Color Duplex evaluation of the mesenteric artery[☆]

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KEYWORDS

Mesenteric artery;
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Abstract Ischemic colitis is the most common form of intestinal ischemia. Diagnosis is made at clinical examination and endoscopy and completed by vascular imaging, but color Doppler US may become a first-line imaging technique for the evaluation of the mesenteric circulation.

We present the case of an 80-year-old woman hospitalized for recurrent ischemic colitis of the sigmoid. At a previous hospitalization, color Doppler US examination showed medium to severe stenosis at the origin of the inferior mesenteric artery. However, CT angiography was negative and the condition was therefore misdiagnosed. Eight months later the patient was admitted again with abdominal pain and rectal hemorrhage. Rectosigmoidoscopy documented the presence of ischemia of the sigmoid mucosa. Angiography showed the presence of severe stenosis at the origin of the inferior mesenteric artery so revascularization was carried out by percutaneous transluminal angioplasty (PTA) during the same session. Follow-up showed normal patency of the inferior mesenteric artery after revascularization, and subsequent endoscopic evaluation documented gradual colonic mucosal ischemia resolution. Blood flow at the level of the inferior mesenteric artery was assessed using color Doppler US. The presented case confirms that color Doppler US is a valid first-line imaging technique in the assessment of ischemic intestinal lesions. It is reliable in the evaluation of the mesenteric arterial circulation, and it also allows assessment of blood flow alterations caused by stenosis and identification of localized hemodynamic stenosis which may be missed at CT-angiography or MR-angiography. Arteriography remains the examination of choice in case of discrepancy between first- and second-line imaging techniques and in all cases which offer the possibility of endovascular revascularization.

Sommario La colite ischemica è la forma più frequente di ischemia intestinale. La diagnosi è clinica ed endoscopica ed è completata dall'imaging vascolare. Lo studio Eco-Color Doppler può rappresentare la metodica d'imaging di primo livello nella valutazione del circolo mesenterico.

Presentiamo il caso di una donna di 80 anni ricoverata per recidiva di colite ischemica del sigma. Dopo un primo ricovero con Eco-Color Doppler che evidenziava stenosi medio-elevata all'origine della arteria mesenterica inferiore, ma Angio-TC negativa e diagnosi finale misconosciuta, la paziente presentava insorgenza di dolore addominale e rettorragia e veniva

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effettuato un nuovo ricovero ospedaliero. La rettosigmoidoscopia documentava la presenza di ischemia della mucosa del sigma. Veniva quindi effettuato uno studio angiografico che evidenziava la presenza di stenosi critica dell'arteria mesenterica inferiore all'origine e si procedeva nella stessa seduta a rivascolarizzazione mediante angioplastica percutanea transluminale.

I successivi controlli evidenziavano normale pervietà dell'arteria mesenterica inferiore dopo rivascolarizzazione; la successiva valutazione endoscopica ha documentato la graduale risoluzione dell'ischemia della mucosa colica con restitutio ad integrum. Per valutare il flusso a livello dell'arteria mesenterica inferiore è stato effettuato follow-up mediante Eco-Color Doppler.

Il caso in esame conferma che, nella patologia ischemica intestinale l'Eco-Color Doppler rappresenta una metodica di imaging di primo livello, affidabile, per la valutazione del circolo arterioso mesenterico; consente inoltre, valutando le alterazioni di flusso secondarie alla stenosi, di individuare stenosi emodinamiche localizzate che possono sfuggire alla valutazione mediante metodiche di secondo livello quali l'Angio-TC o l'Angio-RM. L'arteriografia rimane l'esame di scelta nel caso di discordanza tra metodiche di primo e secondo livello e in tutti i casi in cui si preveda la possibilità di una rivascolarizzazione endovascolare.

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Introduction

Intestinal ischemia is a morbid condition that can be caused by occlusion of the splanchnic arteries or veins or by systemic hypoperfusion associated with vasoconstriction of the splanchnic microcirculation. Both the occlusive and non-occlusive form may cause acute or chronic ischemia [1]. Ischemic colitis is the most common form of intestinal ischemia (50%–60%). It is caused by ischemia of the colon in the arterial districts of the superior and inferior mesenteric arteries [2]. These segments of the colon are the splenic flexure and sigmoid colon. They are subject to ischemic injuries as the collateral vessels connecting the two mesenteric arteries are often underdeveloped, and because the small vessels penetrating the intestinal wall (vasa recta) are occluded by arteriosclerosis.

Ischemic colitis can be classified clinically as gangrenous and non-gangrenous. The non-gangrenous form (80%–85%) may be transient (50%), chronic (20%–25%) or chronic with stricture (10%–15%) [2]. Diagnosis is based on clinical examination and diagnostic imaging and is completed by endoscopy and biopsy.

Intestinal ischemia is primarily an age-related disease (>65 years) caused by the presence of atheromatous lesions in the mesenteric arteries [3]. A recent study carried out on an elderly population in the United States [4] identified the presence of significant stenosis of the superior mesenteric artery or celiac tripod, which was asymptomatic in 17.5% of subjects, with a higher prevalence of isolated stenosis of the celiac tripod. Most cases of stenosis identified at color Doppler US are asymptomatic due to abundant collateral circulation [1].

Color Doppler US is widely used in the study of splanchnic arterial stenosis. An experienced US operator can identify the celiac tripod and the superior mesenteric artery in 80%–90% of patients. The examination is performed early in the morning on a fasting patient in order to minimize the interference from intestinal gas [5].

The patient is placed in the supine position with the head of the bed raised 30°. For this study 2–5 MHz convex probes are commonly used. B-mode examination assesses the anatomy of the segments of the analyzed vessels

including pathological changes in the inner vessel wall. Doppler examination includes assessment of the presence or absence of blood flow, measurement of peak systolic velocity (PSV) and end diastolic velocity (EDV) as well as Doppler spectral analysis of the morphology. Velocity must be recorded using a sampling angle of <60°, as greater than 60° will result in an erroneous estimation of flow velocity.

The celiac trunk and superior mesenteric artery have different blood flow morphologies: PSV is higher in the superior mesenteric artery than in the celiac tripod, and EDV is higher in the celiac trunk than in the superior mesenteric artery.

When the patient is fasting, a short reverse flow at the level of the superior mesenteric artery can be registered in telesystolic phase, associated with a low EDV. This pattern indicates a high peripheral resistance. In contrast, an elevated EDV at the level of the celiac trunk reflects the presence of low resistance which is typical of the hepatic and splenic arterial circulation. Tables 1 and 2 show flow velocity characteristics of the main arteries.

The criteria applied in the diagnosis of mesenteric artery stenosis are taken from various studies on Doppler US evaluation of stenosis of the superior mesenteric artery and celiac trunk followed by comparison with angiography, which started in the late 1980s [5–9,11–14]. These studies established the current flow velocity cut-off levels applied in the diagnosis of hemodynamically significant stenosis of the main splanchnic arteries. PSV >275 cm/s at the level of the superior mesenteric artery identifies stenosis >70%

Table 1 Values of maximum systolic velocity ($V_{\max}$) in cm/s and resistive index (RI) based on data reported in literature [6–9].

Blood flow velocity characteristics of the main arteries	$V_{\max}$	RI
Celiac tripod	100–237	0.66–0.82
Splenic artery	70–110	0.58–0.64
Hepatic artery	70–120	0.58–0.66
Superior mesenteric artery	124–218	0.75–0.90
Inferior mesenteric artery	108–155	0.80–0.90

Table 2 Normal values of mesenteric arterial blood flow.

Doppler parameters	Celiac trunk	Sup. Mesenteric artery	Inf. Mesenteric artery
PSV	90–190	80–200	90–140
EDV	30–65	—	0–10
RI	—	0.8–0.85	>0.9
PI	1.5 ± 0.02	2.6–4.8	>3.5
D	—	—	3
BF	—	380–640	80–130

PSV: peak systolic velocity (cm/s); EDV: end diastolic velocity (cm/s); RI: resistive index; PI: pulsatility index; D: diameter (mm); BF: arterial blood flow (ml/min) (10).

(sensitivity 92%, specificity 96%, positive predictive value 80%, negative predictive value 99%). PSV >200 cm/s at the level of the celiac trunk identifies stenosis >70% (sensitivity 87%, specificity 80%, positive predictive value 63%, negative predictive value 94%) [11–13].

Clinical case

An 80-year-old woman was admitted to hospital with abdominal pain, temperature symptoms, diarrhea and bloody mucus in the stool. The patient's clinical history included chronic atrial fibrillation, current pharmacological treatment of hyperthyroidism and a recent hip arthroprosthesis operation followed by prolonged bed rest during the period of rehabilitation. A few days before admittance, she had experienced an episode of syncope caused by orthostatic hypotension due to physical deconditioning.

The abdomen was soft and non-tender on clinical examination, but deep palpation caused pain in the left quadrants. Blood tests showed mild anemia (hemoglobin 11.1 g/dl), hypoalbuminemia (2.3 g/dl), hypokalemia (3.4 mEq/dl), increased inflammation index (C-reactive protein 11 mg/dl), normal leukocyte count and shape, negative for cytoncrosis enzymes (LDH, ALT, myoglobin, CPK). Rectosigmoidoscopy evidenced presence of hyperemic, proliferative and ulcerated mucosa. Color Doppler US of the abdominal vessels showed severe stenosis at the origin of the inferior mesenteric artery with high-velocity blood flow, marked turbulence and "blooming" (Fig. 1). Abdominal CT-angiography was carried out but stenosis at the inferior mesenteric artery was not confirmed (Fig. 2).

As analysis of the stool confirmed presence of fecal toxins A and B of *Clostridium difficile*, antibiotic therapy was initiated with vancomycin. Pre-discharge colonoscopy showed complete *restitutio ad integrum* of the sigmoid mucosa. Since CT-angiography was negative, test for toxins A and B of *C. difficile* was positive and symptoms cleared up after antibiotic treatment, final diagnosis was infectious colitis.

After about eight months, the patient was admitted again for onset of abdominal pain and rectal hemorrhage. Blood tests showed mild neutrophilic leukocytosis (13000/mm³), increased inflammation indices (CRP = 10 mg/dl, ESR 32 mm/s) mild dysproteinemia, mild hypokalemia (3.4 mEq/l), absence of A and B toxins of *C. difficile* and absence of cytoncrosis enzymes.

Rectosigmoidoscopy evidenced ischemia of the sigmoid mucosa. Considering this clinical relapse, angiography of the celiac tripod and mesenteric arteries was carried out despite the previous CT-angiography which was negative for hemodynamically significant stenosis. Angiography evidenced moderate stenosis at the origin of the celiac tripod and severe stenosis at the origin of the inferior mesenteric artery with poor left colic artery injection (Fig. 3a). Revascularization was successfully carried out during the same session by percutaneous transluminal angioplasty (PTA) of the inferior mesenteric artery (Fig. 3b). Subsequent endoscopic evaluation documented gradual resolution of ischemia of the colonic mucosa with simultaneous disappearance of symptoms.

The patient was discharged with a diagnosis of recurrent ischemic colitis of the sigmoid due to inferior mesenteric artery stenosis treated with revascularization by PTA in a patient with moderate stenosis of the celiac tripod,

Fig. 1 Color Doppler evaluation of the abdominal vessels: severe stenosis at the origin of the inferior mesenteric artery with high-velocity blood flow (a), marked turbulence and "blooming" (b) and ostial stenosis of the inferior mesenteric artery evidenced by power Doppler (c).

Fig. 2 CT-angiography of the inferior mesenteric artery does not evidence severe stenosis at the origin of the vessel.

chronic atrial fibrillation, sub-clinical hyperthyroidism currently being treated and a recent hip arthroprosthesis operation. Oral anticoagulant therapy with wafarin and administration of statins were recommended after discharge.

At follow-up one month after discharge, symptoms had disappeared and color Doppler US evidenced mild residual stenosis of the inferior mesenteric artery after PTA.

Informed consent was obtained from the patient for publication of this case report.

Discussion

Most studies reported in the literature on color Doppler US assessment of splanchnic arteries are limited to the study of the celiac tripod and superior mesenteric artery. US exploration of the inferior mesenteric artery is more

difficult because of its small size and position next to the loop of the small intestine. The first study on color Doppler US evaluation of the inferior mesenteric artery was reported by Mirk et al. [6], who published data which were reconfirmed in later studies [15,16].

From these studies parameters of reference emerged which are useful for the recognition of inferior mesenteric artery occlusive diseases. Flow data related to the inferior mesenteric artery in patients without arterial splanchnic pathologies reported by Mirk et al. [16] show a high-resistance blood flow, a maximum systolic velocity of $1.4 \text{ m/s} \pm 0.48$, a minimum diastolic velocity of $0.10 \text{ m/s} \pm 0.16$ and a pulsatility index of 3.49 ± 0.49 .

In the last 20 years, Color Doppler US of the mesenteric circulation has become a method which can be carried out in most patients. It is a first-line diagnostic imaging technique, non-invasive, inexpensive and reliable, and it is indicated in all cases of suspected splanchnic artery disease (suspected ischemic bowel due to steno-occlusive disease or aneurysms of the visceral vessels).

In patients with ischemic symptoms in whom color Doppler US is positive for hemodynamically significant stenosis, angiography is indicated with the objective to confirm stenosis and possibly treat it by endovascular revascularization procedure. If color Doppler US is negative for significant stenosis, further investigation such as CT-angiography or MR-angiography should be carried out before considering angiography. This approach is justified by the high negative predictive value of color Doppler US for excluding severe stenosis (negative predictive value for stenosis of the superior mesenteric artery is 99%, of the celiac tripod $>50\%$) [5,10]. Moreover, by assessing flow alterations caused by stenosis, color Doppler US furthermore permits identification of hemodynamically localized stenosis which can be missed at second-line evaluation such as CT-angiography or MR-angiography.

Fig. 3 Angiography of the inferior mesenteric artery. Left (a): severe stenosis at the origin of the vessel; right (b): inferior mesenteric artery after PTA.

Arteriography remains the examination of choice in case of discrepancy between first- and second-line methods and in all cases where revascularization may be possible.

Conflict of interest statement

The authors have no conflict of interest.

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