Evaluation of different algorithms to identify the scleroderma pattern in nailfold videocapillaroscopy

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Abstract

Objective

Although the role of nailfold videocapillaroscopy (NVC) in the investigation of Raynaud's phenomenon (RP) and systemic sclerosis (SSc) is well established, there is significant heterogeneity in the parameters used to identify the scleroderma pattern. Recently, different algorithms have been proposed for the identification of the scleroderma pattern associated with SSc. This study aimed to explore the accuracy of different capillaroscopic parameters and algorithms (the Fast Track algorithm and the CAPI-score) for identifying the scleroderma pattern in individuals with and without RP and autoimmune rheumatic diseases.

Methods

A total of 258 NVCs were analysed. The accuracy and area under the curve (AUC) of qualitative and quantitative NVC parameters were analysed to discriminate between scleroderma and non-scleroderma patterns.

Results

The scleroderma pattern was identified in 101 (39.15%) NVCs. A density of ≤8 capillaries/mm was defined as the optimal cut-off point (AUC 0.911, 95% CI 0.871–0.950), yielding the highest accuracy (87.94%) for identifying the SD pattern versus normal and nonspecific microangiopathy. Cut-off values of ≤3 or ≤6 capillaries/mm resulted in lower sensitivity despite high specificity. The presence of giant capillaries demonstrated high specificity (98.09%) and an accuracy of 85.66%. The accuracy improved when the presence of giant capillaries and ≤8 capillaries/mm or ≤7 capillaries/mm were combined (accuracies of 91.08% and 86.82%, respectively).

Conclusion

The combination of two capillaroscopy parameters (giant capillaries and capillary density) inspired by the Fast Track and CAPI-score, was highly accurate for defining the scleroderma pattern in our cohort.

Key words

nailfold videocapillaroscopy, Raynaud's phenomenon, systemic sclerosis, scleroderma patterns

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Introduction

Nailfold videocapillaroscopy (NVC) is a simple, non-invasive, cost-effective and reproducible imaging method, that enables *in vivo* visualisation of microvascular circulation through direct observation of the distal row of capillary loops in the periungual region of the fingers (1, 2). It is widely used for investigating Raynaud's phenomenon (RP) and for the diagnosis of systemic sclerosis (SSc), in which specific anatomical changes are identified in the peripheral microcirculation by nailfold capillaroscopy (3). Given its importance in the early diagnosis of the disease, nailfold capillaroscopy was incorporated into the ACR/EULAR SSc classification criteria in 2013 (4).

Patients with SSc and scleroderma spectrum disorders exhibit a typical capillaroscopic pattern known as the 'scleroderma' (SD) pattern, which is characterised by the presence of dilated capillaries (enlarged and/or giant capillaries), a reduction in the number of capillaries, microhaemorrhages, neo-angiogenesis (bushy or branched capillaries), and vascular array disorganisation to varying degrees (5, 6). The SD pattern is present in 83–98% of SSc patients, although it might also be observed in mixed connective tissue disease, dermatomyositis and overlap syndromes, and rarely in patients with systemic lupus erythematosus (SLE) (6-9).

Despite the advances that have occurred in the standardisation of NVC parameters and the greater dissemination of the method, there is still subjectivity in the interpretation and measurement of some parameters and in the definition of 'normal' and 'non-normal' results (10, 11). The distinction between normality and alterations considered 'non-specific'', such as tortuous, coiled, elongated, and slightly enlarged capillaries, can also be a challenge, especially for professionals with little experience using this method (11).

Furthermore, the definition of the SD pattern is not homogeneous since it is based on the combination of morphological alterations of the capillary loops. To overcome these limitations, standardisation of nailfold capillaroscopy acquisition and analysis was proposed in 2020 (12). In this consensus, a standardised definition of 'normal', 'non-specific abnormalities' and the 'scleroderma pattern' was presented. Certain characteristic capillaroscopic abnormalities were considered specific to the SD pattern, including the presence of giant capillaries or the combination of abnormal shapes with a low capillary count.

In addition, Smith *et al*. proposed a 'Fast Track' algorithm for defining the SD pattern that consists of three rules: if there are ≥7 capillaries/mm and no giant capillaries, the image is classified as a non-scleroderma pattern (Category 1). If giant capillaries or ≤3 capillaries/mm in combination with abnormal shapes (late pattern) are present, it is a scleroderma pattern (Category 2). If neither condition applies, it is classified as a non-scleroderma pattern (Category 1) (13). However, these criteria may be insensitive and do not include patients with early changes (14). More recently, Gracia-Tello *et al*. presented another algorithm, the CAPI-score, a quantitative algorithm inspired by the Fast Track method (15). In this score, the following parameters were proposed to define an SD pattern: capillary density ≤6 capillaries/mm and/or the presence of giant capillaries and/or proportions of abnormal capillaries >10%.

This study aimed to evaluate the sensitivity, specificity, and accuracy of different capillaroscopy parameters for identifying the SD pattern in individuals with or without RP and autoimmune rheumatic diseases. Second, we aimed to analyse the different algorithms recently published and proposed a simple algorithm, which uses only two capillaroscopy parameters to define the SD pattern, based on the algorithm proposed in the 'Fast Track' and 'CAPI-score'.

Materials and methods

Study design and population

This retrospective and observational study included 258 adults who underwent NVC and were included in a database collected at the SSc outpatient clinic of the Rheumatology Service of Hospital São Paulo/UNIFESP from February 2012 to November 2022. A

healthy control group that consisted of companions of patients and of students and hospital employees at Medical School Hospital used in a previous study (16) was also included.

The inclusion criteria were age ≥18 years and clinical data available in the Hospital São Paulo's electronic medical records. Subjects were excluded if they lacked information on demographic data or diagnosis in their electronic medical records. Patients with SSc with severe flexion contracture of the hands and subjects with poor visibility of nailfold capillaries were also excluded.

The study was submitted to and approved by the local Ethics Committee (Study no. 6.030.472). All patients provided written informed consent.

Sociodemographic data and clinical characteristics, including age, sex, and diagnosis, were collected during NVC and reviewed in the medical records.

Patients with SSc were required to meet the 2013 ACR/EULAR SSc classification criteria (4) or the classification proposed by LeRoy *et al*. for early SSc (17). Patients with idiopathic inflammatory myopathy (IIM) were required to meet the EULAR/ACR classification criteria from 2017 (18), and the International Consensus criteria for the diagnosis of RP (19) were used to define primary RP. Patients with SSc were categorised according to their cutaneous subtypes into limited cutaneous SSc, diffuse cutaneous SSc, and SSc sine scleroderma (20). Those who presented overlapping syndromes with SSc, including Sjögren's syndrome and rheumatoid arthritis, were included in the SSc group. Patients with other diagnoses, including systemic lupus erythematosus (SLE), mixed connective tissue disease, undifferentiated connective tissue disease, rheumatoid arthritis, primary Sjögren's syndrome, antiphospholipid antibody syndrome, and localised scleroderma, were also included and grouped together.

Table I. Sociodemographic and clinical characteristics of the patients and healthy controls.

Clinical and demographic data	(n=258)
Age (mean and standard deviation), years	47.03 ± 15.15
Female/Male sex	233 (90.3%) / 25 (9.7%)
Diagnosis	
Healthy controls	53 (20.5%)
Primary Raynaud phenomenon	37 (14.3%)
Systemic sclerosis	101 (39.2%)
Early SSc	9 (8.9%)
Sine scleroderma	6 (5.9%)
Limited cutaneous	54 (53.5%)
Diffuse cutaneous	32 (31.7%)
Inflammatory myopathies	6 (2.3%)
Other diagnoses *	61 (23.7%)

SSc: systemic sclerosis.
*Other diagnoses: systemic erythematosus lupus, mixed connective tissue disease, undifferentiated connective tissue disease, rheumatoid arthritis, primary Sjögren's syndrome, antiphospholipid antibody syndrome, and localised scleroderma.

Nailfold capillaroscopy acquisition

NVC was performed with a video capillaroscope under 200× magnification with computerised equipment and a video system (Videocap 8.14 software, DS-Medica, Milan, Italy). In all fingers, except the thumbs, four consecutive images of at least 1 mm of the periungual capillary network were captured and archived. The following parameters were evaluated in each image: 1) number of capillaries/mm; 2) number of microhaemorrhages; 3) number of enlarged capillaries/mm (apical diameter of the capillary loop between 20 μm and 49 μm); 4) number of giant capillaries/mm (apical diameter of the capillary loop ≥50 cm); and 5) avascular score. The evaluation and quantification of the number of enlarged and giant capillaries were performed by measuring the diameter of the apical region of each capillary loop visualised in the most distal row of nailfold capillaries within the 1 mm area (12). The mean number of each parameter was calculated.

To measure capillary loss (avascular score), the following values were used: score 0: ≥8 capillaries/mm; score 1: 6 to 7 capillaries/mm; score 2: 4 to 5 capillaries/mm; and score 3: ≤3 capillaries (12, 21, 22). All NVC exams were classified into three capillaroscopic patterns: normal, non-specific microangiopathy and the SD pattern. Patients with the SD pattern were classified into early, active and late SD patterns, as previously reported (23).

Statistical analysis

Data were recorded anonymously in an Excel spreadsheet, and SPSS v. 20.0 (Chicago, IL) and MedCalc software were used for statistical analysis. The data are presented as means, standard deviations, 95% confidence intervals (CIs) and frequencies. The Kolmogorov-Smirnov test was used to assess the normal distribution of continuous variables. The level of statistical significance adopted was 5% ($p<0.05$).

The ability of capillaroscopic parameters, alone or in combination, to identify the SD pattern *versus* non-SD pattern (normal and non-specific microangiopathy) or to diagnose SSc *versus* healthy controls and patients with primary RP was analysed using sensitivity, specificity, positive predictive value (PPV), negative predictive value (NPV), and accuracy using 2×2 contingency tables.

The ability of each NVC parameter to distinguish between the SD pattern and non-SD pattern and to differentiate individuals with primary RP and controls from those with SSc was assessed by analysing the area under the curve (AUC) of the ROC curve.

The values used to interpret the area under the curve of the ROC curve were as follows: 0.90–1 = excellent; 0.80–0.90 = good; 0.70–0.80 = mild; 0.60–0.70 = low; and 0.50–0.60 = weak. For each NVC parameter, the best cut-off point was identified considering the SD pattern or diagnosis of SSc as a positive or abnormal test, using the maximum Youden index criteria.

The cut-off points for the number of capillaries/mm previously proposed to define the SD pattern, such as the number of capillaries ≤3, ≤6 and ≤7 (12, 13, 15), were also evaluated.

Table II. Videocapillaroscopy parameters in healthy controls, primary Raynaud's phenomenon (RP), systemic sclerosis, inflammatory myopathies and patients with other diagnoses.

	Healthy controls and primary RP (n=90)	Systemic sclerosis (n=101)	Inflammatory myopathies (n=6)	Other diagnoses (n=61)
Capillaroscopic patterns				
Normal pattern	83 (92.2%)	8 (7.9%)	2 (33.3%)	25 (41.0%)
Non-specific microangiopathy	7 (7.8%)	9 (8.9%)	3 (50.0%)	20 (32.8%)
Scleroderma pattern	0 (0%)	84 (83.2%)	1 (16.7%)	16 (26.2%)
Early	-	11 (13.1%)	-	10 (62.6%)
Active	-	53 (63.1%)	1 (100%)	3 (18.7%)
Late	-	20 (23.8%)	-	3 (18.7%)

Data presented as frequency and percentage.

Results

Clinical and demographic characteristics of the study participants

Of the 258 individuals included, most patients had SSc (39.2%), and most of these patients had limited SSc. A total of ninety subjects (34.8%) were healthy controls or patients with primary RP. The clinical and demographic characteristics of the population are described in Table I.

Among the 258 NVCs, 118 (45.7%) had normal results, 39 (15.1%) had non-specific abnormalities, and 101 (39.2%) had a scleroderma pattern. Among those with a scleroderma pattern, 21 (20.8%) had an early pattern, 57 (56.4%) had an active pattern, and 23 (22.8%) had a late pattern (Table II). As presented in Table II, of the 90 examinations performed in healthy controls and patients with primary RP, 92.2% of the results were normal, and none of them had an SD pattern. Among the 101 NVCs performed in patients with SSc, only 7.9% were normal, and 83.2% had an SD pattern.

The capillaroscopic parameters according to the diagnosis and capillaroscopy patterns are shown in Figures 1 and 2. The mean number of capillaries/mm was 7.71±1.71 in patients with SSc, 6.48±2.24 in patients with IIM and 10.08±0.85 in patients with primary RP and controls. The mean number of capillaries/mm according to the capillaroscopy patterns was 10.04±0.84, 9.45±1.08 and 7.53±1.69 for the normal, non-specific microangiopathy and SD patterns, respectively (Fig. 2).

Test characteristics and ROC curve analysis for different video capillaroscopic parameters and for the identification of the SD pattern

The performance of different NVC parameters in identifying the SD pattern *versus* the non-SD pattern was evaluated. According to the ROC curve analysis, a mean number of capillaries/mm ≤ 8 was defined as the best cut-off point and was the value that obtained the best accuracy (87.94%) and sensitivity (74.26%), maintaining good specificity (96.81%), as well as good positive predictive value (PPV) (93.75%) and negative predictive value (NPV) (85.39%) results for identifying the SD pattern *versus* normal and non-specific microangiopathy (Fig. 3 and Table III). ROC curve analysis for the number of capillaries/mm revealed an area under

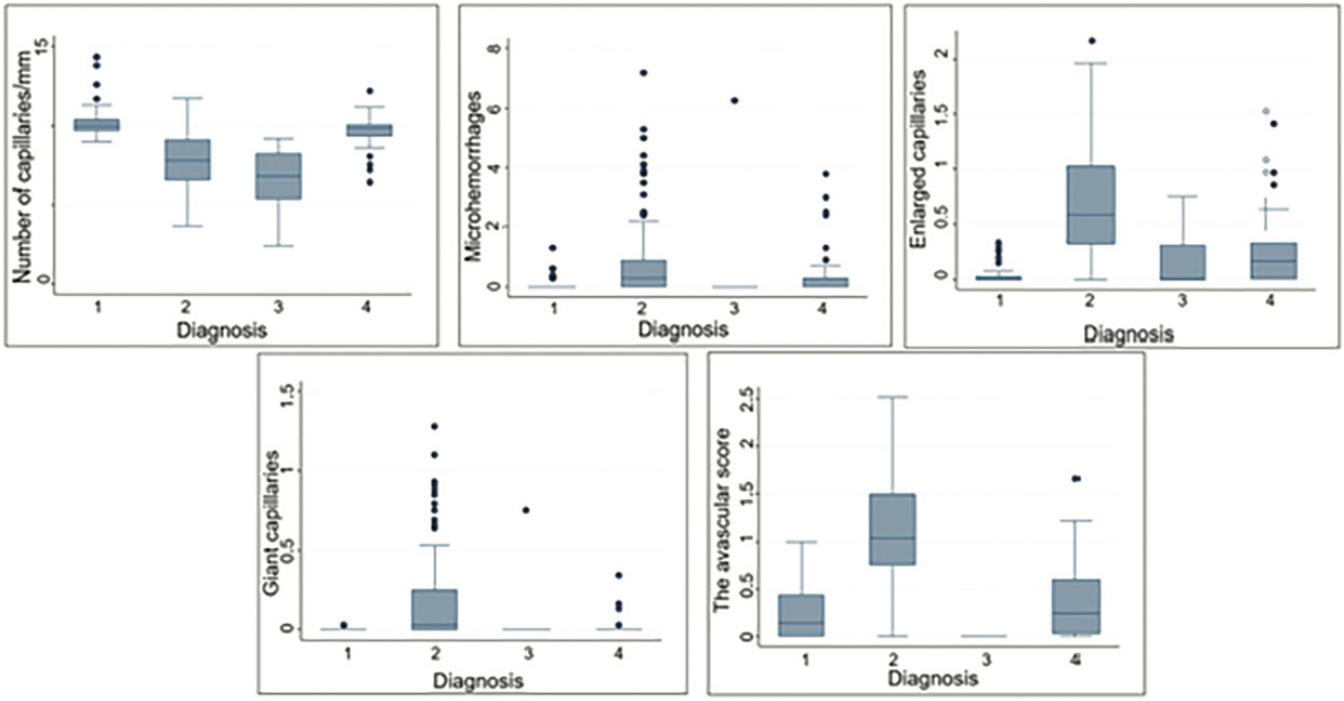

Fig. 1. Videocapillaroscopy parameters according to the diagnosis: healthy controls and primary Raynaud's phenomenon (1), systemic sclerosis (2), inflammatory myopathies (3) and other diagnoses (4). The was a significant difference between the number of capillaries/mm, the number of microhaemorrhages, enlarged and giant capillaries and the avascular score between groups (p<0.001).

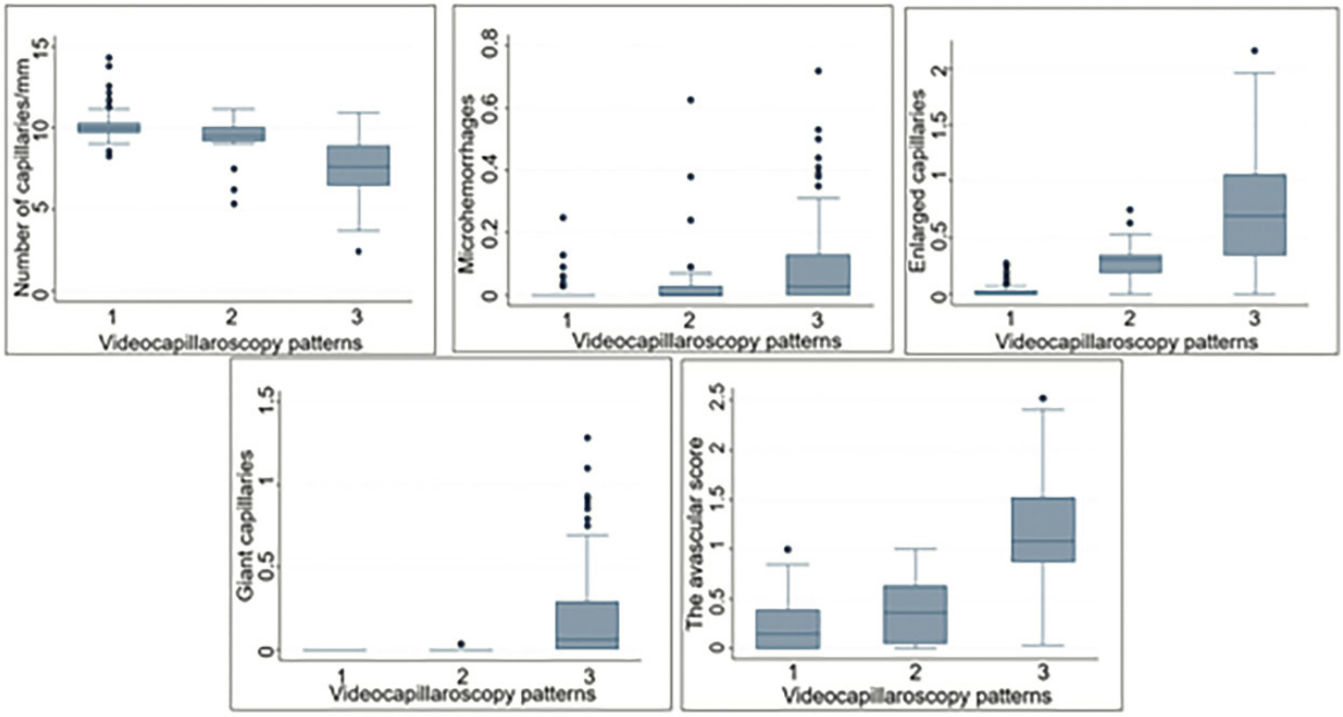

Fig. 2. Videocapillaroscopy parameters according to normal (1), non-specific microangiopathy (2) and SD pattern (3) patterns.

the curve (AUC) of 0.911 (p<0.0001, 95% CI 0.871–0.950) to discriminate the SD pattern from normal NVC and non-specific microangiopathy (Fig. 3A). Cut-off points for the number of capillaries/mm ≤3, ≤6 and ≤7 per mm are described in Table III.

According to the ROC curve analysis (Fig. 3B-E), a mean number of enlarged capillaries ≥0.31, the presence of giant capillaries, a mean number of microhaemorrhages ≥0.05 and an avascular score ≥ 0.5 were defined as the best cut-off points for identifying the SD pattern *versus* the non-SD pattern (Table III). ROC curve analysis for the avascular score revealed an AUC of 0.921 (p<0.0001, 95% CI 0.888–0.954) (Fig. 3B). For the presence of enlarged capillaries, the AUC was 0.929 (p<0.0001, 95% CI 0.817–0.906) (Fig. 3C), and for the presence of giant capillaries, the AUC was 0.827 (p=0.0001, 95% CI 0.780–0.875) (Fig. 3D). Analysis for the presence of giant capillaries displayed a sensitivity of 66.34% and high specificity (98.09%), with an accuracy of 85.66% (Table III). ROC curve analysis for the number of microhaemorrhages revealed the lowest AUC (AUC: 0.706; p<0.0001, 95% CI 0.648–0.764) (Fig. 3E).

The combination of two parameters (number of capillaries/mm and the presence of at least one giant capillary) presented greater sensitivity for a number of capillaries/mm ≤8 and/or the presence of one giant capillary, maintaining excellent specificity and better accuracy (91.08%) than the parameters evaluated individually (Table III). The accuracy of the combination of the number of capillaries/mm ≤7 and/or the presence of one giant capillary was also good (86.82%), with a sensitivity of 71.29% and a specificity of 96.81%.

ROC curve analyses for the combined parameter set (number of capillaries/mm and/or at least 1 giant capillary) are shown in Figure 3F. ROC curve analyses for the number of capillaries/mm ≤3 and/or at least 1 giant capillary had an AUC of 0.822 (p<0.0001, 95% CI 0.775–0.870), and those for the number of capillaries/mm ≤6 and/or at least 1 giant capillary had an AUC of 0.819 (p<0.0001, 95% CI 0.771–0.867). ROC curve analyses for the number of capillaries/mm ≤7 and/or at least 1 giant capillary showed AUCs of 0.841 (p<0.0001, 95% CI 0.794–0.887) and 0.900 (p<0.0001, 95% CI 0.861–0.939) for the combination of the number of capillaries/mm ≤8 and/or at least 1 giant capillary.

The test characteristics and ROC curve analysis for different video capillaroscopic parameters and the diagnosis of SSc *versus* controls and patients with primary RP are shown in Supplementary Table S1 and Supplementary Figure S1.

Discussion

NVC is a key technique for detecting microvascular changes in patients with RP and SSc. In our study, we evaluated the accuracy of multiple parameters, including capillary density (capillaries/mm), the presence of enlarged and giant capillaries, microhaemorrhages, and avascular score, with the aim of developing a simple and reproducible method to differentiate SD patterns from non-SD patterns using a real-life NVC database. Furthermore, we assessed for the first time the performance of the 'Fast Track' and 'CAPI-score' algorithms within our study population, excluding the presence of 'abnormal shapes' from the analysis. Moreover, different capillary density cut-offs were explored.

In our study, we achieved good accuracy using the combination of two parameters (number of capillaries/mm and the presence of giant capillaries)

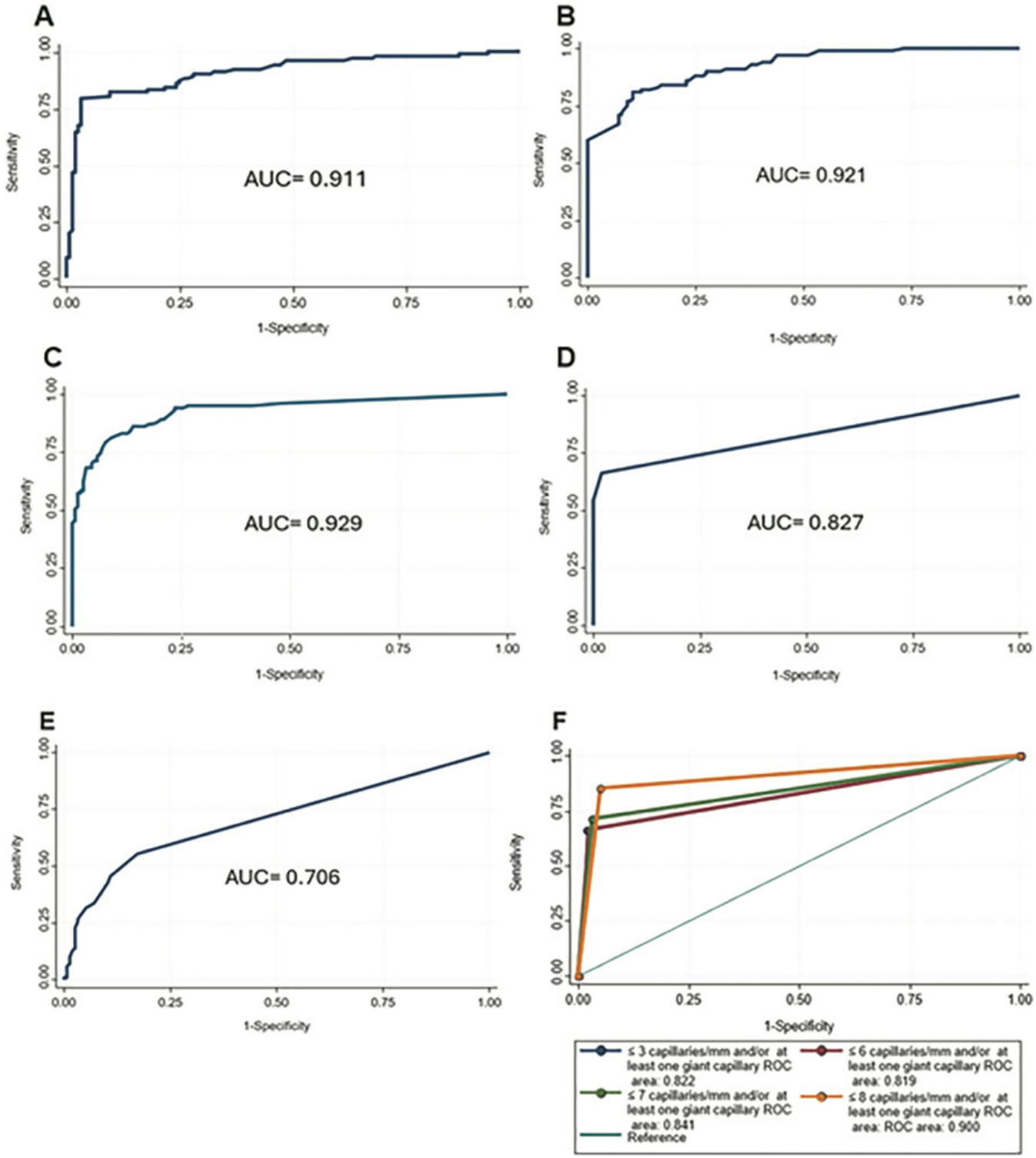

Fig. 3. Receiver operation characteristic (ROC) curve analysis of the diagnostic performance of individual and combined NVC parameters to identify the SD pattern *versus* non-SD pattern: number of capillary loops/mm (AUC = 0.911) (**A**); avascular score (AUC = 0.9219 (**B**); enlarged capillaries (AUC = 0.929) (**C**); presence of giant capillaries (AUC = 0.827) (**D**); microhaemorrhages (AUC = 0.706) (**E**); and the combination of number of capillaries ≤3, 6, 7, or 8/mm and/or giant capillaries (**F**); showing high performance in identifying the SD pattern.

for the identification of the SD pattern *versus* the non-SD pattern in NVC. These two parameters are also the basis of the Capillaroscopic Skin Ulcer Risk Index (CSURI), a validated score that predicts digital ulcers in SSc, reinforcing its clinical relevance (24).

The use of a higher cut-off point for the number of capillaries/mm allowed us to increase the sensitivity and accuracy of the algorithm without compromising its specificity. Despite the higher cut-off for the number of capillaries/mm, our findings are in line with the 2020 consensus, which considered the presence

Table III. Sensitivity, specificity, positive and negative predictive values and accuracy of videocapillaroscopy parameters for identifying SD *versus* non-SD pattern.

Capillary parameters	Cut-off point	Sensitivity (%)	Specificity (%)	PPV (%)	NPV (%)	A (%)
Number of capillaries/mm	≤ 3	1.00	100	100	61.09	61.24
	≤ 6	15.84	99.36	94.12	64.73	66.67
	≤ 7	32.67	98.73	94.29	69.51	72.87
	≤ 8	74.26	96.81	93.75	85.39	87.94
Microhaemorrhages	≥ 0.05	42.57	89.80	72.88	70.85	71.32
Enlarged capillaries	≥ 0.31	81.19	91.08	85.42	88.27	87.21
Giant capillaries	Presence	66.34	98.09	95.71	81.91	85.66
Avascular score	≥ 0.5	86.14	74.52	68.50	89.31	79.07
Number of capillaries/mm ≤ 3 and/or at least one giant capillary	-	66.34	98.09	95.71	81.91	85.66
Number of capillaries/mm ≤ 6 and/or at least one giant capillary	-	66.34	97.45	94.37	81.81	85.27
Number of capillaries/mm ≤ 7 and/or at least one giant capillary	-	71.29	96.81	93.51	83.98	86.82
Number of capillaries/mm ≤ 8 and/or at least one giant capillary	-	85.15	94.90	91.49	90.85	91.08

A: accuracy; NPV: negative predictive value; PPV: positive predictive value.

of giant capillaries or the combination of reduced capillary density with abnormally shaped capillaries, as specific to the scleroderma pattern (12).

The number of capillaries/mm is one of the main quantitative parameters analysed in nailfold capillaroscopy. The capillary density ranges from 7 to 12 capillaries per mm, with an average of 9.11 capillaries per mm in healthy individuals (25, 26). With that in mind, a mean number of ≥7 capillaries/mm was considered normal in the 2020 Consensus.

Consistent with previous studies (26, 27), in our study, healthy control individuals and patients with primary RP had a mean number of capillary loops ≥10 capillaries/mm. As expected, a lower number of capillaries was observed, particularly in patients with SSc who presented with the SD pattern. A lower capillary density was also found in patients with IIM who presented with the SD pattern (mean 2.44 capillaries/mm), although the number of patients evaluated was low. Similarly, Torres-Ruiz *et al*. demonstrated a high frequency of NVC abnormalities in a multi-ethnic cohort of patients with IIM. Moreover, capillaroscopic parameters improved following immunosuppressive treatment. These findings highlight the broader applicability of NVC beyond SSc and reinforce its role in the evaluation and monitoring of IIM (28).

In the Fast Track algorithm, a capillary density ≤3 capillaries/mm and abnormal shapes or the identification of giant capillaries allows the identification of an SD pattern (13). This algorithm was created to allow easy and reproducible identification of the SD pattern even by untrained rheumatologists. However, it may have low sensitivity for the diagnosis of SSc, since patients with early and active SD patterns have densities greater than 3 capillaries/mm (14). In our study, we observed that a number of capillaries ≤3 presented an extremely low sensitivity of 1.00%, despite a specificity of 100%. The presence of giant capillaries was associated with a higher sensitivity of 66.34%, with an accuracy of 85.66%. With the combination of the two parameters, the same sensitivity (66.34%) and accuracy (85.66%) were observed compared with the values obtained when the presence of giant capillaries was evaluated as an isolated parameter. This finding suggests that the presence of giant capillaries is the most useful and specific parameter for the identification of the scleroderma pattern. Our findings are also in line with the suggestion of the 2020 Consensus and with the Fast Track algorithm, in which the presence of giant capillaries is a specific parameter for the identification of the SD pattern (12, 13).

More recently, Gracia-Tello *et al*. presented another algorithm, the CAPI-score, a quantitative algorithm inspired by Fast Track, which uses automated analysis measurements of vessel morphology and density (15). The emergence of artificial intelligence has significantly transformed the medical landscape. This technology presents substantial potential for enhancing health care practices and patient outcomes. The following parameters were proposed to define an SD pattern: capillary density ≤6 capillary capillaries/mm and/or the presence of giant capillaries and/or proportions of abnormal capillaries >10%. As in our study, the algorithm proposed by Gracia-Tello *et al*. used a higher cut-off for the capillary density for identifying the SD pattern. Using the capillary density cut-off suggested by the CAPI-score, we observed high specificity but a sensitivity of 15.84% for the identification of the SD pattern in our cohort. However, the accuracy of the combination of the number of loops ≤6.0 and/or the presence of giant capillaries in our study was similar (85.27%) to that reported in the study by Gracia Tello *et al*., which was 88% (15).

While automated AI approaches such as the CAPI-score are promising and may increase the accessibility of NVC interpretation, they remain limited by technical complexity and cost. In this context, our simplified approach, based on easily assessed features such as capillary density and presence of giant capillaries, could be used as a basis for developing AI tools or even as a screening method prior to advanced automated analyses.

In our study, when a cut-off point of 7.0 was used, as proposed in the 2020 Consensus (12), the specificity was high, and the accuracy was 86.82%. The difference between the number of capillaries/mm ≤7 and ≤8 may be due to the method by which the number of capillaries per mm was counted in dif-

ferent centres. Therefore, we consider that the cut-off point of the number of loops ≤7.0, associated with the presence of at least one giant capillary, can also be used as a good cut-off point for identifying the SD pattern.

We did not evaluate the presence of "abnormal capillaries" as used in the CAPI-score and as suggested in the 2020 Consensus. Since we evaluated exams collected from 2012 to 2022, this parameter was not recorded in our database. Furthermore, we proposed the analysis of simple parameters to discriminate between the SD pattern and non-SD pattern, and it is known that loops considered abnormal, such as bushy loops or those with neoangiogenesis, require greater expertise in their identification and have been reported to have low reliability (26, 29).

Other parameters, such as the number of enlarged capillaries and avascular score, also showed good accuracy for the identification of the SD pattern in our study. However, these parameters have lower specificity, and enlarged capillaries are considered non-specific alterations by many authors (12). In addition, the number of microhaemorrhages presented low accuracy, suggesting that it is not a good parameter for the identification of the SD pattern.

An advantage of our study is that we observed patient diagnosis and compared patients with SSc with patients with primary RP and healthy controls. As expected, no participants in the healthy control and primary RP groups had an SD pattern. The number of capillaries/mm ≤8 and/or at least 1 giant capillary also presented the highest accuracy for the identification of patients with SSc *versus* those with primary RP and healthy controls.

Our study has several limitations. This was a single-centre study with retrospective data. Despite the advantages of a large sample, it is crucial to consider the need for validation of these findings in different populations to ensure their generalisability.

In conclusion, our results highlight the importance of combining capillaroscopic parameters in NVC for defining patterns associated with scleroderma, which may guide future clinical guidelines. The cut-off points of ≤3 capillaries/mm (as proposed by the FAST Track algorithm) and ≤6 capillaries/mm (as proposed by the CAPI-score), presented low sensitivity despite high specificity for the identification of the SD pattern. The mean number of capillaries/mm ≤8 or ≤7 presented higher sensitivity and specificity for the identification of the SD pattern in our cohort. Finally, we propose a simple algorithm approach that combines only two capillaroscopy parameters (giant capillaries and number of capillaries/mm) to define the SD pattern *versus* the non-SD pattern in patients with RP and SSc. This might simplify and increase the use of NVC in clinical practice, allowing early diagnosis of SSc.

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