-Doppler	0	Bifurk.	extra-cranial	intra-cranial
0	9	1		
Bifurk	6	19		
extra-cranial	3	2	1	
intra-cranial	3			2

Furthermore, how many of the stenoses/occlusions assessed identically by USD and DSA had been confirmed by conventional angiography was determined (Table 7). In all angiographically controlled cases, there were no contradictory results in lumen restrictions over 75% including the occlusions. Remark-

Table 5. Localization – DSA versus angiography (5 arteries in DSA not evaluable) $n = 46$

Angio \ DSA	0	Bifurk.	extra-cranial	intra-cranial
0	7	1		
Bifurk.	6	15	1	
extra-cranial	4	1	1	
intra-cranial	2	1		2

Table 6. Localization – CW-USD versus DSA (5 arteries in DSA not evaluable) $n = 98$

DSA \ cw-Doppler	0	Bifurk.	extra-cranial	intra-cranial
0	47	5		
Bifurk.	6	26	1	
extra-cranial	4	1	2	
intra-cranial				1

Table 7. Comparison of identical CW-USD and DSA findings with angiography. In 8 cases in which CW-USD and DSA showed normal findings, angiography revealed the following results: 1. Intra-cranial lesions ($n = 3$); 2. Lesions near to base of skull ($n = 2$) 3. Minimal lesions in bifurcation are ($n = 3$)

	Regular	1–49%	50–74%	75–99%	Occl.
Corresponding findings of CW-USD and DSA for degree of stenosis	46	1	2	8	6
Angiography	9	1	–	7	4
Agreement	1	0	–	7	4

ably there was a high number of vessels assessed by conventional angiography with pathological findings, in which CW-USD as well as DSA showed negative findings, but because of existing clinical symptomatology invasive diagnostic procedures were carried out. The negative findings of CW-USD and DSA were confirmed just once, in three internal vessels "minimal lesions" were found near to the bifurcation area, in two others stenoses close to the base of the skull, and in three other cases intra-cranial internal carotid stenoses.

Discussion

Angiological diagnoses by means of CW-USD are based on the measurement of functional parameters of blood flow, which enable conclusions of type and localization of morphological changes in the examined vessels. Because of this, its diagnostic range ends in stenoses and plaques which lead to haemodynamic non-effective cross-section restrictions of less than 50%. Since CW-USD has been introduced, its diagnostic accuracy compared to angiography has been examined repeatedly. For stenoses (more than 50%) and occlusions of the extra-cranial internal carotid artery, a diagnostic specifity of 90%–98% has been shown by experienced investigators [3, 6, 7, 8, 10, 12, 15, 19, 21].

Angiographic techniques are able to show morphological details of vessel lesions irrespective of their haemodynamic relevance. Whereas "conventional" angiography requires strict indication in view of known complication risks, i.v. DSA has proved to be of low risk and can also be used for outpatients. Nevertheless, for methodological reasons a worse image quality has to be accepted. In individual cases, factors like swallowing, moving the head, or insufficient cardiac output leads to inadequate results; sometimes diagnostic conclusions are impaired by overshadowing effects of the principal simultaneously contrasted supra-aortal branches [1, 4, 5, 9, 11, 14, 17, 18]. Thus an analysis from May 1982 to March 1984 of DSA findings showed in 650 patients [13] that only 70% (internal carotid artery) and 66% (external carotid artery) of the presented vessels had an image quality shown to be very high. Identical data have been presented by Chilcote et al. and by Peterson et al. [4, 16]; Arlart et al. [1] quoted 88%. In a direct comparison with conventional angiography, an accurary of about 90% is given in the literature for DSA regarding extracranial sections of the internal carotid artery [1, 13, 20].

According to the results of the present study, the diagnostic accuracy of CW-USD and of i.v. DSA with regard to the degree of stenosis and its localization has to be taken as equal at the moment for the extra-cranial region of the internal carotid artery compared to conventional angiography. Both procedures, however, should not be regarded as competitive, but as complementary principles within the scope of an early diagnosis. Together, they produce the combination of morphological information (DSA) on a vessel stenosis (like localization, size, shape, and surface), and data about haemodynamical changes (CW-USD) changed by them (like blood stream velocity, incidence of turbulence, flow reduction, demonstration of collateral pathways).

The indication for conventional angiography still exists, if there is for instance a clinical symptomatology in the form of transient ischaemic attacks, and also CW-USD and DSA investigations result in negative or discrepant findings. To what extent technical improvement of DSA and new USD procedures (like Duplex scanning or trans-cranial Doppler sonography) will change the diagnostic procedure in future, remains to be seen.

The results of this study suggest that no additional information could be expected by angiography, if CW-USD and DSA demonstrate congruently haemodynamic effective stenoses (more than 75% lumen restriction) or occlusions. In this situation, the renunciation of pre-operative catheter angiography can reduce the diagnostic risk decisively. An identical conclusion was drawn by Berger et al. [2] after comparing conventional angiography, DSA, and Doppler-echoflow.

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