Toward the development of a Web Ultrasonic Plaque Analysis (WUPA) Tool

José Seabra, João Sanches *
Instituto de Sistemas e Robótica
Instituto Superior Técnico
Av. Rovisco Pais, 1049-001 Lisboa, Portugal
jseabra@isr.ist.utl.pt jmrs@ist.utl.pt

Abstract

Recently, several atherosclerotic plaque characterization methods were proposed based on plaque morphology assessed through 2D ultrasound. It is of extreme importance to establish an objective quantification measure which allows the physicians to determine the risk of plaque rupture, and thus, of brain stroke. This paper is a first attempt to incorporate such measure in a web based platform. This tool, available for all users of the world wide web (www), provides a way to objectively and interactively characterize the atherosclerotic plaque, to add new data, to use several processing tools to outline the plaque, quantify its stenosis degree, and compute different echogenicity measures. A combination of these features is used to provide an objective measure with clinical significance, known as activity index.

1. Introduction

Carotid atherosclerosis represents the most important source of brain stroke. The degree of stenosis[1] is up to now considered one of the most important features for determining the risk of brain stroke. This feature, together with other patient information such as age, health, clinical history and risk factors, are the main criteria for determining the risk of stroke and thus to decide about surgical intervention to remove the plaque [4]. Ultrasound is a suitable imaging technique to assess this pathological condition mostly because it provides real-time visualization and interpretation of the carotid plaques and also because it is non-invasive, does not involve ionizing radiation and it is cheap.

Past studies established a strong correlation between plaque morphology (appearance), including echogenicity[2] and texture, in ultrasound images and its risk of rupture [2,5,8]. Furthermore, studies have been developed aiming at statistically describe the plaque morphology, namely by using a stratified Gray-Scale Median (GSM) analysis and color mapping of the plaque [9], textural features [3] and a combination of both [5,7]. Moreover, a study conducted in [7] revealed that the GSM and the P_{40} are the most significant variables related to the presence of atherosclerotic disease symptoms. The GSM is used to classify plaques as hypoechogenic (GSM < 32) or hyperechogenic (GSM > 32) [5,7]. The total percentage of hypoechogenic pixels (P_{40} defined as the percentage of pixels with gray levels below 40, can determine the amount of dark regions within the plaque, usually associated with ulceration,

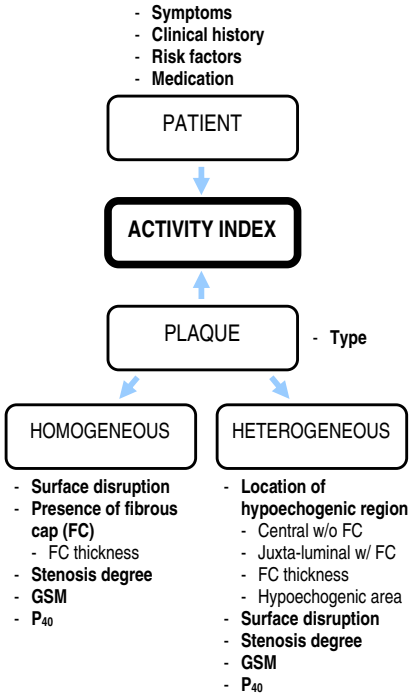
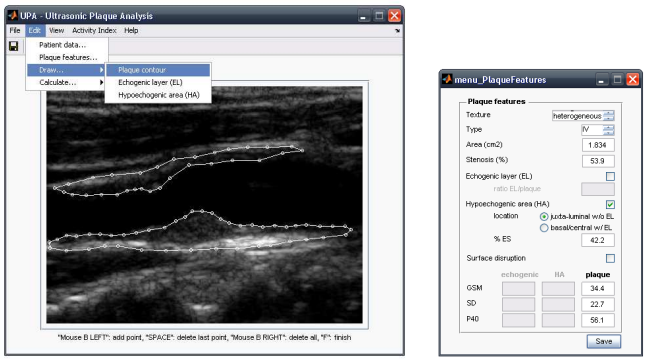


Figure 1. Criteria used to determine the plaque's activity index

*This work was supported by Fundação para a Ciência e a Tecnologia (ISR/IST plurianual funding) through the POS Conhecimento Program which includes FEDER funds.

[1] narrowing of the arterial lumen

[2] degree to which sound waves are reflected by a tissue



(a) (b)

Figure 2. WUPA main window

which is an indicator of plaque instability.

A seminal work by [7] proposed a clinical index, known as *activity index*, to quantify the degree of plaque activity, based on a combination of plaque features. This measure may have relevant clinical significance in therapeutic decision in patients with asymptomatic carotid lesions or with symptomatic stenosis with moderate obstruction.

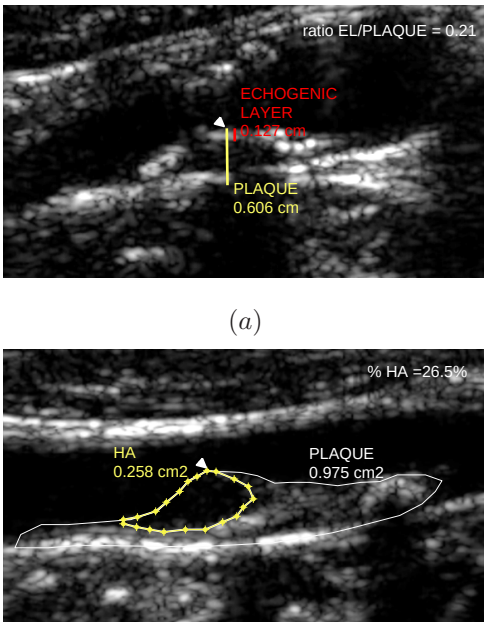
In this paper we intend to extend the paradigm of *activity index* to the medical community by proposing a web-based tool for ultrasonic plaque analysis. This tool aims at quantifying the plaque's *activity index* based on features inherent to the patient and also on a considerable set of plaque features, as described in Fig. 1.

2. Methods

The current version of the web ultrasonic plaque analysis (WUPA) was developed in *MATLAB* (R2007B) and is provided in [1]. A standalone executable was created with the *MATLAB Compiler* which is then deployed in a domestic *Microsoft*'s web server, *Internet Information Server* (IIS), using the *Common Gateway Interface*. The user can have access to a set of menus/commands to ease the process of uploading images, input information, calculate the *activitity index* and store results. These menus/commands are here described:

File menu: provides commands to open new (or existing) data and to save results;

Edit menu: includes 2 submenus where the user can introduce information related to the patient, risk factors and medication (Patient data menu) and features which characterize the plaque (Plaque features menu). Additionally, a set of commands is provided to segment the plaque, get the echogenic layer (fibrous cap in Fig. 1) and the hypoechogenic area, and also to compute the stenosis degree;



(a)

(b)

Figure 3. WUPA main environment

Activity index menu: Here, a score defined as in [6–8] is ascribed to each feature/criteria introduced by the user or computed by the program. These scores are summed and they provide a final $0-100$ score, where a higher score is typical of an active plaque, whereas a low score indicates a stable plaque.

3. Results

Having described the main features of the proposed ultrasonic plaque analysis tool, it is now important to illustrate its usefulness through some examples.

Fig. 2a shows the tool's main window with an opened ultrasonic image. Here, the "Plaque contour" command was used to segment the plaque. In Fig. 2b the "Patient data" menu is shown, with some inputs given by the user which characterize the current plaque.

Fig. 3 illustrates two different utilities of the program. The first, shown in Fig. 3a allows to interactively get the echogenic layer (EL) and plaque (P) thicknesses, which determine a useful clinical criterion designated as ratio $\frac{EL}{P}$ thicknesses. Given that the EL is rigid structure, a higher $\frac{EL}{P}$ ratio indicates that the plaque is more stable. Fig. 3b shows the isolation of the hypoechogenic area (HA), typically associated with ulceration, together with the computation of the percentage of HA with respect to the plaque.

4. Conclusions

This paper proposed a web ultrasonic plaque analysis tool, whose main features were here demonstrated through several

examples. This tool allows the physicians to upload their own medical data, to perform their own studies by using suitable processing tools provided, to compute the *activity index*, and to store and share their information/results. Hence, this tool is useful because it provides an objective characterization of the plaque morphology and quantification of risk of rupture. Moreover, the users' data is kept in a web server's database, which can, in a near future, be used in a large-scale study using data coming from different clinical facilities, acquired under different conditions and processed by different physicians.

References

[1] Ultrasonic plaque analysis application (beta version 1.0). http://users.isr.ist.utl.pt/ jseabra/wupa.html.

[2] L. Baroncini, A. Filho, L. Junior, A. Martins, and S. Ramos. Ultrasonic tissue characterization of vulnerable carotid plaque: correlation between videodensitometric method and histological examination. *Cardiovasc Ultrasound*, 4:32, 2006. Comparative Study.

[3] C. Christodoulou, C. Pattichis, M. Pantziaris, and A. Nicolaides. Texture-based classification of atherosclerotic carotid plaques. *IEEE Transactions on Medical Imaging*, 22(7), 2003.

[4] Consensus Group. Consensus statement on the management of patients with asymptomatic atherosclerotic carotid bifurcation lesions: international angiology. *Int Angiology*, (14):5–17, 1995.

[5] T. Elatrozy, A. Nicolaides, T. Tegos, and M. Griffin. The objective characterization of ultrasonic carotid plaque features. *Eur J Vasc Endovasc Surg*, 16:223–230, 1998.

[6] L. Pedro. *Uma janela para a aterosclerose. A ultrassonografia de alta definicão no estudo da parede arterial*. PhD thesis, Faculdade de Medicina de Lisboa, 2003.

[7] L. Pedro, J. Fernandes, M. Pedro, I. Gonçalves, and N. Dias. Ultrasonographic risk score of carotid plaques. *European Journal of Vascular and Endovascular Surgery*, 24:492–498, December 2002.

[8] L. Pedro, M. Pedro, I. Goncalves, T. Carneiro, and C. Balsinha. Computer-assisted carotid plaque analysis: characteristics of plaques associated with cerebrovascular symptoms and cerebral infarction. *Eur J Vasc Endovasc Surg*, 19:118–123, 2000.

[9] R. Sztajzel, S. Momjian, I. Momjian-Mayor, N. Murith, and K. Djebaili. Stratified gray-scale median analysis and color mapping of the carotid plaque: correlation with endarterectomy specimen histology of 28 patients. *Stroke*, 36(4):741–745, 2005.