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Carotid Imaging in 2023: Stenosis and Beyond

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SHORT ABSTRACT

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ABSTRACT

In the last two decades, significant advances have been made in the further understanding of carotid atherosclerosis and stroke risk. While currently practical stratification regarding a surgical intervention in patients with symptomatic carotid disease is made based on the degree of luminal narrowing, several plaque features have been identified as independent risk factors for the development of downstream ischaemic events. Several of these plaque features can be readily identified on routine CT- and MR-examinations, and will be discussed during this lecture. Consequently, a contemporary radiology report must go beyond a mere description of the presence and degree of luminal narrowing, and must also provide information on plaque morphology and other vessel wall characteristics. This comprehensive approach will enable the referring clinical to better stratify their patients regarding current and future risk, leading to better patient management and clinical outcomes.

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1. INTRODUCTION

Stroke is a major cause of illness and death worldwide, accounting for 5% of disability-adjusted life years lost and more than 10% of deaths globally. In Europe and the USA, the rate of stroke occurrence is approximately 200 per 100,000 people every year, with 80% of these strokes being caused by ischemia [1].

Over the past two decades, significant progress has been made to understand better the aetiology of carotid-related strokes, particularly regarding the vulnerability of some carotid plaques.

Previous concepts of atherosclerosis as a cause of stroke, often limited to the effects of luminal narrowing on downstream organ systems, are now being re-evaluated. Over the years, investigators have identified complex molecular and cellular processes influenced by the endothelium which affect the overall health of vessel walls. While early atherosclerotic processes usually lead to a relatively predictable asymptomatic progression of disease, it can later evolve into a more complex disease state influenced by many factors with unpredictable manifestations, which can possibly end in downstream ischemic events [2]. Often, ischemic stroke events will be unrelated to the degree of luminal stenosis but caused by other plaque characteristics.

Fortunately, imaging techniques have improved, enabling the evaluation of plaque composition and morphological features associated with increased vulnerability in addition to stenosis severity measurement. Consequently, several societies have published consensus statements on the current role of CT and MR imaging in assessing carotid disease, highlighting the additional role of plaque morphology in assessing stroke risk [3–5].

As a result, the current role of the radiologist in evaluating carotid artery disease has evolved from a mere evaluation of potential luminal obstruction to a more comprehensive assessment of the underlying plaque and its characteristics, identifying and reporting additional risk factors of plaque instability. The result is a more complete evaluation of both current disease and future stroke risk, guiding medical treatment.

2. QUANTIFICATION OF STENOSIS: UNDERSTANDING THE MEASUREMENT

Current decisions regarding interventional treatment of patients with symptomatic carotid disease are pragmatically based on the degree of luminal narrowing. This decision path is the result of the landmark NASCET and ESCT trials, which demonstrated the ability of carotid endarterectomy (CEA) to prevent strokes and death in symptomatic patients with severe carotid stenosis [6, 7]. In these trials, the percentage degree of stenosis in the internal carotid artery (ICA) was used as the main parameter to guide a straightforward and repeatable strategy for evaluating stroke risk in patients and determining whether surgical or non-surgical treatment options were appropriate.

When reporting numerical values of the degree of stenosis, it is not only important to specify which measurement method was used, but it is also paramount to understand the significance of the reported value. Currently, the most used measurement of stenosis is based on the NASCET-trial calculation, comparing the maximal degree of luminal narrowing to a more distal disease-free post-bulbar vessel segment using conventional angiography as the chosen two-dimensional imaging modality. As opposed to the ESCT-method, this calculation does not account for the normal outward bulging of the carotid bulb, implicating that, for example, a NASCET-calculated stenosis of 0% does not equal no luminal narrowing. Also, some situations do not allow formal calculation, as in a near-occlusion of the carotid lumen.

Finally, caution must be taken when comparing diameter-derived stenosis, as is customary in conventional angiography as well as CT and MR angiography, with an area stenosis as communicated in Doppler ultrasound reports.

3. LOOKING BEYOND STENOSIS

Despite all the advances in plaque imaging, stenosis severity remains the only available validated parameter in current guidelines for treatment decision making based on the 70% stenosis cut-off following the NASCET method. As such, it remains one of the main components of the radiology report and should be measured correctly.

However, additional information should be provided on the morphological characteristics of the underlying plaque, carotid vessel wall morphology and every other evaluable plaque and vessel wall feature which may improve stroke risk stratification and influence decision making.

Plaque surface morphology is an easy-to-evaluate and important morphological feature, as the presence of contour irregularities is associated with the development of ischemic neurological symptoms secondary to plaque fragmentation and micro-embolic events. Specifically, plaque ulceration is recognized as the most important parameter among the possible luminal surface irregularities, given its strong association with cerebrovascular events. Its presence increases future stroke risk independently of the degree of stenosis, although this relationship is probably more complex [8, 9].

Another illustration of atherosclerosis having significant effects beyond mere luminal narrowing is the concept of arterial remodelling, which refers to a change in vessel size (cross-sectional area) in reaction

to atherosclerotic changes [10]. Arterial remodelling can have many presentations, including plaque growth beyond the normal outer diameters of the normal vessel wall without a comparable effect on inward luminal narrowing [11]. As such, a prominent plaque with positive remodelling still represents significant atherosclerosis despite NASCET-derived stenosis measurements within non-interventional ranges.

Intraplaque haemorrhage is currently one of the most important biomarkers of carotid plaque instability, which can be detected through radiological means [12, 13]. The most important imaging modality here is MR imaging, which can visualise intraplaque blood degradation products. While signal characteristics vary, intraplaque bleeding is typically characterised as producing high signal intensity on fat-suppressed T1-weighted images. The importance of intraplaque hemaorrhague is further illustrated by the knowledge that it is also more prevalent in carotid arteries ipsilateral to embolic strokes of unknown origin [14, 15].

Other important biomarkers like perivascular inflammation, plaque neovascularisation and detailed analysis of a possible lipid-rich necrotic core with thin fibrous cap are in general not used in clinical practice for practical reasons, their study often reserved for research labs. However, as technology and post-processing mathematical powers progress, they might become easier to detect in the future. As with all novel biomarkers, it is important to also develop a standardized reporting and validation system, as well as guidelines on how to convert these new imaging insights into practical clinical treatment decisions.

4. NON-ATHEROSCLEROTIC DISEASE

Despite the age-correlated prevalence of atherosclerotic disease in the Western population, it is also important to understand that important events can also occur secondary to non-atherosclerotic disease. Knowledge of the underlying conditions and their imaging characteristics is critical to correctly diagnose and manage these patients, which are often younger of age, and prevent unnecessary downstream testing for other conditions. Such conditions include embolic stroke from non-carotid sources and carotid dissection, either isolated or as a manifestation of fibromuscular dysplasia.

5. CONCLUSION

It has become clear that contemporary carotid imaging with CT and MR goes beyond the mere reporting of luminal narrowing. Plaque characteristics have become an important and integral part of the radiology report, delivering a more complete assessment of current and future stroke risk and in determining patient management.

COMPETING INTERESTS

The author has no competing interests to declare.

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