ASSESSMENT OF AUTOMATIC ALGORITHMS FOR SEGMENTATION OF ATHEROSCLEROTIC CAROTID PLAQUES

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AIM

Atherosclerosis is one of the major causes of cerebrovascular diseases and its diagnosis is considered one of the most important medical examinations for the prevention of cerebral and cardiovascular events. The finding of plaques in ultrasound image is important for the clinician to correctly evaluate the degree of severity of atherosclerosis disease in an asymptomatic or symptomatic individual at risk of stroke [1]. Segmentation of ultrasound images is essential for objective measurement of plaques, by using markers such as shape, area, eccentricity and thickness [2-3].

MATERIALS AND METHODS

In this study we analyzed Ultrasound (US) images from patients with atherosclerosis and we implemented a two different version of segmentation algorithms to identify carotid plaques. We studied 22 subjects with atherosclerotic carotid artery stenosis. The anamnestic risk clinical factors (diabetes, smoking, hypertension, dyslipidemia) of subject, were collected. The patients (63.82 ±16.66 mean age years old), presented carotid stenosis between 20% and 60%. We compared the two segmentation algorithms: watershed and snake algorithms. In the watershed algorithm, we placed the Hierarchical Cluster Analysis (HCA) inside the Watershed algorithm code: in this way we avoid the problem of undesirable oversegmentation results produced by the use of the only Watershed technique (figure 1-2). In the snake algorithm, we implemented an automatic snake algorithm based on the application of cubic spline functions that allow the best approximation of the snake at contour of plaques (figure 2).

RESULTS

In table 1 we showed a socio-demographic characteristics of subjects. We obtained 27 regions with watershed algorithm, 24 were classified as plaques with an average signal echogenicity of 245.0±10.0 and 3 were classified as non-plaques, with an average signal echogenicity of 198.6±25.6. The diagnostic accuracy was 89%, with 100% of sensitivity (table 2).
The mean perimeter, area and mean intensity obtained by automatic segmentation by snake algorithm were 65.52 ± 11.42, 521.88 ± 16.85 and 226.12 ± 18.92. The diagnostic accuracy was 82%, sensitivity of 86% and specificity of 77% (table 3).

Watershed Algorithm

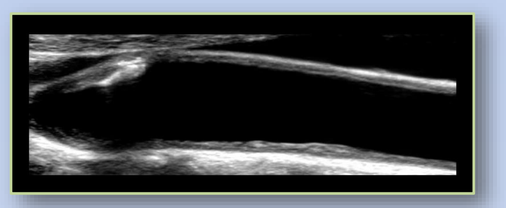

Figure 1. Original Image.

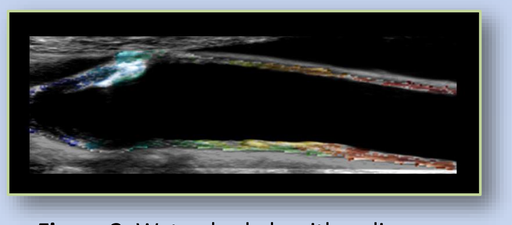

Figure 2. Watershed algorithm diagram

Table 1 Socio-demographic characteristics of subjects.

	Patients	Controls
Nr. Subjects	22	22
Gender		
M	10	4
F	12	18
Age (Mean ± SD)	63.8 ± 16.7	57 ± 21
Smoker (%)	27.3	4.5
Ex Smoker (%)	31.8	9.1
Non Smoker (%)	40.9	86.4
Diabetes (%)	22.7	1.3
Dyslipidemia (%)	72.7	2.5
Hypertension (%)	59.1	40.9

Snake Algorithm

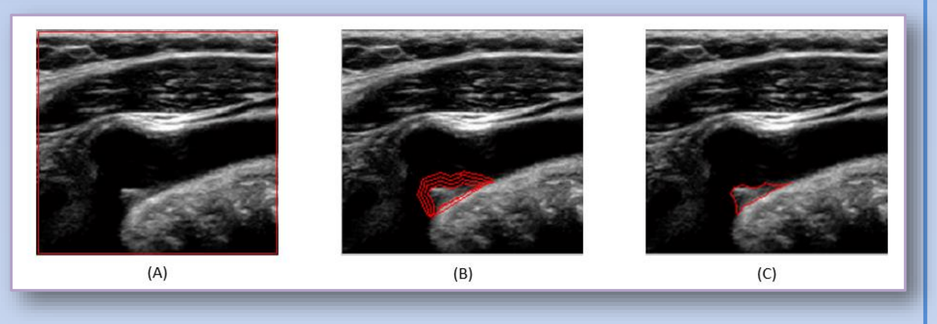

Figure 3. Processing phase. A) A squared region of interest; B) final step of iterations of the snake near the boundary of the plaque; C) Final snake.

Table 2 ROC analysis data

Cut-off	TP	FP	TN	FN	Sens.	95% CI	Spec.	95% CI	PPV	NPV	AUC (95% CI)
>229.3	51	41	186	9	85.0	73.4-92.9	81.94	76.3-86.7	0.55	0.95	
>231.7	51	39	188	9	85.0	73.4-92.9	82.8	77.3-87.5	0.57	0.95	
>232.2	50	39	188	10	83.3	71.5-91.7	82.8	77.3-83.5	0.56	0.95	
>236.8*	50	33	194	10	83.3	71.5-91.7	85.5	80.2-89.8	0.60	0.95	0.89 (0.85-0.92)
>237.9	49	33	194	11	81.7	69.6-90.5	85.5	80.2-89.8	0.60	0.95	
>238.1	49	32	195	11	81.7	69.6-90.5	85.9	80.7-90.2	0.60	0.95	
>241	46	28	199	14	76.7	64-86.6	87.7	82.7-91.6	0.62	0.93	

Legend: *Criterion corresponding with highest Youden index. CI= Confidence Interval; TP: True Positive; FP: False Positive; TN: True Negative; FN: False Negative; Sens.=Sensitivity; Spec.=Specificity; PPV=Positive Predictive Value; NPV=Negative Predictive Value; AUC=Area Under The Curve; CI= Confidence Interval.

Table 3. Validity of US image as a screening tool for segmentation of plaque and no plaque.

Characteristics	Segmentation	No Segmentation	Sens. (95% CI)	Spec. (95% CI)	PPV (95% CI)	NPV (95% CI)
Image with plaque	19 (TP)	3 (FP)	0.79 (0.62-0.96)	0.85 (0.70-0.99)	0.86 (0.85-0.88)	0.77 (0.60-0.95)
Image without plaque	5 (FN)	17 (TN)				

Legend: CI= confidence interval; TP = true positive; FP= false positive; TN = true negative; FN = false negative; Sens.= sensitivity; Spec. = specificity; PPV = positive predictive value; NPV = negative predictive value.

DISCUSSIONS

The obtained results confirmed that watershed algorithm is feasible and has a good agreement with the expert neurologist. Our validated systems, without the need of any user-interaction, could be considered a method that generates an objective and repeatable detection out-put that could be useful in second opinion.

CONCLUSION

The automatic plaque segmentation and the developed characterization package could be useful for clinicians to quantify the morphological and texture features and to improve objectivity the plaque interpreting. Advantaged of segmentation algorithms is that identify in objective manner without the bias of operator.

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