Duplex Scanning and CT Angiography in the Diagnosis of Carotid Artery Occlusion: a Prospective Study

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Objectives: Differentiating total occlusion from tight stenosis of the internal carotid artery is crucial with regard to treatment and prognosis. At our institution, the diagnosis of carotid stenosis is based on duplex scanning. In cases of occlusion, duplex is not reliable, and angiography is performed, thereby increasing morbidity. We tried to determine whether a combination of duplex scanning and CT angiography (CTA) can replace angiography in the diagnosis of carotid occlusion.

Design: Prospective study.

Materials and methods: From 1995 to 1997, 148 patients were diagnosed as having carotid occlusion by duplex scanning. CTA was performed on all patients. Forty-four patients underwent angiography and 10 patients were surgically explored. Both procedures were considered "gold standard" for the diagnosis of occlusion.

Results: Arteries found to be occluded by both CTA and duplex scan were confirmed as occluded by angiography or operation in 95% of the cases (42/44). Arteries found to be occluded by duplex but patent by CTA were confirmed as patent in 100% of cases (10/10). CTA has a significantly higher positive predicting value for diagnosing occlusion than duplex scan (95% vs. 77%, p value <0.01).

Conclusions: Combination of duplex scanning and CTA is safe and accurate in the diagnosis of carotid occlusion and can replace angiography in most cases, thereby reducing morbidity.

Key Words: Internal carotid artery occlusion; CT angiography; Duplex; Angiography

Introduction

Differentiating total occlusion from tight stenosis of the carotid artery is crucial with regard to treatment and prognosis. Symptomatic stenosis is an indication for carotid endarterectomy (CEA), whereas occlusion of the internal carotid artery (ICA) is usually treated conservatively. Diagnosis and treatment of carotid artery stenosis is based upon duplex scanning. Tight stenosis with minimal flow can be misdiagnosed as occlusion, therefore angiography is traditionally performed. Angiography is still considered the "gold standard" of carotid artery imaging, its major drawback being its morbidity (i.e., stroke) and mortality rates, which constitute a significant portion of the overall complications associated with CEA. The morbidity of angiography increases in patients having “pseudo-occlusion” (very tight stenosis with a "string sign" on angiography), emphasizing the need for a safer imaging modality in diagnosing suspected occlusions. The positive predictive value (PPV) of duplex scanning in diagnosing occlusion has been reported to be between 86-98% when compared to an angiography as a standard. These studies concluded that although duplex scanning is sufficient for diagnosis in some patients, in certain subgroups of patients angiography is still required for a final diagnosis. CT angiography (CTA) is a new non-invasive modality that is based on spiral CT with injection of intravenous contrast agent. Using computer analysis, a three-dimensional projection is obtained. Accuracy of CTA in diagnosing stenosis of the carotid artery is high. There are also encouraging results from CTAs used in the diagnosis of internal carotid artery occlusion (ICO). In our study, we tried to determine the accuracy of CTA and duplex scanning in diagnosing ICO.

Patients and Methods

From 1995 to 1997, 148 patients were diagnosed as having ICO by colour duplex scans. Average age at
presentation was 70 years (43–89), though most patients were between 60–80 years old. One hundred and two of the 148 (70%) patients were male. Patients were classified according to their epidemiologic characteristics and risk factors for atherosclerosis. Ninety-nine patients (67%) had hypertension, 85 (58%) were current or past smokers, 64 (44%) had a history of ischaemic heart disease, 56 (38%) had hypercholesterolaemia, 44 (30%) had diabetes, and 38 patients (26%) had peripheral vascular disease. Five patients (3%) had a history of neck radiation. Neurological symptoms were studied (Fig. 1), and CT scans of the brain were performed on most patients to identify lesions compatible with infarction.

The duplex examination was performed by ATL, HDI 3000 system (Advanced Technology Laboratories, Bothell, WA, U.S.A.) using a linear 5–10 MHz, 38 mm transducer. Each artery was examined transversely and longitudinally in two plains along the course of the vessel by 2D ultrasound evaluation and then by a pulsed Doppler using a 1.5 mm cubed sample volume at 60 degree flow angle, according to the protocols of the American Society of Vascular Technology. It is important to note that patients in whom the duplex scan was equivocal, with poor visualisation of the ICA, were excluded from the study. Only cases in which a technically satisfactory duplex scanning was obtained were included.

CTA of the carotid arteries was performed on all patients. The CT angiograms were performed using a dual slip ring CT scanner, obtaining two slices per rotation at a rate of one rotation per second (Elscint Twin helical scanner, Haifa, Israel). A slice thickness of 2.7 mm and 1.5 mm increment were used, reconstructed at 1 mm, obtaining 120–150 slices per patient, each overlapping 2 mm. An area of 100–140 mm was covered in about 20 s. Contrast material was injected through an antecubital vein (Telebrix 38, Guerbet; 300 mg iodine per millimeter) with an autonomic power injector. The CT angiogram images were produced by a maximum intensity projection (MIP) algorithm. Post-acquisition data manipulation was done on a satellite workstation (Omni-pro), for segmentation and bone removal. Results of CTA were compared to those of the duplex scan.

Carotid artery angiography was performed on 44 patients and surgical exploration was performed on 10 patients; both procedures were considered “gold standard” methods for differentiating occlusion from stenosis. The angiograms were obtained by selective catheterisation of the common carotid and vertebral arteries. Digital subtraction angiographic imaging was obtained in the AP, lateral, and oblique projection. The results from the different imaging modalities were compared in terms of occlusion vs. patency of the artery in question. Ten cases had duplex scan and angiography done before the introduction of CTA, and work-up was later completed with CTA. The indications for angiography included:
1. Discrepancy between CTA and duplex scan.
2. Symptoms originating in the suspected occluded side.
3. Suspected common carotid occlusion.

Surgical exploration on the occluded side was performed on 10 patients whose clinical evaluation or CTA indicated possible patency of the carotid artery. The maximum time interval between a duplex scan or CTA showing a patent artery and a “gold standard” procedure showing occlusion was 30 days. Cases with longer intervals were excluded from the study.

Results

Presenting symptoms

At the time ICO was diagnosed by duplex scanning 32 patients (22%) were asymptomatic, and 45 patients (31%) had suffered a stroke, 81% on the side of the occlusion.

On the occluded side, 35 patients (24%) had a stroke and 29 patients (20%) had no neurological symptoms. Thirty-four patients (23%) demonstrated transient symptoms (transient hemiplegia or amaurosis fugax) and 46 patients (31%) described non-hemispheric symptoms (dizziness, syncope) (Fig. 1).

On the side contralateral to the occlusion, nine patients (6%) had a stroke and 15 patients (10%) demonstrated transient neurological symptoms. Seventy-eight patients (53%) had no neurological symptoms (Fig. 1).
Brain CT Scans

One hundred and forty-two patients underwent CT scans of the brain. Sixty-eight patients (48%) had evidence of cerebral infarction. Sixty-six per cent of the lesions on CT were ipsilateral to the occluded side. Six of the 32 (18%) asymptomatic patients and 19 of the 46 (41%) patients who complained of non-hemispheric symptoms had evidence of infarction on CT.

Diagnosis

One hundred and forty-eight patients were evaluated by duplex scanning and CTA. Arteries diagnosed as occluded by duplex scanning were also diagnosed as occluded on CTA in 92% (136/148) of the cases. Twelve arteries diagnosed as occluded using duplex scanning were found to be patent on CTA. In 10 of these 12 patients a "gold standard" procedure was indicated and ICAs were found patent in 100% of the cases. The remaining two patients were severely debilitated and were not candidates for surgery, therefore angiography was not performed. One hundred and thirty-six arteries were diagnosed as occluded using duplex scanning and confirmed as occluded on CTA. Forty-four of these cases had angiography or exploration for the indications listed above, and were found to be truly occluded in 95.5% of the cases (42/44).

Considering the "gold standard" as a control, CTA had a significantly higher PPV for diagnosing ICO than duplex scanning (95.5% vs. 77%, p value <0.01).

Discussion

Differentiating total occlusion from tight stenosis of the carotid artery is crucial with regard to treatment and prognosis. Whereas symptomatic stenosis (>70%) is an indication for CEA, occlusion of the ICA is treated conservatively. Angiography is considered the "gold standard" for carotid artery imaging. Since it is an invasive procedure it has a complication rate. The North American Symptomatic Carotid Endarterectomy Trial (NASCET) reported 1% death or major stroke following angiography. Hankey et al. reported eight prospective and seven retrospective studies in which angiography was followed by rare cases of death (<0.1%), 1% major stroke, 3% minor neurological events, 2.1% hypersensitivity reactions and several cases of renal failure in patients with prior renal insufficiency. The complications of angiography are a significant part of the overall perioperative complications associated with CEA, reported by NASCET to be 2.1% stroke or death. The morbidity is higher in patients having very tight stenosis of the carotid arteries. O'Leary et al. reported post angiographic neurological events in 15% of patients with pseudo-occlusion (5/34).

In recent years there has been considerable progress in the technology and experience of imaging the carotid arteries. In many centres duplex scanning has replaced angiography in the diagnosis of carotid artery stenosis. A number of attempts were made to discern whether duplex is sufficient in the diagnosis of occlusion. They concluded that in asymptomatic patients occlusion can be diagnosed by duplex scan alone, whereas angiography is indicated in patients who have no contraindication for surgery and who continue to have neurological symptoms. Kirsch et al. reported PPV of duplex scanning to be 92%, and also concluded that angiography is needed only when the patient is symptomatic and a possible CEA candidate. Mattos et al. and Mansour et al. reported a PPV of 87% and 98%, respectively, for diagnosis of occlusion by duplex. They concluded that angiography is required when duplex scanning is equivocal. Berman et al. found PPV of colour flow doppler to be 97%, and they concluded that this modality is sufficient for diagnosis of ICO. In summary, most authors agree that duplex scanning can be used to diagnose ICO in most cases. However, in symptomatic patients or in patients with equivocal duplex scans, angiography is required to complete the investigation.

In our institution, CEA is performed in the majority of cases of duplex scanning alone, without angiography. In recent years we started performing CTA in certain cases of carotid stenosis. CTA has been used in the imaging of the carotid arteries for a few years and shows excellent correlation with angiography in identifying and grading carotid stenosis. It also adds a clear anatomical description of the artery.

It is obvious from the reviewed literature that duplex is not sufficient for diagnosis of ICO in all cases. Our study supports this conclusion. A PPV of 77% is clearly unacceptable since the remaining 23% of cases would be incorrectly diagnosed as having ICO. These patients would not undergo CEA and would remain at high risk for future stroke; therefore, further imaging is required. CTA shows high accuracy in distinguishing
tight stenosis from occlusion, with a PPV of 95%, and a negative predictive value of 100% in cases of suspected occlusion based on duplex, thus providing an excellent alternative to angiography.

The low PPV of the duplex method when compared to the “gold standard” raises concern about its reliability. However, the PPV of duplex in identifying ICO is higher (92%) when compared to the CTA method. The “gold standard” procedure was performed mainly in cases of suspected patency (i.e. ongoing symptoms): of the 148 patients in our study, “gold standard” procedure was performed on only 54 patients (36%). We believed apriori that asymptomatic patients with ICO shown on both duplex and CTA were truly occluded, and that exposing them to the risks of angiography would be unjustified. However, this means that in the remaining cases there was no control, and this is one of the weaknesses of this study.

It is important to mention that we do not address the drawbacks of CTA in cases of carotid stenosis, such as calcified plaques which cause overestimation of the stenosis, and the inability to demonstrate intracranial, aortic or vertebral artery disease.

In conclusion, we recommend the following guidelines for management of patients showing ICO on duplex:

1. CTA should be performed on all patients showing ICO on duplex scans, whether symptomatic or asymptomatic, (if the surgical policy is to operate on asymptomatic tight stenosis).
2. When a diagnosis of occlusion has been made by both duplex scans and CTA, no further work-up is indicated.
3. When duplex scan shows ICO and CTA shows patency of the ICA, angiography is not required and CEA may be performed if indicated.

References


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