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FULL RESEARCH ARTICLE

US-based radiomics and conventional US of subclinical carotid plaques in patients with psoriatic arthritis and control subjects: A pilot study

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ABSTRACT

Introduction: *The characteristics of carotid atheromatous plaques by conventional ultrasound (US) and US-based radiomics have not been defined in psoriatic arthritis (PsA) patients. The aim of this study was to describe subclinical carotid plaque findings by conventional US and US-based radiomics in PsA patients and control subjects.* **Material and Methods:** *PsA patients and control subjects matched for age and sex with subclinical carotid plaques were included. Conventional US was performed, assessing the number, size, echogenicity, calcification, echotexture, and surface of carotid plaques. Semiautomated image segmentation of the region of interest was performed and analyzed with histogram parameters for US-based radiomics.* **Results:** *Forty carotid plaques were analyzed, 20 from 17 PsA patients and 20 from 13 control subjects. Atheromatous plaques were predominantly hyperechoic and homogeneous in both groups with conventional US. Subclinical carotid plaques with less than 50% stenosis were found in PsA patients and control subjects. No significant differences were found between the two groups in the histogram parameters of minimum, mean, standard deviation, maximum, skewness, kurtosis, entropy, and energy of US-based radiomics.* **Conclusion:** *This study is the first to describe the characteristics of subclinical carotid plaques in PsA patients using conventional US and US-based radiomics. The results of our exploratory study do not allow us to recommend US-based radiomics as a complementary imaging modality to conventional US in PsA patients.*

Keywords: *US-based radiomics. Carotid Doppler. Ultrasound. Psoriatic arthritis. Carotid plaques.*

INTRODUCTION

Psoriatic arthritis (PsA) is a systemic inflammatory disease associated with an increased risk of cardiovascular disease[1,2]. PsA activity and the presence of carotid plaques have been reported as independent predictors of cardiovascular events such as acute myocardial infarction and cerebral ischemia. Risk prediction is important to classify patients and provide early therapy. However, clinical prediction algorithms underestimate cardiovascular risk in patients with PsA[3]. Conventional carotid ultrasound (US) is an essential tool for assessing carotid plaques to determine cardiovascular risk. It allows characterization of carotid plaques and appropriate follow-up because of its wide availability[4–6]. Assessment of carotid plaque on ultrasound provides stroke risk information beyond the measurement of luminal stenosis.

Assessment of plaque components with US, computed tomography (CT), and magnetic resonance imaging (MRI) has allowed defining their content and clinical behavior[7]. The plaque characteristics that are determinants for brain ischemia are related to size, degree of stenosis, hypoechogenicity, and ulceration[6,8,9].

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Radiomics is a novel tool with high diagnostic performance. It is mainly used in the differentiation of malignant tumors[10,11]. On the other hand, it has proven to be a useful tool for detecting vulnerable carotid plaques using radiomics models based on US[9,12–15], CT[16], and MRI[17], which are superior to clinical models in accurately defining vulnerable plaques[6,7,16]. Radiomics provides an objective analysis of carotid plaque composition to extract and analyze quantitative features that reflect the underlying pathophysiology[18]. This approach uses a computational process that converts images into numerical data[6,8]. Various software, such as LIFEx (http://www.lifexsoft.org/)[19], ITK-SNAP[6,17], Plaque Texture Analysis[13], MATLAB Texture tools[12], and TexRAD[16] have been used for radiomics characterization of carotid plaques.

US-based radiomics has been used to predict the risk of cerebrovascular events associated with symptomatic and asymptomatic carotid plaques[9,12–15]. There are no studies that compare the characteristics of atheromatous plaques by conventional and US-based radiomics in PsA patients. The aim of this study was to describe the conventional US and US-based radiomics findings of subclinical carotid plaques in PsA patients and age- and sex-matched control subjects.

MATERIAL AND METHODS

A case-control study was conducted from January 2019 to December 2020 in the Department of Radiology and Diagnostic Imaging, the Cardiology Clinic, and the Rheumatology Clinic at the Hospital Universitario "Dr. Jose E. Gonzalez" in Monterrey, Nuevo Leon, Mexico. PsA patients and control subjects older than 18 years with subclinical carotid plaques detected by conventional US were included. Control subjects were recruited from the general population via social media. PsA patients and control subjects with ischemic cardiovascular disease, cancer, pregnant, and carotid intimal hyperplasia on conventional US examination with no evidence of associated carotid plaque were excluded. Participants provided informed consent. This study was approved by the Institutional Ethics in Research and Research Committees.

Information was obtained from the PsA patients' medical records and by clinical history in control subjects. Age, sex, active smoking, body mass index, and comorbidities of PsA patients and control subjects were recorded. PsA characteristics such as years of disease duration, Disease Activity in Psoriatic Arthritis (DAPSA) index, and PsA treatment were documented.

Definitions

Case: patients with confirmed diagnostic criteria for PsA[20] with a subclinical carotid atheromatous plaque on conventional US examination with no cerebrovascular or cardiovascular disease symptoms. These patients were matched for age (±2 years) and sex with control subjects.

Control: participants with no rheumatic, cerebrovascular or cardiovascular disease symptoms with evidence of carotid atheromatous plaque on conventional US examination.

Carotid intimal hyperplasia: a carotid artery inner layer wall thickness of 0.8–1.19 mm below the bifurcation.

Carotid plaque: a localized protrusion of the artery wall extending into the lumen ≥ 1.2 mm[21]. In subjects with 2 or more carotid plaques, the one with the greatest thickness and stenosis was selected.

Stenosis: reduction of the arterial lumen at the level of the carotid plaque relative to the area of the artery at the same site[22].

Severe stenosis: a peak systolic velocity greater than 230 cm/sec with a significantly visible plaque (with a structural reduction in grayscale equal to or greater than 50%), aliasing with color Doppler US, spectral broadening, turbulence after stenosis, and bruit artifacts[23].

Vulnerable plaque on conventional US: any of the following: heterogeneous, hypoechoic, with > 50% stenosis, and/or an irregular surface[9].

Conventional US protocol

Conventional carotid US in grayscale, color, and spectral Doppler was performed with EPIQ 5 ultrasound equipment (Koninklijke Philips, Amsterdam, The Netherlands) with a 10-MHz linear transducer. The image acquisition protocol was performed in both carotid arteries, including the common carotid, extracranial internal carotid, external carotid, and vertebral arteries. Peak systolic flow velocities were measured with a Doppler angle between 45° and 60°.

The following ultrasonographic carotid plaque variables were recorded: number (single or multiple), size (thickness, length, area, and stenosis), echogenicity (hyperechoic and hypoechoic in relation to the vascular wall), calcification (present or absent), echotexture (homogeneous or heterogeneous), and surface (regular or irregular).

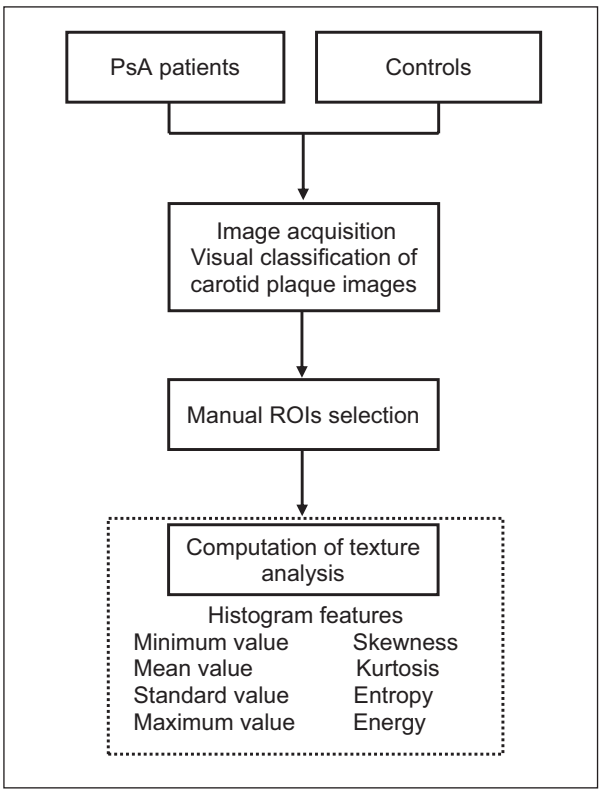


Figure 1. A flowchart of the carotid plaque histogram parameters on US-based radiomics performed with LIFEx software (version 7.1 http://www.lifexsoft.org/).

PsA: psoriatic arthritis; ROI: region of interes; US: ultrasound.

US-based radiomics analysis

Carotid plaque in a longitudinal projection was selected for radiomics segmentation. Digital Imaging and Communications in Medicine (DICOM) images were imported into the LIFEx software package (version 7.1, http://www.lifexsoft.org/) for calculation of texture analysis. This software is included in the "Image Biomarker Standardization Initiative" for the standardization and validation of radiomics parameters[24]. We manually selected the region of interest (ROI) of the plaques[25] (Figure 1). A single radiologist (ACGA) performed the image analysis. The evaluator was blinded to the patients' clinical information.

US-based radiomics evaluation was performed with first-order parameters using a histogram calculation of images, which is a set of metrics calculated from digital images based on mathematical analysis[19,24] with the following parameters:

Minimum: reflects the minimum intensity value in the ROI.

Mean ± standard deviation: the mean intensity value in the ROI.

Maximum: the maximum intensity value in the ROI.

Skewness: is the asymmetry of the grey-level distribution.

Kurtosis: the shape of the grey-level distribution (peaked or flat) compared to a normal distribution.

Entropy: the randomness of the distribution. We used the logarithm to base 10 in the LIFEx software.

Energy: reflects the uniformity of the distribution.

PsA severity subanalysis

The characteristics of carotid atheromatous plaques in PsA patients were compared based on disease severity using the DAPSA index. Two groups were formed. The first group included patients in remission or with mild disease activity and the second cases with moderate or severe disease activity.

Conventional US and US-based radiomics were performed to compare the characteristics of carotid atheromatous plaques in PsA patients based on disease severity with the DAPSA index.

Statistical analysis

Continuous and categorical descriptive variables were recorded. The Kolmogorov-Smirnov test was used to determine normal distribution. Continuous variables with normal distribution were expressed as means ± standard deviation. Variables with non-normal distribution were expressed as median and interquartile ranges. Student's t-test was used to compare parametric continuous variables. The Mann-Whitney U test was used for nonparametric continuous variables. The chi-square test was used to compare categorical variables. A p-value < 0.05 was statistically significant. SPSS v.25.0 software (IBM Corp., Armonk, NY, USA) was used.

RESULTS

Seventeen PsA patients and 13 age- and sex-matched control subjects were included. Demographics, clinical characteristics, and comorbidities are shown in Table 1. No significant differences were found between the two groups. Age was comparable (55.2 ± 7.2 and 56.0 ± 7.2 years, respectively). The duration, disease activity index, and treatment of PsA patients are described.

Conventional US features

A comparison of carotid plaques in PsA patients and control subjects is shown in Table 2. Forty carotid plaques

Table 1. Demographic and clinical characteristics in PsA patients compared with control subjects

Parameter	PsA group (n = 17 patients)	Control group (n = 13 subjects)	p-value
Age, years ± SD	55.2 ± 7.2	56.0 ± 7.2	0.77
Sex male/female, n	10/7	8/5	0.88
Active smoking	2 (11.8)	3 (23.1)	0.09
BMI, kg/m^2 (IQR)	30.4 ± 5.3	29.5 ± 4.6	0.61
Comorbidities[a], n (%)			
Diabetes mellitus	3 (17.6)	5 (38.5)	0.24
Hypertension	7 (41.2)	5 (38.5)	0.88
Dyslipidemia	10 (58.8)	5 (38.5)	0.27
Obesity	7 (41.2)	7 (53.8)	0.48
Duration of PsA, years	10 (6–13)	–	–
DAPSA			
Remission, n (%)	5 (29.4)	–	–
Mild, n (%)	6 (35.3)	–	–
Moderate, n (%)	2 (11.8)	–	–
Severe, n (%)	4 (23.5)	–	–
PsA Treatment, n (%)			
MTX	8 (47.0)	–	–
Monoclonal antibody	1 (5.9)	–	–
MTX + Monoclonal antibody	6 (35.3)	–	–
MTX + Glucocorticoids	2 (11.8)	–	–

BMI: body mass index; DAPSA: disease activity score for psoriatic arthritis; IQR: interquartile range; MTX: methotrexate; PsA: psoriatic arthritis; SD: standard deviation.
[a]More than one comorbidity may be present in a patient or control subject.

were analyzed, 20 from 17 PsA patients and 20 from 13 control subjects. Atheromatous plaques in PsA patients were thicker (2.2 mm vs. 1.7 mm), longer (12.9 mm vs. 8.7 mm), and more extensive area (22.6 mm^2 vs. 17.8 mm^2) than in control subjects, although the differences were not statistically significant. Atheromatous plaque stenosis was 29.1% (22.8–33.3) in PsA patients and 29.9% (25.4–34.7) in control subjects (p = 0.57); stenosis was less than 50% in both groups. No hemodynamic effects were observed, and no increase in peak systolic velocity > 125 cm/s at or after the level of the carotid plaques. No vulnerable atheromatous plaque or severe stenosis, according to the definitions, was found in either the case or control group. The atheromatous plaques in both groups were predominantly hyperechoic and homogeneous. An irregular surface was observed in 3 (15.0%) plaques in both groups. Figure 2 shows a comparison of echogenicity and the presence or absence of calcifications in carotid plaques by conventional US in two PsA patients. Figure 3 shows a comparison of echogenicity and echotexture with conventional US in a PsA patient and a control subject.

When the characteristics of atheromatous plaques in the carotid artery of PsA patients were compared by conventional US based on disease activity (in remission or mild activity versus moderate or severe activity), no statistically significant differences were found (Table 3). Plaques with greater length, area, and stenosis were observed in the mild activity or remission group compared to the moderate or severe activity group: 14 versus 9 mm, 18.9 versus 14.1 mm^2, and 31.3 versus 26.7% (p: ns), respectively. In both groups, atheromatous plaques without calcifications predominated in 9 (69.2%) of 13 plaques of PsA patients with mild activity or remission and 4 (57.1%) of 7 plaques of PsA patients with moderate or severe activity. Homogeneous atheromatous plaques were observed in 12 (92.3%) and 7 (100%) and with a regular surface in 10 (76.9%) and 7 (100%) in PsA patients with mild activity or remission and moderate or severe activity, respectively.

Table 2. Comparison of conventional US findings of carotid subclinical plaques in PsA patients and control subjects

Parameters	PsA group (n = 17 patients)	Control group (n = 13 subjects)	p-value
Number of plaques[a]	20	20	–
Single (%)	15 (75.0)	11 (55.0)	0.61
Multiple (two or more) (%)	5 (25.0)	9 (45.0)	0.39
Plaque size			
Thickness, mm (IQR)	2.2 (1.6–2.6)	1.7 (1.4–2.8)	0.39
Length, mm (IQR)	12.9 (8–18)	8.7 (7.7–12.1)	0.21
Area, mm^2 (IQR)	22.6 (11.3–31.1)	17.8 (11.8–19.3)	0.31
Stenosis, % (IQR)	29.1 (22.8–33.3)	29.9 (25.4–34.7)	0.57
Echogenicity			
Hyperechoic, n (%)	19 (95.0)	18 (90.0)	1.00
Hypoechoic, n (%)	1 (5.0)	2 (10.0)	–
Calcification			
Present, n (%)	7 (35.0)	11 (55.0)	0.52
Absent, n (%)	13 (65.0)	9 (45.0)	–
Echotexture			
Homogeneous, n (%)	19 (95.0)	20 (100)	1.00
Heterogeneous, n (%)	1 (5.0)	0	–
Surface			
Regular, n (%)	17 (85.0)	17 (85.0)	0.45
Irregular, n (%)	3 (15.0)	3 (15.0)	–

IQR: interquartile range; PsA: psoriatic arthritis; US: ultrasound.

[a]Some PsA patients had more than one unilateral plaque.

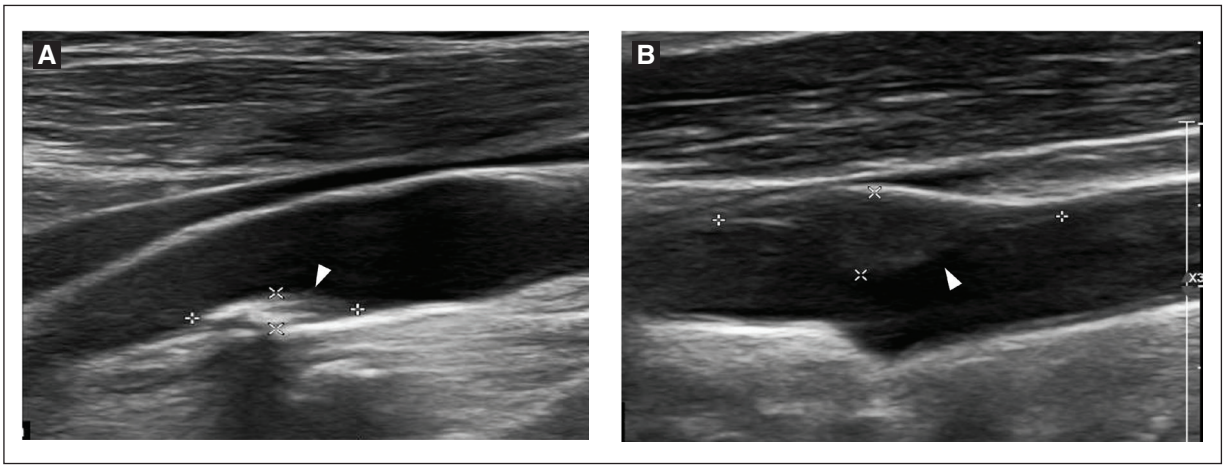


Figure 2. Conventional grayscale US. **A:** a 64-year-old man with PsA with calcified and hyperechoic atheromatous carotid plaque (arrowhead). **B:** a 44-year-old man with PsA with noncalcified and hypoechoic atheromatous carotid plaque (arrowhead).

PsA: psoriatic arthritis; US: ultrasound.

US-based radiomics features

Histogram parameters of subclinical plaques from PsA patients and control subjects are shown in Table 4. The mean (24.09 versus 22.29), standard deviation (0.79 versus 0.84), maximum (207.5 versus 205.0), skewness (0.79 versus 0.84), kurtosis (4.21 versus 3.83), entropy (1.55 versus 1.52), and energy (0.03 versus 0.04)

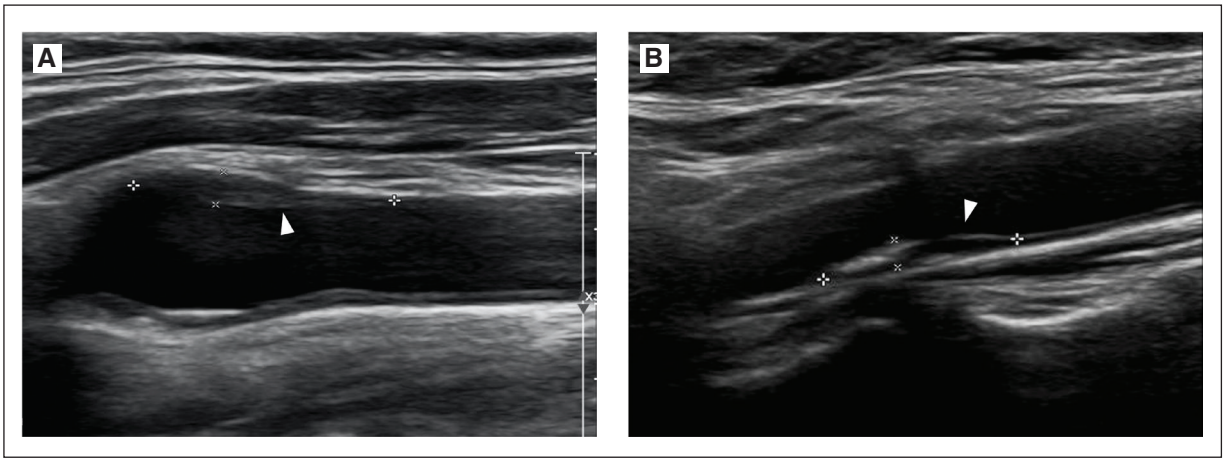


Figure 3. Conventional grayscale US. **A:** 50-year-old man in control group with homogeneous and hypoechoic atheromatous carotid plaque (arrowhead); **B:** 62-year-old man with PsA with heterogeneous and hyperechoic atheromatous carotid plaque (arrowhead).
PsA: psoriatic arthritis; US: ultrasound.

Table 3. Comparison of conventional US findings of the 20 subclinical carotid subclinical plaques in 17 patients in relation to PsA activity with the DAPSA index

Parameters	PsA remission (n = 5 patients) PsA mild (n = 6 patients)	PsA moderate (n = 2 patients) PsA severe (n = 4 patients)	p-value
Number of plaques, n	13[a]	7[b]	–
PsA patients with a single plaque (%)	9 (81.8)	5 (83.3)	0.61
PsA patients with two plaques (%)	2 (18.2)	1 (16.7)	0.40
Plaque size			
Thickness, mm (IQR)	1.8 (1.5–2.7)	2.2 (1.4–2.4)	0.66
Length, mm (IQR)	14 (0.7–2)	9 (6.9–16.2)	0.36
Area, mm^2 (IQR)	18.9 (10.4–32.3)	14.1 (10.4–27.7)	0.55
Stenosis, % (IQR)	31.3 (17.9–46.8)	26.7 (16.8–39.3)	0.66
Echogenicity			
Hyperechoic, n (%)	12 (92.3)	7 (100)	0.63
Hypoechoic, n (%)	1 (7.7)	0	0.58
Calcification			
Present, n (%)	4 (30.8)	3 (42.9)	0.37
Absent, n (%)	9 (69.2)	4 (57.1)	0.33
Echotexture			
Homogeneous, n (%)	12 (92.3)	7 (100)	1
Heterogeneous, n (%)	1 (7.7)	0	1
Surface			
Regular, n (%)	10 (76.9)	7 (100)	0.25
Irregular, n (%)	3 (23.1)	0	0.52

DAPSA: Disease Activity in Psoriatic Arthritis; IQR: interquartile range; PsA: psoriatic arthritis; US: ultrasound.
[a]Nine PsA patients had one carotid plaque and two PsA had two carotid plaques; [b]Five PsA patients had one carotid plaque and one PsA had two carotid plaques.

Table 4. US-based radiomics of carotid plaques from patients with PsA and control subjects

Histogram parameters	PsA group (n = 17 patients)	Control group (n =13 subjects)	p-value
Number of plaques[a]	20	20	–
Minimum, (IQR)	0 (0–4.333)	0 (0–15.750)	0.97
Mean, ± SD	24.09 ± 8.17	22.29 ± 5.25	0.41
Standard deviation, (IQR)	0.79 (0.28–1.21)	0.84 (0.33–1.24)	0.45
Maximum, (IQR)	207.5 (136.3–234.0)	205.0 (158.2–245.2)	0.78
Skewness, (IQR)	0.79 (0.28–1.21)	0.84 (0.33–1.24)	0.64
Kurtosis, (IQR)	4.21 (2.50–5.21)	3.83 (2.74–5.67)	0.88
Entropy, mean ± SD	1.55 ± 0.15	1.52 ± 0.14	0.55
Energy, (IQR)	0.03 (0.02–0.04)	0.04 (0.03–0.05)	0.20

IQR: interquartile range; PsA: psoriatic arthritis; SD: standard deviation; US: ultrasound.

[a]Some PsA patients had more than one unilateral plaque.

Table 5. US-based radiomics of 20 subclinical carotid plaques in relation to activity index (DAPSA) in 17 PsA patients

Histogram parameters	PsA remission (n = 5 patients) PsA mild (n = 6 patients)	PsA moderate (n = 2 patients) PsA severe (n = 4 patients)	p-value
Number of plaques (%)	n = 13[a]	n = 7[a]	–
Minimum, (IQR)	1 (1–1)	1 (1–1)	–
Mean, ± SD	22.26 (8.89)	23.77 (6.73)	0.78
Standard deviation, (IQR)	10.33 (8.64–12.42)	9.56 (7.02–13.17)	0.72
Maximum, (IQR)	64 (64–64)	64 (64–64)	1
Skewness, (IQR)	0.89 (0.23–1.83)	1.06 (0.37–1.42)	0.84
Kurtosis, (IQR)	4.50 (2.79–7.49)	4.34 (3.11–5.48)	0.90
Entropy, mean ± SD	1.50 (1.86)	1.51 (0.09)	0.66
Energy, (IQR)	0.03 (0.02–0.05)	0.03 (0.02–0.05)	0.66

DAPSA: Disease Activity in Psoriatic Arthritis; IQR: interquartile range; PsA: psoriatic arthritis; SD: standard deviation; US: ultrasound.

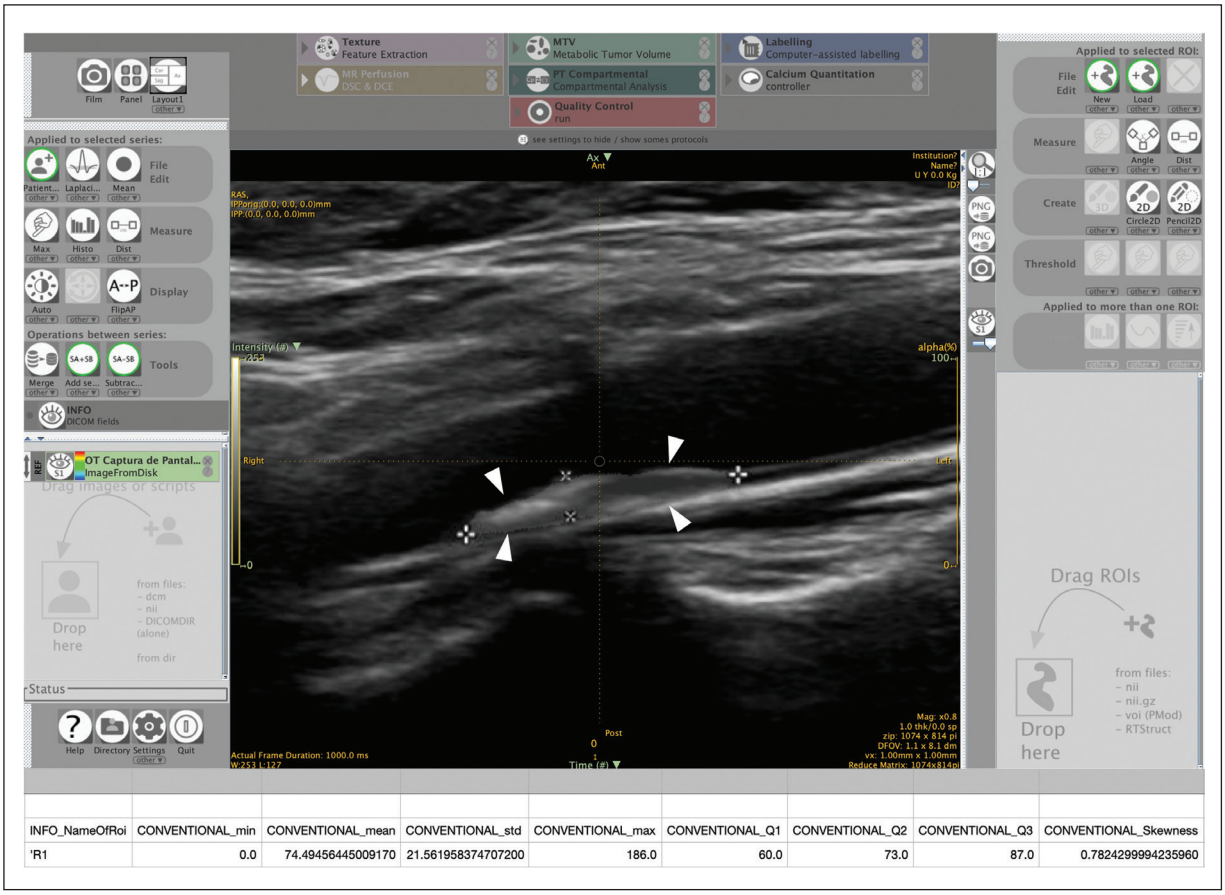
[a]Some PsA patients and control had more than one unilateral plaque.

were comparable between PsA patients and control subjects and showed no significant differences. Histogram analysis of the carotid atheromatous plaques in relation to the PsA activity index is shown in Table 5. No significant differences in carotid plaque histogram parameters were observed between patients in remission and with mild activity compared with moderate and severe rheumatologic disease activity. An example of carotid plaque segmentation from a patient with PsA is shown in Figure 4. The quantitative results of histogram analysis using LIFEx software are shown at the bottom of the image. Figure 5 shows a conventional US carotid image demonstrating an irregular surface and carotid plaque segmentation in a patient with PsA.

DISCUSSION

In our study, subclinical carotid plaques with less than 50% stenosis in PsA patients and age- and sex-matched control subjects had comparable findings on conventional US examination and US-based radiomics. It is likely that no significant differences were demonstrated because of the incipient stage of atheromatous disease and the fact that most PsA patients were in remission or with mild disease activity. This study is the first to describe the characteristics of subclinical carotid plaques in PsA patients using conventional US and US-based radiomics.

US-based radiomics is a tool that has proven useful and superior to clinical models[6]. Radiomic studies of atheromatous plaques have focused on distinguishing between symptomatic and asymptomatic plaques. A single study reporting on the evaluation of carotid plaques comparing US-based radiomics with conventional US was published by Huang et al.[9] On the other hand, a LIFEx software study compared the fibrous or fatty content of 78 noncalcified atherosclerotic coronary plaques in asymptomatic patients with moderate coronary stenosis[19]. Histogram analysis using the ROC



INFO_NameOfRoi	CONVENTIONAL_min	CONVENTIONAL_mean	CONVENTIONAL_std	CONVENTIONAL_max	CONVENTIONAL_Q1	CONVENTIONAL_Q2	CONVENTIONAL_Q3	CONVENTIONAL_Skewness
'R1	0.0	74.49456445009170	21.561958374707200	186.0	60.0	73.0	87.0	0.7824299994235960

Figure 4. An example of carotid plaque segmentation (arrowheads) from a patient with PsA. The quantitative results of histogram analysis using LIFEx software are shown at the bottom of the image.

PsA: psoriatic arthritis.

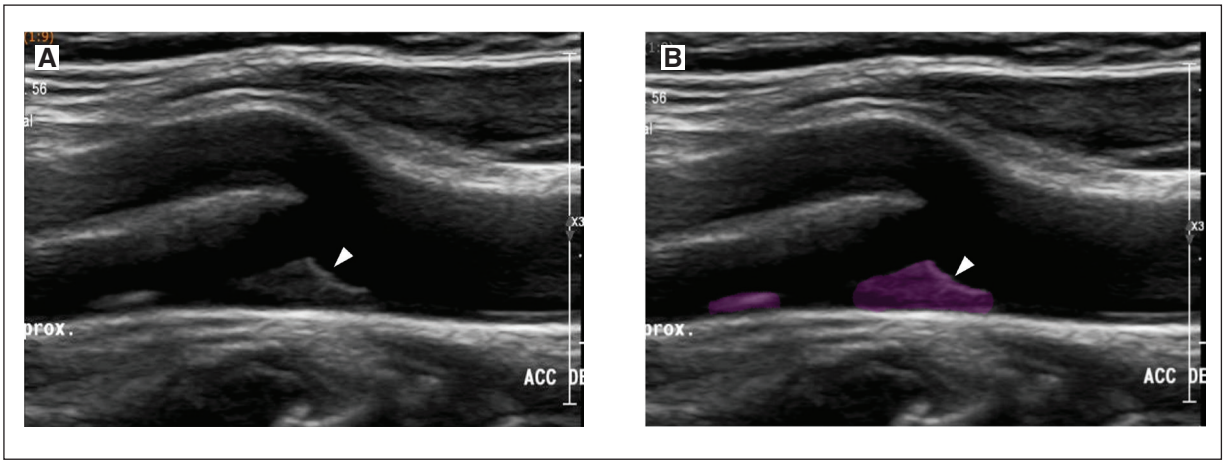


Figure 5. Conventional US in a 57-year-old woman with PsA. **A:** atheromatous carotid plaque with irregular surface (arrowhead). **B:** segmentation of carotid plaque image (arrowhead).

PsA: psoriatic arthritis; US: ultrasound.

curve showed a superior diagnostic performance (AUC 0.92) of angio-CT-based radiomics compared with the conventional angio-CT and integrated intravascular backscatter US (AUC 0.83) (p = 0.001). The authors concluded that angio-CT-based radiomics was superior in classifying coronary atherosclerotic plaques. In our study, no significant differences were demonstrated between PsA patients and control subjects in the

histogram parameters of US-based radiomics and the morphological features of conventional US. In both groups, carotid plaques showed less than 50% stenosis and subclinical behavior. It is likely that the findings were comparable because of the incipient stage of atheromatous disease and the fact that most PsA patients were in remission or with mild activity.

Detection of carotid plaques by conventional US in PsA patients allows the determination of cardiovascular risk and has been shown superior to clinical classifications[3]. In a study examining the carotid plaques of 81 Mexican PsA patients with conventional US, there was a higher prevalence of subclinical atherosclerosis compared to 81 control subjects (n = 36, 44.4% vs. n = 20, 24.7%, respectively, p = 0.008)[3]. On the other hand, US-based radiomics has been shown useful for cardiovascular risk stratification[19]. Huang et al.[6] constructed a nomogram for predicting symptomatic carotid plaques with US-based radiomics using the software ITK-SNAP and demonstrated its superior diagnostic performance compared with clinical variables and conventional US, which had little effect on the final nomogram, suggesting that they do not provide additional information for identifying symptomatic carotid plaques[26]. US-based radiomics has potential and appears useful for predicting symptomatic carotid plaques. In 548 plaques from a subgroup of low-risk patients, the average carotid plaque length was 11 mm. This result is comparable with our study in PsA patients, with a length of 12.9 mm, in contrast to control subjects with 8.7 mm, although there was no significant difference between the carotid plaques findings on conventional US and US-based radiomics because our sample size was small.

Adequate treatment of rheumatologic disease is directly related to control of progression from subclinical to clinical atherosclerosis[27]. Various indices have been used to define PsA activity, with the DAPSA index being the most recommended. Minimal sustained PsA activity has a protective effect on plaque progression with a smaller increase in total area and a reduction in intima-media thickness[27]. In our study, 2 out of 3 treated PsA patients were in remission or with low activity. On the other hand, no significant differences in the findings of conventional US or US-based radiomics of carotid plaques were observed in patients with remission or mild activity compared to patients with moderate or severe activity. No vulnerable plaques were detected in PsA patients and control subjects with subclinical atherosclerosis. The results of conventional US and US-based radiomics findings were comparable between the two groups, regardless of PsA disease activity. Because disease control plays a protective role in carotid plaque progression and thus indirectly in the risk of developing a cardio/cerebrovascular event, we hypothesize that treatment of rheumatologic disease in our patients has a protective effect on carotid plaque progression reflected in ultrasonographic findings comparable to those of control subjects.

Our study had several strengths. The case-control design was matched for age and sex. A conventional US examination was performed, which is widely available and increases the reproducibility of our results. In addition, the segmentation of images by US-based radiomics was performed by a single operator, which reduces measurement variability. On the other hand, US-based radiomics examination does not increase the cost because the texture analysis software (LIFEx) is free. The limitations of the study are related to the small sample size. In PsA patients, the disease course was variable. In addition, only patients and control subjects with subclinical atheromatous disease were included, and only the most extensive carotid plaque was analyzed. Furthermore, the variability of texture measurements in US-based radiomics is still high and there are current initiatives for standardization[24]. On the other hand, US-based radiomics requires operator skills and a longer examination time than with conventional US. Interobserver variability was not determined and radiomic segmentation of carotid plaque ROI was performed manually by a single radiologist. A previous study reported good to excellent interobserver and intraobserver agreement[6].

CONCLUSION

In our study, subclinical carotid plaques with less than 50% stenosis in PsA patients and age- and sex-matched control subjects had comparable findings with conventional US and US-based radiomics. It is likely that no significant differences were demonstrated because of the early stage of atheromatous disease and the fact that most PsA patients were in remission or with mild disease activity. Conventional US has widely demonstrated its usefulness in the evaluation of carotid plaques[4–6]. The results of our exploratory study do not allow us to recommend US-based radiomics as a complementary imaging study to conventional US in PsA patients. Prospective cohort studies with US-based radiomics should be performed in patients with a recent diagnosis of PsA to evaluate the behavior of carotid plaques, whether asymptomatic or symptomatic, to define its clinical usefulness.

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Conflicts of interest

The authors declare that they have no conflicts of interest.

Ethical disclosures

Protection of individuals. This study was conducted in compliance with the Declaration of Helsinki (1964) and its subsequent amendments.

Confidentiality of data. The authors declare that they followed their center's protocol for sharing patient data.

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