Carotid Artery Plaque Tracking

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VisionQuest *Biomedical*

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SIGNIFICANCE

Cardiovascular disease (CVD) is the third leading cause of death and adult disability in the industrial world after heart attack and cancer. It is estimated that 80 million American adults have one or more type of CVD. Of all the deaths caused by CVD among adults aged 20 and older, an estimated 6 million are attributed to coronary heart disease and to stroke, with atherosclerosis as the underlying cause.

A method based on an analysis of ultrasound (US) images of carotid plaques that can differentiate between stable plaques that tend to remain asymptomatic and unstable ones that eventually produce symptoms has the potential to refine the basis for surgery and spare some patients from an unnecessary, costly operation which itself carries a 2.7-3.1% risk of stroke.

OUR PRODUCT

The objective of our research is to identify plaque surface motion patterns that can be used to differentiate between symptomatic and asymptomatic cases, and quantify increases in transient ischemic attack (TIA) or stroke risk. Moreover, the quantification of elevated risk will allow the treatment of patients before they develop symptoms saving many lives since the mortality of stroke is extremely high with most of the patients suffering a stroke from previously asymptomatic lesions.

Our methodology presents a new high-resolution, low-cost, non-invasive approach to identifying vulnerable plaques that lead to stroke. Using optical flow techniques[1] and a novel Amplitude Modulation Frequency Modulation (AM-FM) method for motion estimation[2] , the system will provide reliable motion vectors of US videos of CA plaques[3]. Our methodology can measure plaque motion and deformation at the pixel level by providing the plaque principal axis of deformation and producing elastography maps for each time step or frame of the B-mode US sequence calculating detailed maps of how plaque motion and deformation change throughout the cardiac cycle. The steps of the system are summarized in Figure 1.

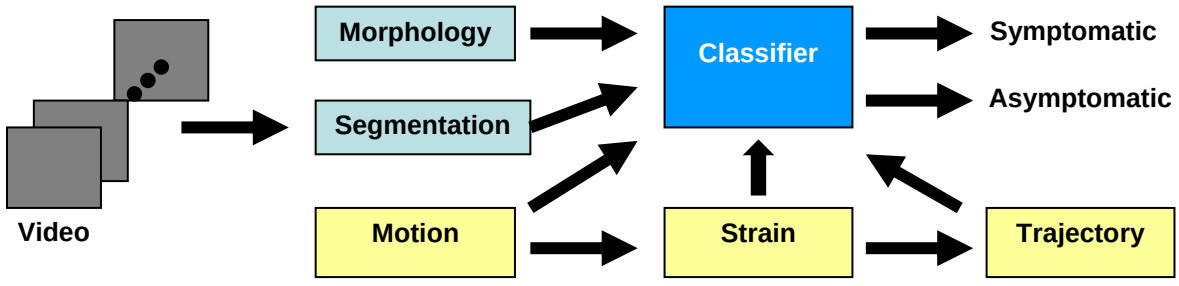

Figure 1. Basic system for using plaque motion features, plaque morphology, and segmentation to classify input videos into symptomatic and asymptomatic.

Strain measurements from preliminary clinical cases are presented in Figure 2. The principal axes of deformation plot (figure 2a), indicates the line-direction where the largest and smallest deformations

occur. The longer vectors indicate significantly increased levels of strain. Small deformation will have a very short axis indicating better stability. Unstable plaque components will be characterized by very long deformation vectors. When both vectors are of equal magnitude, we have stress that is distributed uniformly over all directions. However, when we have a high stress (large vector magnitude) along a single dominant axis, the strain is also highly concentrated along this single direction. The trace of the strain matrix is shown in Figure 2(b). Negative values indicate compression and positive values, bright areas, indicate extension. In this example, we have contractions in upper part of the plaque (regions G, F/E). On the other hand, we have significant expansions in the central part of the plaque (regions C and D). This distribution characterizes an asymptomatic case. We would expect a symptomatic to have expanding plaque surface characteristics, potentially leading to rupture.

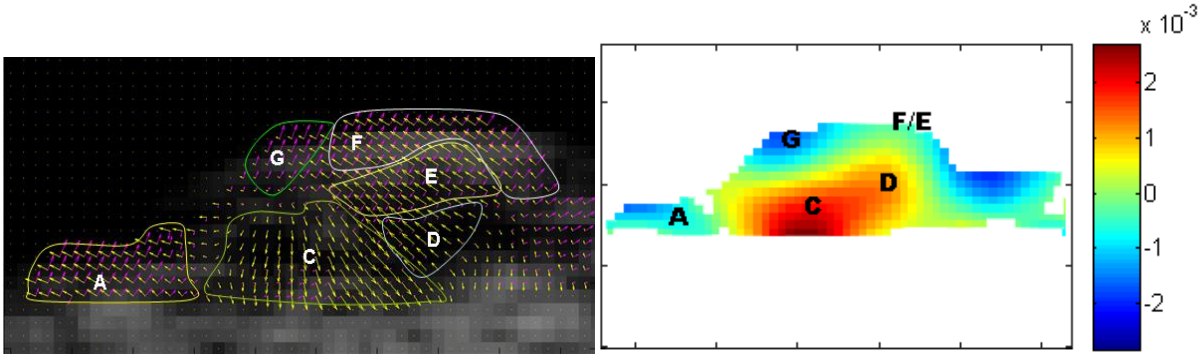

Figure 2. Preliminary strain results on asymptomatic plaque: (a) Principal axes of deformation of the plaque. Vector magnitude is logarithmically transformed for visualization. Regions of similar deformation are marked. C and D show the greatest strain due to motion. (b) Strain matrix trace plot indicating regions of strong relative area deformations.

THE FUTURE

Based on on-going longitudinal studies funded by the National Institutes of Health, the objective is to develop a system that can be used to detect risk changes. This can be accomplished by comparing features from each video to detect factors that can contribute to an increase in risk. We provide a list of factors that are associated with an increase in the risk of stroke or TIA:

- Significant increase in plaque surface velocity.
- Significant increase in plaque strain values.
- Significant increase in stenosis.
- Significant are increase in low-intensity image regions and their associated motions.

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