Chapter XI
Assessment of Stroke by Analysing Carotid Plaque Morphology

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ABSTRACT

Stroke is the third leading cause of death in the Western world and a major cause of disability in adults. The objective of this work was to investigate morphological feature extraction techniques and the use of automatic classifiers; in order to develop a computer aided system that will facilitate the automated characterization of carotid plaques for the identification of individuals with asymptomatic carotid stenosis at risk of stroke. Through this chapter we summarize the recent advances in ultrasonic plaque characterization and evaluate the efficacy of computer aided diagnosis based on neural and statistical classifiers using as input morphological features. Several classifiers like the K-Nearest Neighbour (KNN) the Probabilistic Neural Network (PNN) and the Support Vector Machine (SVM) were evaluated resulting to a diagnostic accuracy up to 73.7%.

INTRODUCTION

High-resolution ultrasound has made possible the noninvasive visualization of the carotid bifurcation and for that reason it has been extensively used in the study of arterial wall changes; these include measurement of the thickness of the intima media complex (IMT), estimation of the severity of
stenosis due to atherosclerotic plaques and plaque characterization (Reilly, 1983; El-Barghouti, 1996; Elatrozy, 1998). Applications of carotid bifurcation ultrasound include: (1) identification and grading of stenosis of extracranial carotid artery disease often responsible for ischemic strokes, transient ischemic attacks (TIAs) or amaurosis fugax (AF); (2) Follow-up after carotid endarterectomy; (3) evaluation of pulsatile neck mass; (4) investigation of asymptomatic neck bruits: severe internal carotid artery stenosis is a predictive factor for future stroke; (5) cardiovascular risk assessment: the presence of carotid bifurcation atherosclerotic plaques is associated with increased cardiovascular mortality (Joakimsen, 2000; Schmidt, 2003); (6) clinical studies on the effect of lipid-lowering and other medications on carotid intima media thickness (IMT) which includes plaque thickness (Salonen, 2003).

During the last decade, the introduction of computer aided methods and image standardization has improved the objective assessment of carotid plaque echogenicity (El-Barghouti, 1996; Elatrozy, 1998) and heterogeneity (El-Barghouti, 1996; Salonen, 2003) and has largely replaced subjective (visual) assessment (Reilly, 1983; Reilly, 1988) that had been criticized for its relatively poor reproducibility (Arnold, 1987). Through this chapter we are trying to introduce the use of morphological image analysis and automatic classifiers for the creation of an automatic ultrasound image classification system for the estimation of the risk of stroke.

BACKGROUND

Visual Classification of Atherosclerotic Plaque in Ultrasound Imaging

High-resolution ultrasound provides information not only on the degree of carotid artery stenosis but also on the characteristics of the arterial wall including the size and consistency of atherosclerotic plaques. Several studies have indicated that “complicated” carotid plaques are often associated with ipsilateral neurological symptoms and share common ultrasonic characteristics, being more echolucent (weak reflection of ultrasound and therefore containing echo-poor structures) and heterogeneous (having both echolucent and echogenic areas). In contrast, “uncomplicated” plaques which are often asymptomatic tend to be of uniform consistency (uniformly hypoechoid or uniformly hyperechoid) without evidence of ulceration (Reilly, 1983; O'Donnell, 1985; Leahy, 1988; Langsfeld, 1989; Geroulakos, 1993).

Different classifications of plaque ultrasonic appearance have been proposed in the literature. Reilly classified (O'Donnell, 1985) carotid plaques as homogenous and heterogeneous, defining as homogeneous plaques those with “uniformly bright echoes” that are now known as uniformly hyperechoic (type 4) (see below). Johnson (1985) classified plaques as dense and soft, Widder (1990), as echolucent and echogenic based on the their overall level of echo patterns, while Gray-Weale (1988) described 4 types: type 1, predominantly echolucent lesions, type 2, echogenic lesions with substantial (>75%) components of echolucency, type 3, predominately echogenic with small area(s) of echolucency occupying less than a quarter of the plaque and type 4, uniformly dense echogenic lesions. Geroulakos (1993) subsequently modified the Gray-Weale classification by using a 50% area cut off point instead of 75% and by adding a fifth type, which as a result of heavy calcification on its surface cannot be correctly classified.

Regarding the clinical significance of carotid plaque heterogeneity, it seems that the heterogeneous plaques described in the three studies published in the 1980’s (Table 1), include hypoechoic plaques. Also heterogeneous plaques in all studies listed in Table 1 contain hypoechoic areas (large or small) and appear to be the plaques which are associated with symptoms or if found in asymptomatic individuals they are the plaques that subsequently tend to become symptomatic.