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RESEARCH ARTICLE

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Coincidence between the distribution of myofascial trigger points and the presence of blood vessels in the gastrocnemius muscle: Implications for invasive procedures

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Abstract

Purpose: The gastrocnemius venous system presents different anatomical variants. There have been described four locations of myofascial trigger points (MTrPs) in this muscle. However, no studies have analyzed the coincidence between vessels and MTrPs present in the gastrocnemius. Therefore, the main objective was to study the anatomical variability of the venous system by ultrasound and its coincidence with the location of the MTrPs.

Methods: A total of 100 lower limbs were studied. The gastrocnemius vessels were analyzed one by one by sector (medial, central, and lateral), quantifying the number of vessels, their distribution, and the coincidence with MTrPs.

Results: All muscle heads showed at least one vessel per section. A large variability was observed, from one to eight vessels per muscle head, with the most frequent number being three in the gastrocnemius medialis and two in the gastrocnemius lateralis. In all cases, the location of the vessels coincided with the MTrPs.

Conclusions: The proximal gastrocnemius venous pattern is very variable between subjects in number of vessels and distribution, which has made it impossible to define a "safe" approach window for invasive procedures without ultrasound guidance. The coincidence between the clinical location of MTrPs of the gastrocnemius and the presence of vessels is total.

KEYWORDS

anatomical variations, gastrocnemius muscle, gastrocnemius vessels, myofascial trigger points, ultrasound

1 | INTRODUCTION

The anatomical area of the gastrocnemius muscle is characterized by the presence of multiple vessels, belonging to three different systems: the superficial, the deep, and the perforating. The superficial system is formed by the superficial veins and the tissue between the skin and the muscular fascia (Figure 1). The deep system is made up of the structures beneath the investing fascia, such as the muscles and deep veins (Figure 2).[1–3] The perforating system is made up of those veins that pass through the muscle fascia and communicate the flow from the superficial system to the deep system.[1,2]

On the one hand, the superficial veins are the great saphenous vein or magna and the lesser saphenous vein or parva. Occasionally the latter may be duplicated or triplicated with veins of different lengths found within the same compartment.[1,2] On the other hand, the deep veins are the popliteal, tibial (anterior and posterior), peroneal and intramuscular veins. The intramuscular gastrocnemius veins, especially those of the gastrocnemius medialis, are pedicles of longitudinal veins that appear as a continuation of the perforating veins in the lower part of the muscle and converge proximally in a single collector that ends in the popliteal vein.[4] The medial veins are the longest and have two to four pedicles of one or two veins.[4]

The intramuscular venous plexus in the gastrocnemius muscle comprises 2–12 veins draining each head of the gastrocnemius and forming a characteristic pattern of termination. 87% of these drain into the popliteal vein, while the other 13% drain into the posterior tibial vein or peroneal vein.[5,6] There are several anatomical variants of the gastrocnemius veins, which have been classified into four types: (1) veins that emerge from both heads converging into a venous trunk that continues into the main trunk of the gastrocnemius (Figure 3A); (2) veins emerging from the heads, draining into collateral trunks, converging into a venous trunk and terminating in the main trunk of the gastrocnemius (Figure 3B); (3) veins emerging from the medial and lateral heads and converging directly into the main trunk of the gastrocnemius (Figure 3C); (4) veins emerging from both heads without convergence to either the trunks of the gastrocnemius (Figure 3D).[5]

Myofascial pain syndrome (MPS) is a collection of motor, sensory, and autonomic signs and symptoms provoked by myofascial trigger points (MTrPs). These have been defined as hyperirritable areas within a musculoskeletal taut band and can cause referred pain.[7–11] There have been described four different MTrPs areas in the gastrocnemius.[12] Different invasive physical therapy procedures such as dry

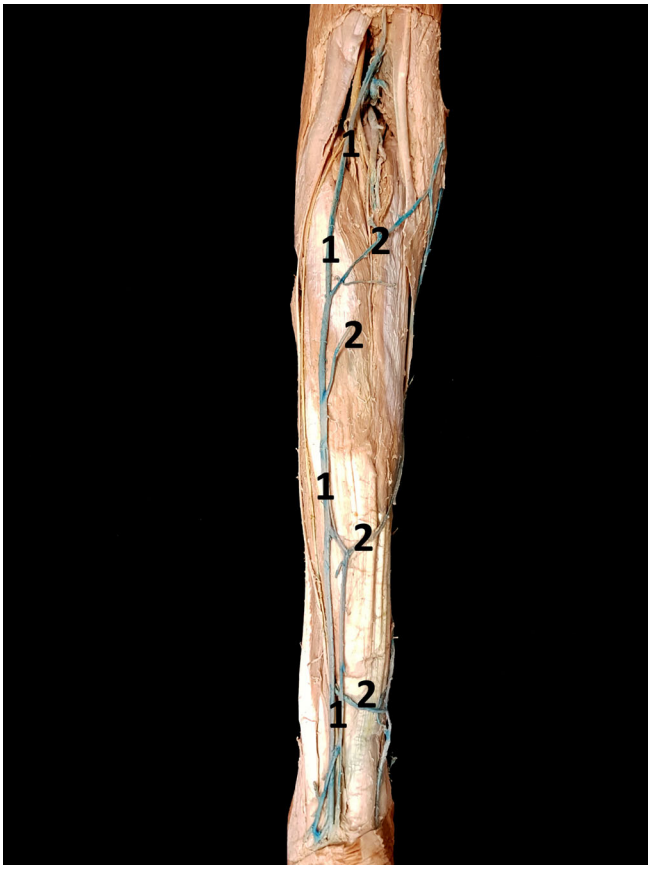

FIGURE 1 Dissection of a sural region, from a left lower limb, showing the trajectory of the small saphenous vein (labeled with "1") and several veins of the communicating system (labeled with "2").

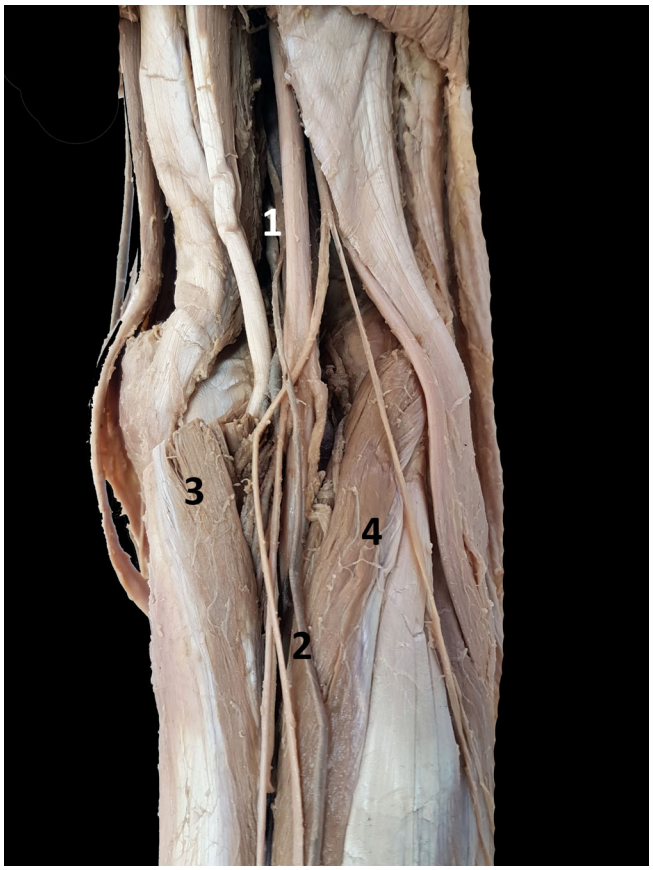

FIGURE 2 Dissection of the popliteal region showing the subfascial plane. The popliteal vein (labeled with "1") is shown, and part of the length of the small saphenous vein (labeled with "2"). The proximal gastrocnemius medialis ("3") and lateralis ("4") have also been labeled.

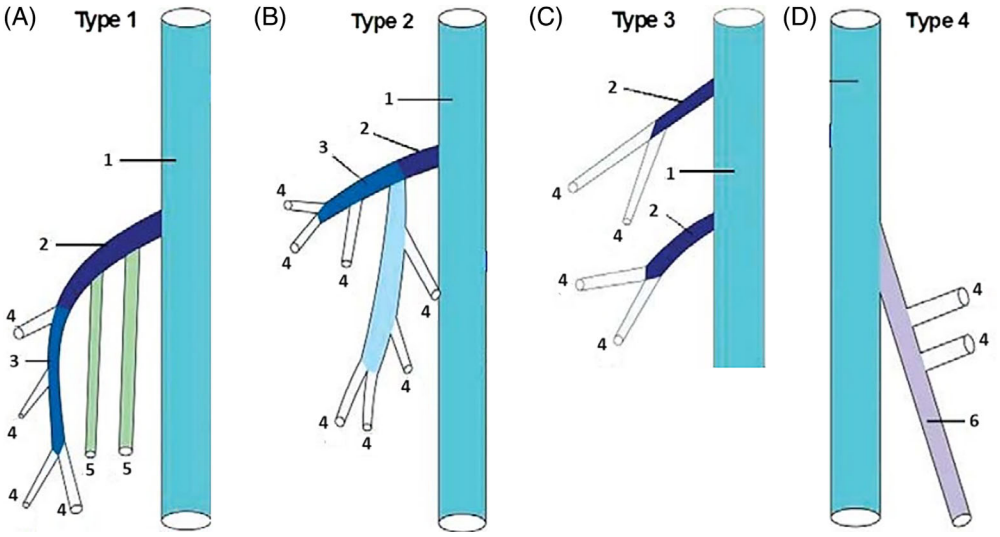

FIGURE 3 Types of gastrocnemius venous network proposed by Aragao et al. in 2006[5] and modified from it. (A) (Type 1): popliteal vein (1) receives one main gastrocnemius trunk (2), continuation of the axial gastrocnemius venous trunk (3) draining gastrocnemius veins (4) and eventually soleal veins (5); (B) (Type 2): popliteal vein (1) receives one main gastrocnemius trunk (2) formed by the confluence of two axial gastrocnemius veins (3) draining gastrocnemius veins (4); (C) (Type 3): independent gastrocnemius trunks (2) receive gastrocnemius veins (4); and (D) (Type 4): collateral gastrocnemius venous trunk (6) drains gastrocnemius veins (4).

needling are being increasingly used to treat MTrPs. These techniques use solid, non-beveled needles to reach the MTrPs and provoke a mechanical disruption of the dysfunctional motor endplates,[13] decreasing or making disappear the abnormal electrical activity characteristic of MTrPs.[14,15]

Dry needling of the gastrocnemius muscle has traditionally been performed without ultrasound guidance despite it is known that there is a risk of reaching a blood vessel and that this may increase post-needling pain. However, to our knowledge, there are no previous studies that have analyzed the coincidence of blood vessels with the different areas where MTrPs are located in the gastrocnemius muscle. Therefore, the main objective of this study was to perform an ultrasonographic description of the venous pattern of the gastrocnemius muscle belly and analyze the coincidence of its distribution with the MTrPs described for this muscle at a proximal level. The secondary objective was to analyze if it is possible to define a "safe" approach window on gastrocnemius.

2 | MATERIALS AND METHODS

2.1 | Study design

A descriptive observational study was carried out on the vascular anatomical variability present in the gastrocnemius muscle at a proximal level and its coincidence with the location of the MTrPs described at this level.

Subjects were selected using a non-probability sampling approach at Sannus Clinic (Madrid, Spain). All the procedures were applied following the Declaration of Helsinki and informed consent was obtained from the participants in the study.

2.2 | Participants

The two lower limbs of 50 participants were analyzed, resulting in a total sample of 100 lower limbs. This sample was made up of 26 men and 24 women with an age of 40.84 ± 8.86 years, who participated voluntarily in the present study after signing an informed consent. Participants with lower limb vascular pathologies and/or surgeries, a history of muscle tears, and acute/subacute phases of a muscle injury were excluded.

2.3 | Material

A LOGIQ S7® and S8® from General Electric ultrasound device was used for ultrasonographic assessments. An ML6-15 linear probe, with a 4.5–15 MHz frequency range was used, with two foci, including the structure to be analyzed between them. Depth was set up at 4 cm and each image was optimized for each subject, adjusting the gain and the frequency to obtain the best possible image.

2.4 | Procedure and data collection

To carry out the ultrasound study, the patients were placed in a prone position, with the ankle in a resting position. A rolled towel was placed under their feet to make a slight knee flexion and remove tension from the muscles. Once the patient was positioned, the evaluator proceeded to locate the area to be assessed. Since the MTrPs established by Travell and Simons[12] at the proximal part of gastrocnemius are described at the same height in similar areas of each muscle head, it was decided to take the same distance to both. The line of the

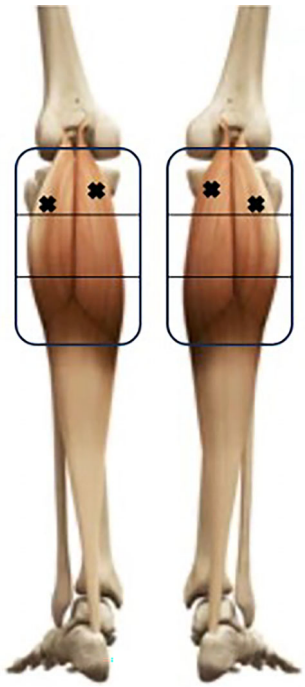

FIGURE 4 Area of the MTrPs in the proximal part of the gastrocnemius medialis and lateralis described by Travell and Simons.

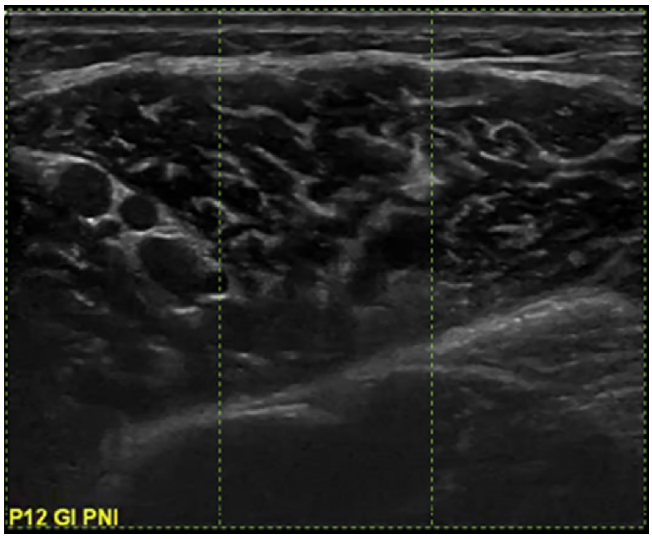

FIGURE 5 Division of the ultrasound image of the gastrocnemius in transverse cut into three equal parts (medial, central, and lateral) for descriptive purposes.

popliteal fossa was taken as a reference and distally the study points were marked 8 cm from it, one in the medial head and another in the lateral one (Figure 4).

The way of obtaining images was protocolized to minimize errors. The protocol consisted of placing the probe notch always directed to the right of the patient in the transverse cut, and cranial in the longitudinal cut. Assessments always started with the gastrocnemius medialis and were followed with the gastrocnemius lateralis of the right lower limb first and after with this same sequence in the left lower limb. Before starting the evaluation of each area, it was written in the lower left corner of the image the following code: patient number, gastrocnemius medialis or lateralis, right or left lower limb. The ultrasound study was done in transverse cut to facilitate the counting of vessels. Power Doppler mode with PRF 1.0 and Gain 18.0 preset was used to visualize the vessels. Some images were also made in longitudinal cut randomly to be able to show the vessel caliber, number, and possible ramifications.

For the image analysis, each muscle head was divided into three equal parts as shown in Figure 5, with the first one being the most medial part of the muscle with respect to the midline of the lower limb, and the third one being the most lateral part, so the measurements will be inverse depending on the head to be analyzed. This partitioning into three proportions was intended to enumerate the number of vessels that appear per muscle section and to be able to establish a more accurate percentage. All vessels present in each area were counted without distinguishing between major or minor vessels, as all vessels are susceptible to pain, bleeding, and hematoma.

3 | RESULTS

A total of 50 subjects participated, of which 52% were men ($n = 26$) and 48% were women ($n = 24$). The mean age was 40.84 years with a standard deviation of 8.86 years, with a range of 22 to 56 years. The analysis of the 100 lower limbs showed that all the muscle heads had at least one vessel in all of the sections analyzed, coinciding with the territory of the clinical location of the MTrPs for the gastrocnemius at the proximal level (see Supplementary Material – Table S1).

In the differentiated analysis by muscle head (gastrocnemius medialis or lateralis), it was observed that each lower limb had a variability between one and eight vessels per section, with between three and four being the most common number of vessels in the gastrocnemius medialis and between two and three in the gastrocnemius lateralis. The number of vessels in the different thirds of the gastrocnemius medialis and lateralis of both lower limbs represented in percentage is described in Table 1 and the results for each of the 50 participants in Supplementary Material – Table S2.

The longitudinal cuts performed demonstrated the great variability of the venous pathway, even in both lower limbs of the same participant, as shown in Figure 6A–D. Likewise, the captured vessels presented different caliber, disposition (more superficial or deeper), numbers and ramifications, as shown in four different patients (Figure 7A–D). This great variability of vessels analyzed in 100 lower limbs of 50 participants impedes the definition of a "safe" window approach, free of vessels, in the area where MTrPs are located in the gastrocnemius medialis and lateralis.

TABLE 1 Number of vessels represented as a percentage in each of the thirds (medial, central, or lateral) of the gastrocnemius medialis and lateralis.

	Gastrocnemius medialis			Gastrocnemius lateralis		
Number of vessels	Medial third	Central third	Lateral third	Medial third	Central third	Lateral third
1	2%	1%	1%	7%	8%	30%
2	26%	8%	17%	39%	22%	42%
3	33%	21%	34%	26%	41%	21%
4	23%	32%	24%	16%	17%	1%
5	5%	22%	15%	10%	9%	4%
6	8%	9%	5%	2%	1%	2%
7	2%	4%	1%	–	–	–
8	1%	3%	3%	–	2%	–

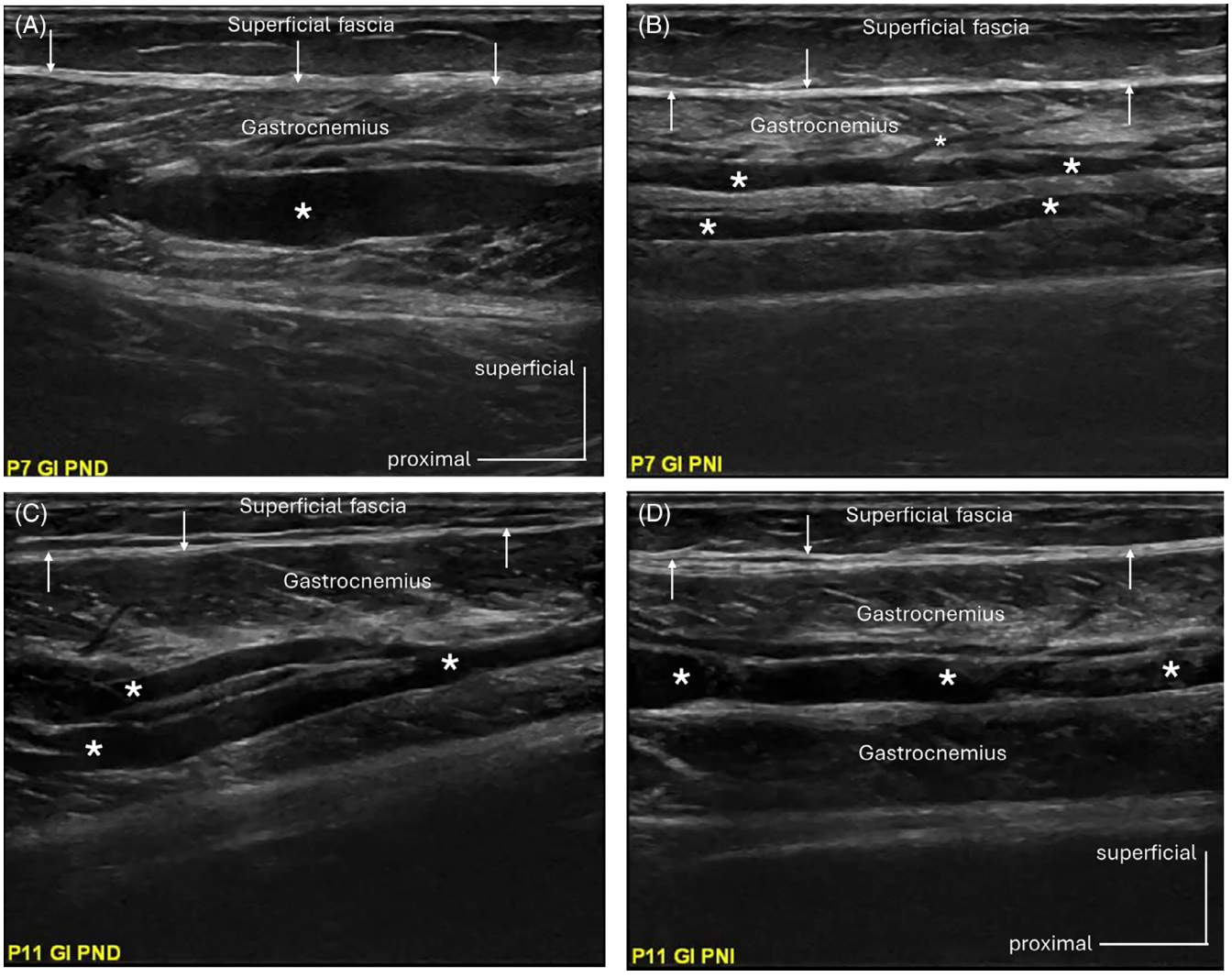

FIGURE 6 (A–D) Ultrasound images in longitudinal cut and sagittal plane of the gastrocnemius medialis. From the surface to deep can be observed the superficial fascia, the investing fascia (white arrows), the gastrocnemius and the soleus. Asterisks label some vessels in the depth of the gastrocnemius. The images on the left (A, C) represent the right lower limb whereas the images on the right (B, D) represent the left lower limb. Images in the same line correspond to the same participant (see the number of the patients included in the image, P7 and P11). Differences can be observed between both sides for the same participants and between the same side for different participants, both for the number, shape and distribution of vessels in each of the muscle bellies.

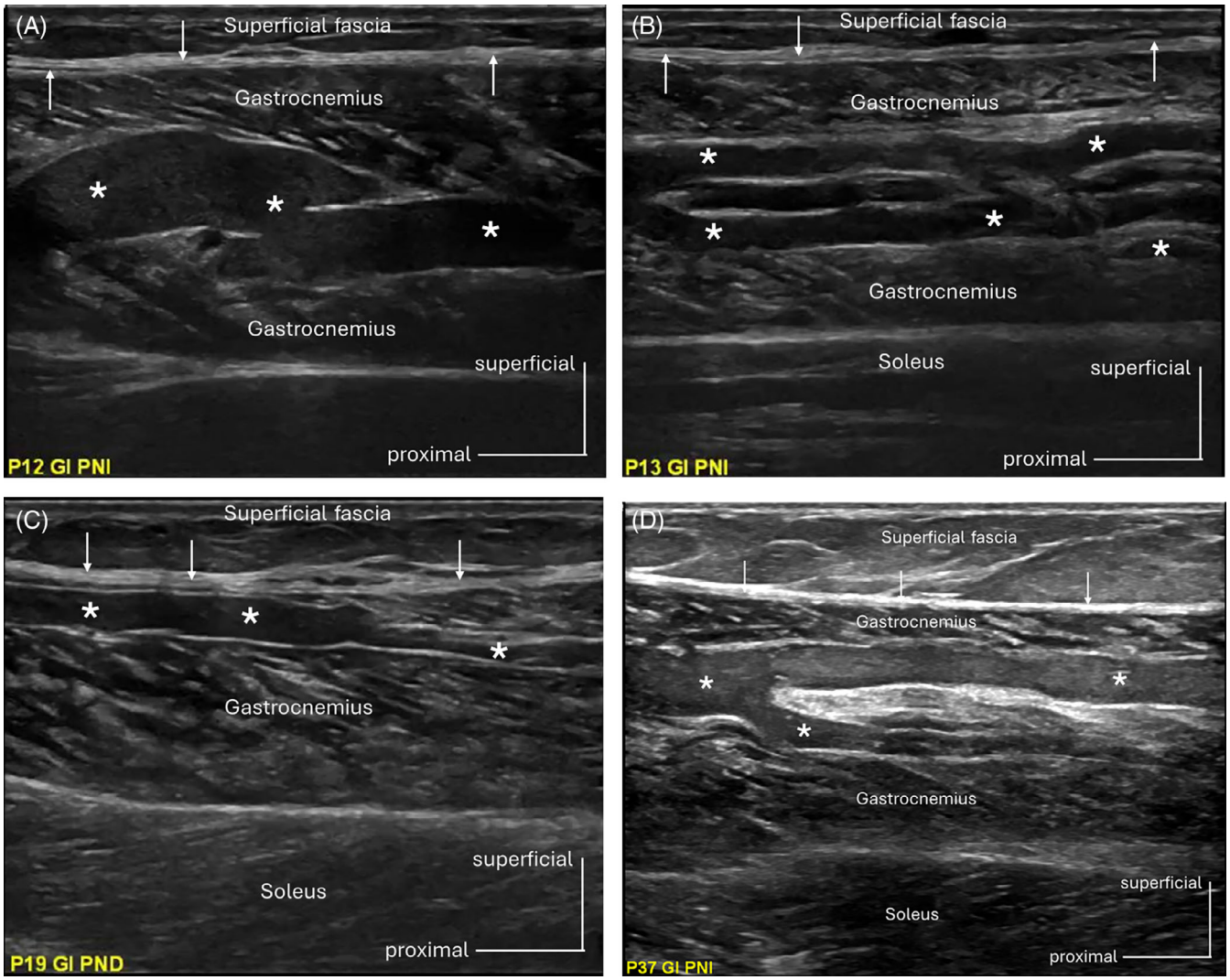

FIGURE 7 (A–D) This set of four ultrasound images illustrates the variability observed among four different patients (P12, P13, P19, and P37) in similar longitudinal cuts and sagittal plane of the gastrocnemius medialis of each of them. From the surface to deep can be observed the superficial fascia, the investing fascia (white arrows), the gastrocnemius and the soleus. Asterisks label some vessels in the depth of the gastrocnemius. Diversity in the depth where the vessels are located, the branching patterns, and their caliber can be appreciated.

4 | DISCUSSION

To date, we have found no studies that have analyzed the coincidence of blood vessels with the needling area of MTrPs of the gastrocnemius muscle. The present study shows that the gastrocnemius is a highly vascularized structure with great variability in the venous pattern. All participants had vessels along the entire transverse area of the cut performed by ultrasound, and all of them coincided with the clinical location of the MTrPs of this muscle at the proximal level described by Travell and Simons.[12] Given that great variability prevents defining a vascular design of the gastrocnemius, performing ultrasound-guided dry needling is recommended in this area to avoid needling vessels and provoking adverse effects such as hematoma.

The current anatomical literature describes four patterns,[5,6] with two of them being the more frequent ones. However, after performing the ultrasound evaluation, the observed variability in the number and distribution of blood vessels in the overlapping area of the MTrPs of the gastrocnemius muscle precludes the determination of a pattern and therefore a "safe" approach window with anatomical references and manual guidance that can be used in the clinical practice. The ultrasound study carried out has shown the tortuosity of the calf vessels and the frequent presence of smaller vessels around the main one, which can easily be crossed during needling if attention is not paid, even with ultrasound guidance. In this regard, there is described a methodology of application of dry needling with ultrasound guidance to ensure the safety and effectiveness of the procedure.[11]

There is currently a growing interest in the analysis of adverse effects found after the application of different invasive techniques. In the case of dry needling, the study by Brady et al.[16] reported a 19.8% rate of adverse effects, the most common being hematoma (7.55%), bleeding (4.65%), pain during treatment (3.01%) and post-treatment pain (2.19%). However, these adverse effects have not been

differentiated by muscle despite that in clinical practice it is observed that dry needling of the gastrocnemius muscle tends to be more painful and that post-needling pain is usually higher than in other muscles, which could be associated with an increased number of hematomas in this area after dry needling.

Although the prevalence of adverse effects in this area is possibly higher than in other body regions because of the high number of blood vessels and the great variability found, it is also important to highlight that dry needling and similar needling procedures such as acupuncture have been performed in this region for many years, guided only by manual palpation and without provoking significant adverse effects. This supports dry needling as a safe technique, also in patients taking antithrombotic drugs, due to the needle's characteristics, since they have a small caliber (from 0.16 to 0.32 mm) and are solid, and non-beveled.[17] The present study has at least managed to establish a possible vascular justification for these adverse effects.

The main strength of the study is the detailed analysis of the number and distribution of blood vessels with ultrasonography which shows the presence of at least one vessel in all the muscle sections analyzed as well as a high variability not only among the participants but also between the two sides in the same participant. While this study has primarily examined dry needling as a prevalent technique for treating MTrPs, it's important to acknowledge that the findings may apply to other invasive procedures such as injections, acupuncture, percutaneous needle electrolysis, and percutaneous needle neuromodulation. This is because the associated risks and precautions are similar across these interventions. However, some limitations must be considered when interpreting the results obtained. First, the main one is that an analysis of inter-examiner reliability in the identification of blood vessels has not been conducted, although the images were analyzed by a single evaluator. On the other hand, the current sample may be somewhat limited, and it would be interesting that future studies also perform an analysis by sex and side. Moreover, the great variability and the impossibility of finding a vascular pattern cannot be translated to other regions, since each body region may have its characteristics. The ultrasound images were all collected with the ankle in a resting position to ensure that blood vessels were visualized correctly since muscle tension could potentially affect the visualization of blood vessels, as reported by previous studies.[18] Furthermore, the caliber of all the vessels observed has not been statistically analyzed either, which could be a determining factor in the degree of hematoma and bleeding caused. Therefore, for future research all these aspects must be considered, as well as new studies comparing the rates of adverse effects depending on the area needled, and whether these can be minimized with ultrasound-guided intervention.

5 | CONCLUSIONS

The proximal gastrocnemius venous pattern is highly variable between subjects in terms of the number of vessels and their distribution, as well as in the same subjects for each side, which makes it impossible to define a "safe" approach window for invasive procedures with manual guidance. All participants presented blood vessels in the territory where MTrPs of the gastrocnemius muscle are located and therefore in case the risk of hematoma needs to be decreased, it is recommended that any invasive procedure in the gastrocnemius area is performed with ultrasound guidance.

AUTHOR CONTRIBUTIONS

Conceptualization and preregistration, Patricia Velasco-Fernández, Fermín Valera-Garrido; methodology, Patricia Velasco-Fernández, Francisco J. Valderrama-Canales, Fermín Valera-Garrido; writing—original draft preparation, Patricia Velasco-Fernández, Fermín Valera-Garrido, Francisco Minaya-Muñoz, Diego Lapuente-Hernández, Pablo Herrero; writing—review and editing, Patricia Velasco-Fernández, Francisco J. Valderrama-Canales, Fermín Valera-Garrido, Francisco Minaya-Muñoz, Diego Lapuente-Hernández, Pablo Herrero; supervision, Francisco J. Valderrama-Canales, Fermín Valera-Garrido. All authors discussed the outcomes and contributed to the final version of the manuscript. All authors have read and agreed to the published version of the manuscript.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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