Measuring carotid artery stenosis
Comparison of postmortem arteriograms with the planimetric gold standard

Abstract  Objective  Five different calliper methods for assessing the degree of carotid artery stenosis and visual estimation (“eyeballing”) of postmortem carotid arteriograms were compared with the planimetric gold standard of the area reduction at the site of the stenosis.  Methods  During autopsy 53 carotid specimens were removed in toto from 31 neurological patients. Carotid arteries were ligated and redistended to a physiological degree for standardised three-plane arteriography. Afterwards, the entire specimen was filled with an embedding medium under the same conditions and sectioned. Slices at the site of stenoses were histologically processed. Computerised planimetric analysis of the lumen area reduction was performed and compared with the arteriographic findings. Arteriograms were evaluated by two independent observers by means of linear Common Carotid Artery (CC), the European Carotid Surgery Trial (ECST) and the North American Symptomatic Carotid Endarterectomy Trial (NASCET), and squared measurements (NASCET², ECST²) after applying the πr² function. Further, three independent observers performed eyeballing of the degree of stenosis from the postmortem arteriographies.  Results  Planimetry was carried out in 29 internal carotid artery (ICA) and 17 common carotid artery (CCA) stenoses ranging from 8.5 to 100%. The smallest mean differences of the degree of stenosis in % between planimetry and arteriography were –0.5 and 0.6%. The narrowest 95% -limits of agreement covered a range of ±24.1 and 26.3% of stenoses, and the highest correlation coefficients were both 0.9 for the CC and ECST² techniques, respectively. By eyeballing, the degree of stenosis was underestimated by 13.5 to 15.8% on average. The narrowest limits of agreement between two observers for eyeballing covered a range of 35%.  Conclusion  Three-plane arteriography has only a moderate accuracy and reproducibility in detecting and measuring carotid artery stenosis independent of the technique of measurement used.

Key words  angiography · pathology · carotid arteries · diagnosis
Introduction

Recent reanalysis of the two largest randomised controlled trials of carotid endarterectomy, the European Carotid Surgery Trial (ECST) and the North American Symptomatic Carotid Endarterectomy Trial (NASCET), versus medical treatment for symptomatic carotid artery stenosis confirmed the high benefit of surgery for patients with 70–99% stenosis or greater (by the measurement technique used in the NASCET) [15]. Furthermore, it was shown that surgery is moderately beneficial for patients with 50–69% symptomatic stenosis but has no effect in patients with 30–49% stenosis. Thus, exact determination of carotid artery stenosis is of crucial importance for the patients’ treatment [13]. Several different techniques of measuring the degree of stenosis from carotid angiograms have evolved and had been compared with each other (i.e. ECST, NASCET, CC-method (Common Carotid Artery)) [16, 17]. Despite numerous angiographic studies on the inter- and intraobserver accuracy of determining carotid artery stenosis by different calliper techniques from the two-plane or three-plane transfemoral cerebral angiograms [6, 21, 23] there have been only very rare series comparing angiographic measurements with the true pathoanatomical gold standard obtained from the intraoperative or postmortem specimen (i.e. the genuine cross-sectional area reduction) [1]. Unlike linear measurements from biplane angiography, the postmortem specimen allows for exact area measurements of the often asymmetric carotid artery lumen reduction [1]. Our aim was to determine the accuracy of the most widely used calliper techniques (linear and squared methods), as well as of the visual impression (“eyeballing”) frequently used in daily practice for assessing carotid artery stenosis from postmortem angiograms. We therefore compared the accuracy and reproducibility of these techniques with the true anatomic gold standard obtained from planimetric measurements of the lumen area reduction.

Materials and methods

■ Patients and acquisition of carotid specimens

Thirty-one autopsy cases of cerebrovascular neurological patients (13 women, 18 men, mean age 72.2 years; whose reason for admission to the hospital was ischaemic stroke n = 17, intracerebral haemorrhage n = 12, subarachnoid bleeding n = 1, brain tumour n = 1; cause of death: pneumonia n = 14, raised intracranial pressure n = 9, cardiopulmonary arrest n = 4, pulmonary embolism n = 3, sepsis n = 1) were investigated in the Department of Pathology of our medical university. Fifty-three en bloc carotid specimens including 5 cm of the common carotid artery (CCA) and 2.5–5 cm of the internal (ICA) and the external carotid artery (ECA) were obtained.

■ Postmortem arteriography and gross pathologic examination of the carotid specimen

Immediately after autopsy, ECA branches were ligated and the ends of the three arterial segments (i.e. CCA, ICA and ECA) were tied to plastic or glass tubes for the injection of an iodinated contrast agent Ultravist 300® (Schering AG, Berlin, Germany). Ultravist 300® was continuously and gradually pressed by hand into the plastic tube at the CCA end of the artery against the pressure of 100 mmHg mimicking physiological in vivo arterial pressure. Still under pressure, the specimen was clamped at the three ends of the vessel tree and was placed under a Craniograph x-ray system (Elema-Schoenander, Stockholm, Sweden). Three-plane angiography was performed using an AGFA CP-B film. Voltage was 42kV (0.05s) and film-focus distance was 90 cm. Three projections were chosen, the first allowing for a Y-shaped visualisation of the bifurcation (both, ICA and ECA next to each other). For the second projection, the ECA was elevated to an angle of 45 degrees. For the third projection, the ECA was further turned for another 90 degrees. The ICA and the CCA were adjacent to the X-ray film in all three projections. A metal cube of 1 cm side length and a metal piece of 3 cm in length and 5 mm in width were placed next to the artery allowing for later calibration. Following arteriography, the specimens were flushed with normal saline. Similar to the filling procedure with Ultravist 300®, the fluid tissue embedding medium (Cryomatix®, Shandon Inc, Pittsburgh PA) was injected into the carotid specimen. Again a pressure of 100 mmHg was applied. This medium is of liquid consistence at room temperature and has been shown not to change volume on freezing. The redistended carotid specimens were frozen at –21°C and were cut in serial 3 mm-cross slices. Photomax with a mm scale were taken from each slice. Technical details of the procedure for postmortem arteriography and macropathological study of the carotid specimen have been described previously [18].

■ Measurement of carotid artery stenosis from postmortem arteriograms

For the visual impression of the degree of stenosis (“eyeballing”), three independent experienced observers (a vascular neurologist, a radiologist, a neuroradiologist), reviewed all arteriograms without knowledge of the planimetric results. The observers were asked to estimate visually the degree of the highest percentage stenosis in each common and internal carotid artery according to their clinical practice. In some cases, mild or moderate stenosis led to differences concerning the location of measurement between the observers and the planimetry as well as among the observers. Degree of stenosis was given in five percent units.

Calliper measurements according to the protocols of ECST and NASCET, as well as the CC-method, were carried out by two of the observers (observers 1 and 2) [1, 15–17]: The diameter of the minimum residual lumen of the ICA at the point of maximum stenosis (ECST), with the diameter of the distal ICA lumen at the point where the vessel walls first appeared parallel (NASCET), and with the diameter of disease-free CCA proximal to the carotid artery bifurcation (CC-method), respectively.

According to Alexandrov et al. [1] the area luminal reduction from the linear NASCET and ECST formulas were calculated using the πr² function and were defined as “squared NASCET” (NASCET²) and “squared ECST” (ECST²). CCA stenoses were only measured according to the ECST method. Measurements were made with the use of a mechanical vernier calliper reading to 0.05 of a millimetre. Similar to eyeballing, the observers were asked to measure the degree of the highest percentage stenosis in each CCA and ICA.

Calliper measurements and eyeballing were carried out with a 2.5- to 2.8-fold magnification of the x-ray films on two separate occasions. There was at least a 4-week interval between eyeballing and calliper measurements.