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The role of ultrasonography in the diagnosis of persistent sciatic artery

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AIM: To investigate the accuracy of ultrasonography in the diagnosis of persistent sciatic artery (PSA) compared to computed tomography angiography (CTA).

MATERIALS AND METHODS: From May 2002 to Dec 2018, 61 consecutive patients seen at Shandong Medical Imaging Research Institute with a clinical suspicion of PSA were included. Ultrasonography was used to assess the abdominal and lower-limb arteries. The main sonographic criteria for a positive diagnosis were the visualisation of PSA, the enlarged internal iliac artery, and abnormality of common femoral artery and superficial femoral artery. These data were compared with CTA findings. Kappa statistics was applied to determine the level of agreement. The sensitivity, specificity, positive and negative predictive values, accuracy, and Youden index of ultrasonography as a diagnostic method were assessed.

RESULTS: Ultrasonography findings were positive in 16 of 61 patients with a clinical suspicion of PSA. The diagnosis was confirmed by CTA in 17 patients. There was one false-positive result and two false-negative results at ultrasonography. The kappa value was 0.875. The sensitivity, specificity, positive and negative predictive values, accuracy, and Youden index of ultrasonography were 88.2%, 97.7%, 93.8%, 95.6%, 95.1% and 0.859, respectively.

CONCLUSIONS: Ultrasonography could be a reliable, accurate, and non-invasive diagnostic imaging method in the diagnosis of patients with suspected PSA.

Introduction

Persistent sciatic artery (PSA) is a rare congenital arterial malformation. PSA was first reported in 1832 when Green discovered its existence at autopsy.[1] In early stage of embryonic development, the sciatic artery is a continuation of the internal iliac artery and functions as the major vessel supplying the lower-limb bud when the embryo develops to about 6 mm. As the fetus develops, the femoral artery system develops when the embryo reaches 12 mm. After the 22 mm embryo stage, most of the sciatic artery involutes to disappear and the femoral artery system usually develops into major arteries, making connection with the popliteal artery, and functions as the dominant inflow source to lower extremity.[2,3] If there is failure of regression of the

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sciatic artery or failure in development of the femoral artery system, the sciatic artery may persist as a dominant artery and function as the major supply to lower extremity, which is called PSA. Its clinical incidence is about 0.025–0.04%.[4] The literature on its imaging diagnosis are mostly case-based and focused on computed tomography angiography (CTA) or digital subtraction angiography (DSA) examination.[5,6] High-frequency ultrasonography diagnosis has seldom been performed according to the literature. Ultrasonography is a non-invasive diagnostic method and its reliability of blood vessels examination is generally accepted. The objective of the present study was to investigate the accuracy of ultrasonography in the diagnosis of PSA compared to CTA, which is the established standard for diagnosis of PSA.

Materials and methods

Between May 2002 and Dec 2018, 61 consecutive patients (29 males and 32 females; age range: 1.6–75 years; mean age: 54.88±17.32 years) seen at Shandong Medical Imaging Research Institute with a clinical suspicion of PSA were included. The study protocol was approved by the ethics committee of the hospital and all methods were performed in accordance with the relevant guidelines and regulations. All patients enrolled in the study submitted informed consent for participation. Of the 61 cases, 49 patients presented suspected symptoms of the PSA, including pulsating sense behind the buttocks or in the popliteal fossa, rest pain, hypertrophy of the soft tissue, lower extremity swelling with claudication and neurological problems; 12 patients (transfer treatment patients) were asymptomatic and were suspected to have abnormalities of the common femoral artery or the superficial femoral artery, which were thinner than the contralateral artery when undergoing health examination in county hospitals.

All patients underwent high-frequency ultrasonography and CTA.

The GE Vivid 7, GE Vivid 7 dimension, Philips i.e. 33, Philips EPIQ 5, Philips EPIQ 7 ultrasound systems were used in ultrasonography examination. A 9–14 MHz broadband linear array probe was used for lower extremity examination, while a 3.5 MHz convex array probe was used for abdominal vascular examination. First, the linear array probe was used on the surface of lower extremity. The scanning range was from the level of the groin to the level of the ankle. Continuous scanning was performed on the common femoral artery, superficial femoral artery, deep femoral artery, and popliteal artery in order to focus on the diameter, location, and continuity of the vessels. Secondly, the convex array probe was used for abdominal vascular examination. The scanning range was from the level of the abdominal aorta to the level of the groin. Continuous scanning was performed on the abdominal aorta, common iliac artery, external iliac artery, and internal iliac artery with a focus on the diameter, location, continuity, and course of the vessels. If necessary, the prone position should be used to detect hip arterial lesions.

Comparison scanning was performed on the contralateral lower extremity as control. The main sonographic criteria for a positive diagnosis were the visualisation of PSA, the enlarged internal iliac artery, and abnormality of common femoral artery and superficial femoral artery. When arterial lesions were found, the range of lesions was determined precisely.

Patients were checked for any previous contrast medium allergy, and if absent, 100 ml contrast medium was injected into the antecubital vein at 4 ml/s using a high-pressure injector when undergoing CTA examination. The concentration of contrast medium was 350 mg iodine/ml. The bolus tracking method was used with a region of interest (ROI) on the abdominal aorta. The scan was initiated with a 7-second delay from when the ROI reached $>$120 HU. The scanning range was from the abdominal aorta to the dorsalis pedis artery. The imaging parameters were 120 kV tube voltage, 130 mAs tube current, 0.8 pitch, 0.6 mm collimation, 1 mm section thickness, and a 0.7 mm reconstruction interval. The diameter, location, continuity, and course of the vessels were evaluated via three-dimensional (3D) reconstruction, including multiplane reorganisation, maximum density projection, and volume rendering.

All the ultrasound examinations were performed by an experienced cardiovascular ultrasound expert with $>$9 years of experience in cardiovascular ultrasound. All CTA examinations were performed by a senior vascular technician, who had 8 years of experience in CTA.

Ultrasonography and CTA images of the cases in the PACS system were all assessed by two cardiovascular radiologists independently, with $>$10 years of imaging diagnostic experience in interpreting ultrasound and CTA examination results. Reference to the original imaging reports was shielded to avoid bias.

The SPSS program (version 22.0; SPSS, Chicago, IL, USA) was used for statistical analysis. The level of agreement between ultrasonography and CTA was determined by the kappa test. The sensitivity, specificity, positive and negative predictive values, accuracy, and Youden index of ultrasonography were obtained.

Results

Of the 61 patients with a clinical suspicion of PSA, CTA was positive for PSA in 17 patients and negative results in 44 patients. There were 13 patients with unilateral and four patients bilateral involvement. Ultrasonography diagnosis was positive in 16 and negative in 45 patients, with 12 patients having unilateral lower extremity involvement (Fig 1), and four patients having bilateral involvement (Fig 2). Compared to CTA, there was one false-positive result and two false-negative results using ultrasonography. Detailed ultrasonography findings in each patient are shown in Table 1. CTA and ultrasonography comparison results are shown in Table 2.

All patients with a negative ultrasonography diagnosis presented negative findings on CTA except two patients with by pelvic bowel gas or obstruction by the pubis, for

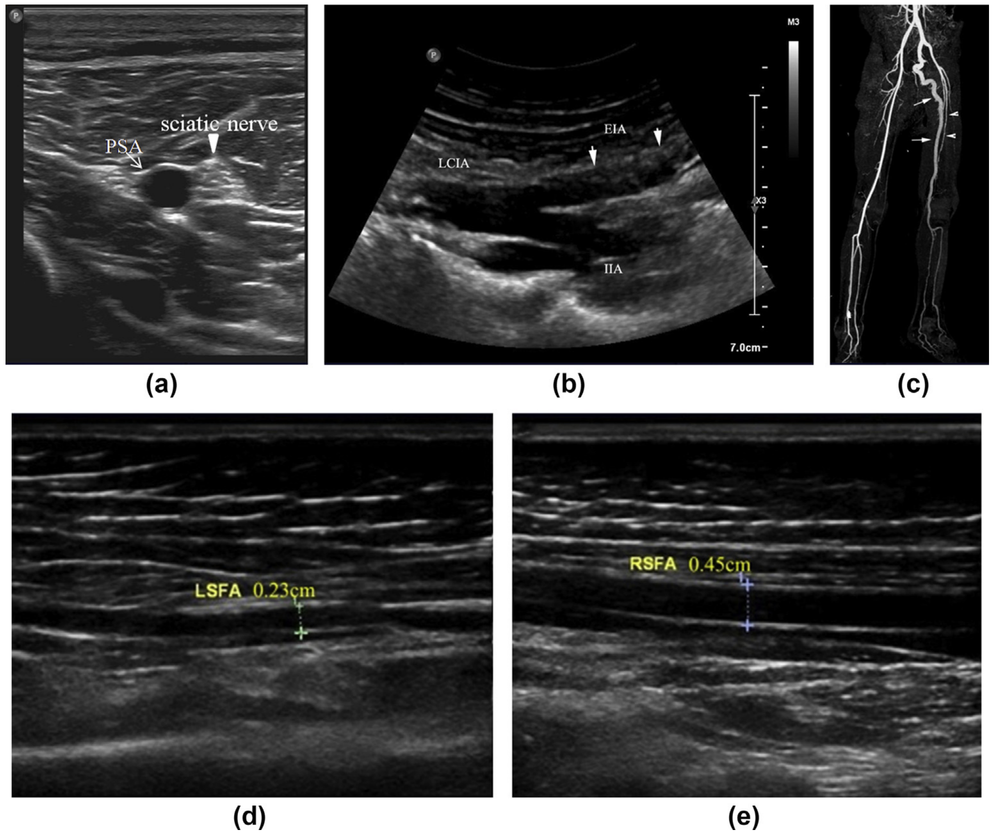

Figure 1 A 1.6-year-old female patient with PSA. (a) The ultrasound image shows the sciatic nerve (arrow head) accompanied by the PSA (arrow) in axial view. (b) The ultrasound image reveals that the left internal iliac artery of the affected limb was significantly enlarged. (c) CTA confirms the course of the PSA from the internal iliac artery to the popliteal artery. (d,e) The left superficial femoral artery was thinner than the contralateral superficial femoral artery.

whom ultrasonography did not display the initial part of the PSA clearly because the sound beam could not penetrate; PSA was confirmed at CTA in these patients. One patient (no. 6 in Table 1) with a positive PSA diagnosis at ultrasonography was proved to have a normal inferior gluteal artery, not PSA, at CTA.

Analysis of internal validity parameters of ultrasonography as a diagnostic test for PSA showed a sensitivity of 88.2%, specificity of 97.7%, a positive predictive value of 93.8%, and a negative predictive value of 95.6%. The overall accuracy was 95.1%. The Youden index of ultrasonography was 0.859. The κ level of agreement between CTA and ultrasonography for PSA was 0.875 (high level; Table 3).

Discussion

In normal circumstances, the abdominal aorta branches into the common iliac arteries at the level of the fourth lumbar vertebra. The common iliac artery is divided into the internal iliac artery and external iliac artery at the level of the lumbosacral joint, and the external iliac artery continues to be the common femoral artery at the level of the inguinal ligament. Then the common femoral artery branches into the superficial femoral artery and deep femoral artery, and the superficial femoral artery continues to be the popliteal artery. Ultrasonography of PSA showed that the internal iliac artery of the affected limb was significantly enlarged, and a large branch could be seen starting from the internal iliac artery and running through the greater sciatic foramen, where its course was close to sciatic nerve. Most of the persistent sciatic arteries continued down to the popliteal artery. Meanwhile, the common femoral artery and the superficial femoral artery were found to be slender.

The PSA is classified into four types by Pillet according to the course of PSA, the sequential relationship, and the development of the common femoral artery and superficial femoral artery[7,8]: in type I, a complete PSA is present in combination with a normal femoral artery; type II represents a complete PSA in combination with an incompletely developed femoral artery, and in subtype IIa, the superficial femoral artery is present, but does not continue down to the popliteal artery, while in subtype IIb the superficial femoral artery is absent; in type III, an incomplete PSA is present, in which only the upper part persists and the femoral artery develops normally; and type IV represents an incomplete PSA in which only the lower part persists with a normal femoral artery. In the present study, two cases were type I, 14 cases were type II, one case was type III, no case of type IV was found, and type II was the most common. This suggests that when the common femoral artery and the superficial

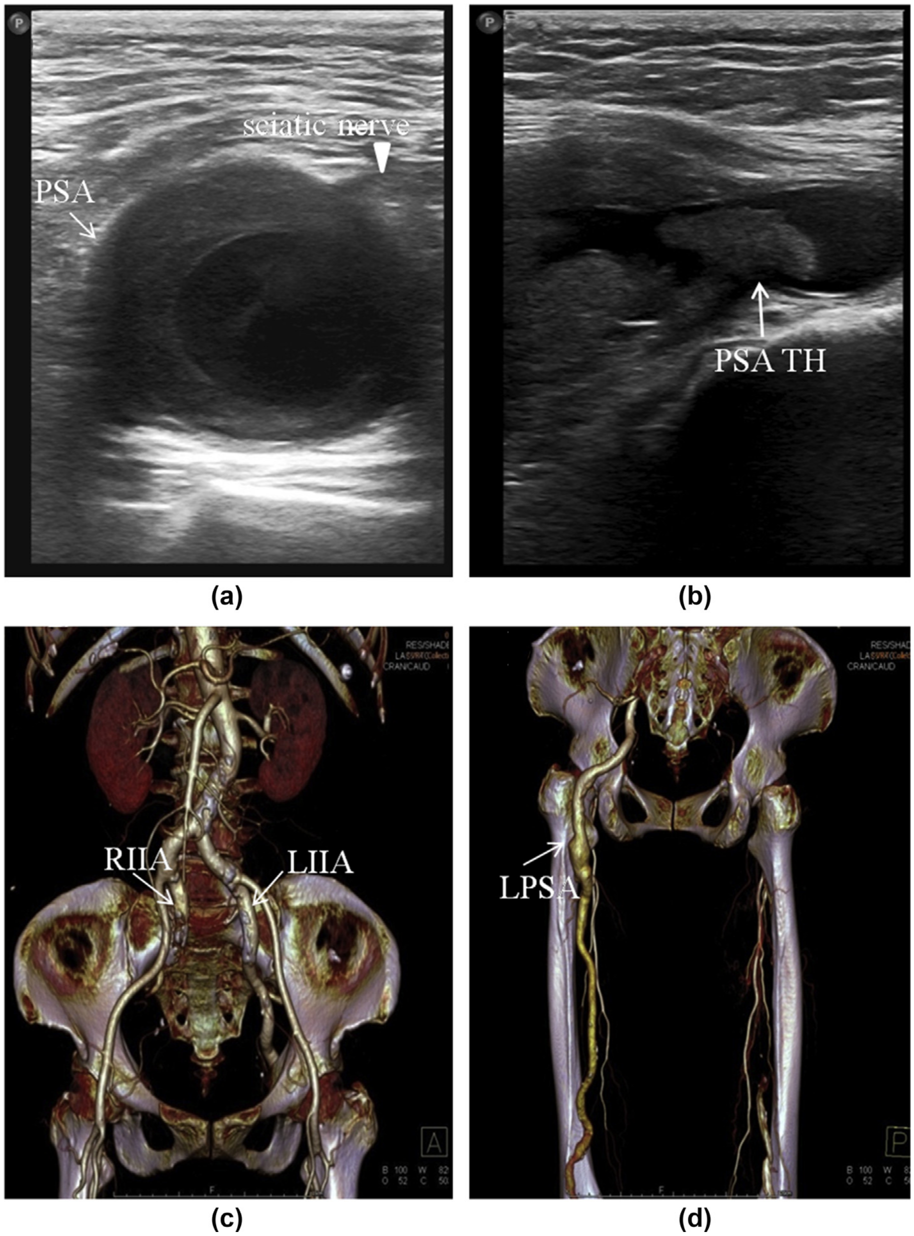

Figure 2 A 75-year-old woman with PSA. (a) The axial ultrasound image shows the PSA (arrow) with aneurysm formation. (b) Ultrasonography shows the partial thrombosis of the PSA. (c) CTA volume-rendered image (anteroposterior) shows the bilateral enlarged internal iliac artery. (d) CTA volume-rendered image (posteroanterior) shows the left PSA (the right PSA was not visualised because of the secondary thrombosis) and the bilateral superficial femoral arteries were slender.

femoral artery are found to be slender during arterial vessel examination of the lower extremity, the iliac artery (external iliac artery and internal iliac artery) and the region close to the sciatic nerve must be carefully scanned in order to eliminate the possibility of PSA.

Various imaging techniques can be used to diagnose PSA, such as ultrasonography, magnetic resonance angiography (MRA), CTA or digital subtraction angiography (DSA),[9,10] etc. Although CTA, DSA, and MRA can visualise the complete course of the PSA, the former two require the administration of contrast medium and DSA is invasive. MRA is a time-consuming, costly, and complicated examination. Ultrasonography is a non-invasive, convenient diagnostic imaging method from which confirmation can be obtained immediately, and it also provides crucial haemodynamic information not available from the other tests. In addition, it is radiation free compared to CTA and DSA.

Nevertheless, ultrasonography does have some limitations. Due to the existence of interference by pelvic bowel gas and obstruction by the pubis, sometimes the initial part of the PSA was not seen clearly at ultrasonography as the penetration of the beam is reduced; however, it can clearly show some indirect signs of PSA, such as internal iliac artery widening, accompanying sciatic nerve, and slender

Table 1
Ultrasonography examination results of persistent sciatic artery.

Patient/sex/age (years)	Characteristic persistent sciatic artery	Deep artery abnormality	Enlarged internal iliac artery	Unilateral/bilateral involvement
No.1/M/20	+	Hypoplastic right superficial femoral artery	+	Unilateral involvement
No.2/F/55	+	Hypoplastic right superficial femoral artery	+	Unilateral involvement
No.3/M/43	+	–	+	Unilateral involvement
No.4/F/45	+	Hypoplastic both superficial femoral arteries	+	Bilateral involvement
No.5/F/73	+	Hypoplastic both superficial femoral arteries	+	Bilateral involvement
No.6/F/59[a]	+	–	–	Unilateral involvement
No.7/M/68	+	–	+	Unilateral involvement
No.8/F/66	+	Hypoplastic left superficial femoral artery	+	Unilateral involvement
No.9/F/1.6	+	Hypoplastic left superficial femoral artery	+	Unilateral involvement
No.10/M/73	+	Absent right femoral artery	+	Unilateral involvement
No.11/M/53	+	Hypoplastic both superficial femoral arteries	+	Bilateral involvement
No.12/M/54	+	–	+	Unilateral involvement
No.13/M/69	+	Hypoplastic right superficial femoral artery	+	Unilateral involvement
No.14/F/65	+	Absent left femoral artery	+	Unilateral involvement
No.15/F/75	+	Hypoplastic both superficial femoral arteries	+	Bilateral involvement
No.16/M/60	+	Hypoplastic left superficial femoral artery	+	Unilateral involvement

[a] The patient was tested for inferior gluteal artery using CTA.

Table 2
Comparison of results: ultrasonography and conventional computed tomography angiography (CTA).

	Conventional CTA angiography		Total
	Positive	Negative	
Ultrasonography			
Positive	15	1	16
Negative	2	43	45
Total	17	44	61

Table 3
Kappa statistics between conventional computed tomography angiography and ultrasonography.

Parameter	Value	Asymptomatic SE	Value/asymptomatic SE	*p*-Value[a]
Kappa	0.875	0.070	6.843	0.000
No. of valid cases	61			

[a] Approximate significance.

development of the superficial femoral artery. It also can display the anatomical structures around PSA for comparison with the contralateral side. Moreover, ultrasonography can display the number and extent of aneurysmal dilatations of PSA,[9] reveal thromboses accurately, and evaluate the operative approach in PSA patients with thrombosis, and monitor the changing process of aneurysms and assess their risks. Ultrasonography is also less expensive. Thus, it provides a reliable, non-invasive, and convenient imaging method for follow-up of patients with PSA.

Treatment for PSA is mainly dependent on patient symptoms. Asymptomatic patients only require close follow-up.[11] Patients with arterial aneurysms or thrombosis caused by PSA should receive vascular reconstruction, such as femoral–popliteal artery bypass or iliac–popliteal artery bypass, etc.[12,13]

Although the reference standard for diagnosis of PSA is DSA or CTA,[14] the present study has shown that ultrasonography is useful in diagnosing PSA because of its high accuracy as a diagnostic test (95.1%), compared with the accuracy of CTA, and there is a high level of agreement between both tests ($k = 0.875$). Therefore, in patients with typical symptoms and positive ultrasonography findings, a reliable diagnosis can be reached.

In conclusion, ultrasonography may provide important imaging evidence for diagnosis, treatment, and follow-up in patients with PSA. It is a reliable, accurate, and non-invasive examination to assess patients with suspected PSA.

Conflict of interest

None declared.

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