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FULL RESEARCH ARTICLE

Arterial Limb Trauma Ultrasonographic Assessment (ALTUA) in the emergency department: A pictorial essay

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ABSTRACT

Introduction: *The spectral patterns for detecting traumatic arterial limb injuries by spectral color Doppler ultrasound (CDUS) have not been clearly defined. The aims of this pictorial essay were to (1) identify spectral patterns on spectral CDUS in patients with suspected arterial limb injuries, and (2) propose an algorithm for diagnosing arterial limb injury in patients in the emergency department.* **Material and Methods:** *We included patients with blunt, penetrating, or gunshot wounds with suspected limb arterial injuries assessed with spectral CDUS and grayscale ultrasound. Spectral patterns were evaluated at the level of the injury and proximal and distal to this site.* **Results:** *Traumatic limb injuries of 582 patients were included. Seven cases with absent arterial flow were referred for computed tomography angiography (CTA) and/or surgical exploration. Arterial spectral flow in the extremities was present in 575 cases; 360 (62.6%) showed a triphasic spectral pattern (normal), and a limb artery lesion was ruled out. In 67 (11.7%) cases, a high-resistance biphasic spectral pattern was identified due to soft tissue edema adjacent to the lesion, so no further imaging studies were indicated. Abnormal spectral patterns for a probable arterial limb lesion were observed in 148 patients (25.7%), such as low-resistance monophasic or biphasic, monophasic "tardus parvus," bidirectional or obstructive, so that CTA and/or surgical exploration were indicated.* **Conclusion:** *For the first time, an Arterial Limb Trauma Ultrasonographic Assessment (ALTUA) algorithm by spectral CDUS is proposed to classify spectral patterns as triphasic or high-resistance biphasic patterns reflecting vessel wall integrity in the absence of arterial injury, and abnormal spectral patterns for probable traumatic arterial limb lesion in the emergency department.*

Keywords: *Ultrasound. Color Doppler. Gunshot wounds. Penetrating wounds. Blunt injuries. Spectral analysis.*

INTRODUCTION

Peripheral vascular injuries of the extremities that result from blunt, penetrating, or gunshot trauma require a timely and accurate diagnosis to reduce morbidity and mortality. Computed tomography angiography (CTA) and/or surgical exploration are the gold standard when a vascular injury is suspected[1,2]. However, access to these resources may be limited, particularly in middle- and low-income countries[3]. Spectral Doppler ultrasound (CDUS) is currently considered the method of choice for the initial evaluation of patients with suspected traumatic vascular injuries of the extremities in the emergency department[4]. Spectral CDUS provides adequate morphologic and hemodynamic assessment of the extremities with high sensitivity and specificity[3,5].

Spectral CDUS is widely available in emergency departments. This procedure avoids delays in evaluating patients with suspected traumatic arterial injury of the extremities and unnecessary CTA or surgery. There

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are insufficient studies on the usefulness of spectral CDUS in evaluating these patients[3]. In addition, no consensus defines the spectral patterns for identifying traumatic arterial limb injuries[6–8]. This pictorial essay aimed to (1) identify the different spectral Doppler patterns in patients with suspected traumatic arterial lesions due to blunt, penetrating, or gunshot injuries of the extremities, and (2) propose an algorithm for diagnosis based on the spectral patterns found in patients in the emergency department.

MATERIAL AND METHODS

This cross-sectional study was conducted from March 2018 to March 2021 at the University Center of Diagnostic Imaging and the Emergency Department of the "Dr. Jose E. Gonzalez" University Hospital in Monterrey, Nuevo Leon, Mexico. Patients with blunt, penetrating, or gunshot extremity injuries and suspected arterial lesions were evaluated in the emergency department with spectral CDUS and grayscale ultrasound. Patients with incomplete imaging studies or images unavailable at PACS were not included. Informed consent was not required for this observational study of information collected during routine clinical care. The institutional ethics and research committees approved the study protocol.

Ultrasound protocol

Spectral CDUS and grayscale ultrasound were performed on Philips EPIQ 5 equipment (Koninklijke Philips, Amsterdam, The Netherlands) with a linear 12-MHz multifrequency transducer. No patient-specific preparation was carried out. Imaging studies were performed by residents in the diagnostic imaging department with guidance from a radiologist (GOC) who specializes in vascular ultrasound and has 20 years of experience. The arterial system was examined proximal to, at the level of, and distal to the lesion site to identify wall integrity or intraluminal filling defects. Grayscale ultrasound was performed with the patient in the supine position in transverse and longitudinal sections of the main artery of the affected limb at the site of the lesion to assess the shape, size of the arterial lumen, and integrity of the wall, defined by its continuity on the image, and the absence of perivascular collections. Spectral CDUS was performed at a fixed velocity scale between 10 and 60 cm/s to identify abnormal flow observed as aliasing, turbulence, and reduced or absent flow areas. Spectral assessment was performed with an insonation angle of 60° or less to locate areas of increased velocity and a change in spectral morphology at the level of the injury and proximal and distal to the site.

The spectral CDUS and grayscale ultrasound protocols performed in patients with traumatic limb injuries are shown in Figure 1. Grayscale images were acquired in the transverse and longitudinal axes of the anatomic region of interest. This region of interest was then evaluated with spectral CDUS at the level of the injury and proximal and distal to this site. The tibial and pedal arteries were assessed at a depth of 2 to 3 cm, and the femoral and popliteal arteries at 5 to 6 cm[3]. The peak systolic velocity (PSV) considered normal in the lower extremity at rest is 1.2 m/s in the iliac segments, while the superficial femoral artery was 0.9 m/s and 0.7 m/s in the popliteal artery[9]. In cases where a greater visualization depth was required, the convex transducer with a wider field of view was used; for example, in obese patients, when edema is present in this area, or when measuring hematomas. CTA of the extremities was performed with a 64-slice LightSpeed™ VCT (General Electric Co., LightSpeed VCT, GE Healthcare Technologies, Waukesha, WI, USA). Ioversol (Optiray® 300) containing 64% injectable solution was administered using the Merad® Stellant Dual contrast injector (Bayer Pharmaceuticals, Hanover NJ, USA).

Definition of arterial limb spectral patterns

The different arterial spectral patterns that may occur in traumatic injuries of the extremities due to blunt, penetrating, or gunshot wounds are described in Figure 2:

Triphasic spectral pattern (Figure 2A): normal findings due to hemodynamic events with anterograde flow during systole, early diastolic retrograde flow, and anterograde end-diastolic flow. These events depend on arterial wall elasticity, peripheral resistance, and transmural gradient. The triphasic pattern reflects arterial vessel integrity and can be found in arteries at any level of the extremities.

High-resistance biphasic spectral pattern (Figure 2B): characterized by loss of anterograde diastolic flow due to increased peripheral resistance and transmural gradient, indicating edema of adjacent soft tissues due to traumatic limb injury with arterial vessel integrity.

Abnormal spectral patterns in traumatic limb injury suggestive of an arterial lesion with loss of vascular

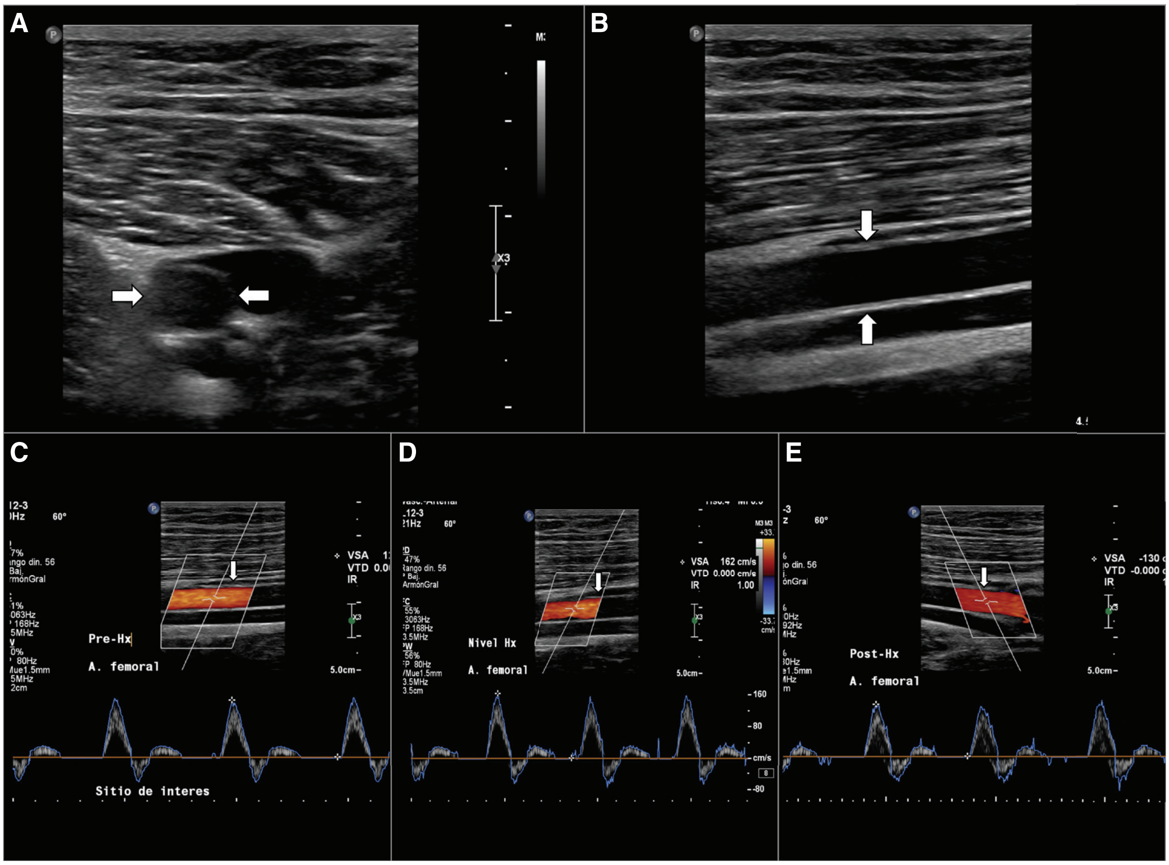

Figure 1. Spectral CDUS and grayscale ultrasound assessing proximal to, at the level of, and distal to the traumatic limb injury. **A:** Artery in transverse-axis (arrows). **B:** longitudinal view (arrows). **C:** proximal to the injury site (arrow). **D:** at the injury site (arrow). **E:** distal to the injury site (arrow). The normal triphasic spectral pattern was observed at the three levels.

CDUS: color Doppler ultrasound.

integrity include low-resistance monophasic or biphasic, monophasic "*tardus parvus,*" bidirectional, and obstructive spectral patterns:

Low-resistance monophasic or biphasic spectral patterns (Figure 2C): characterized by normal PSV with anterograde diastole due to decreased peripheral resistance and a transmural gradient secondary to a distal lesion. This spectral pattern has been referred to as monophasic because the entire spectrum is above the baseline or as a biphasic pattern because it has an initial phase with a systolic peak and a late phase with continuous flow during diastole.

Monophasic spectral pattern, "tardus parvus" type (Figure 2D): anterograde systolic and diastolic flow with decreased PSV and delayed systolic acceleration due to a proximal lesion.

"To and fro" bidirectional spectral pattern (Figure 2E): flow passes through the neck of an arterial pseudoaneurysm. The waveform shows rapid ascending systole with exaggerated deceleration and a pronounced prolonged return component.

Obstructive spectral pattern (Figure 2F): absence of flow due to obstruction at or proximal to the lesion site by arterial thrombosis.

Statistical analysis

Data are presented as frequencies and percentages analyzed with Microsoft Excel^{TM} version 18.0 (Microsoft Corp., Seattle, WA, USA).

RESULTS

During the study period, 5387 spectral CDUS and grayscale ultrasound were performed at our center.

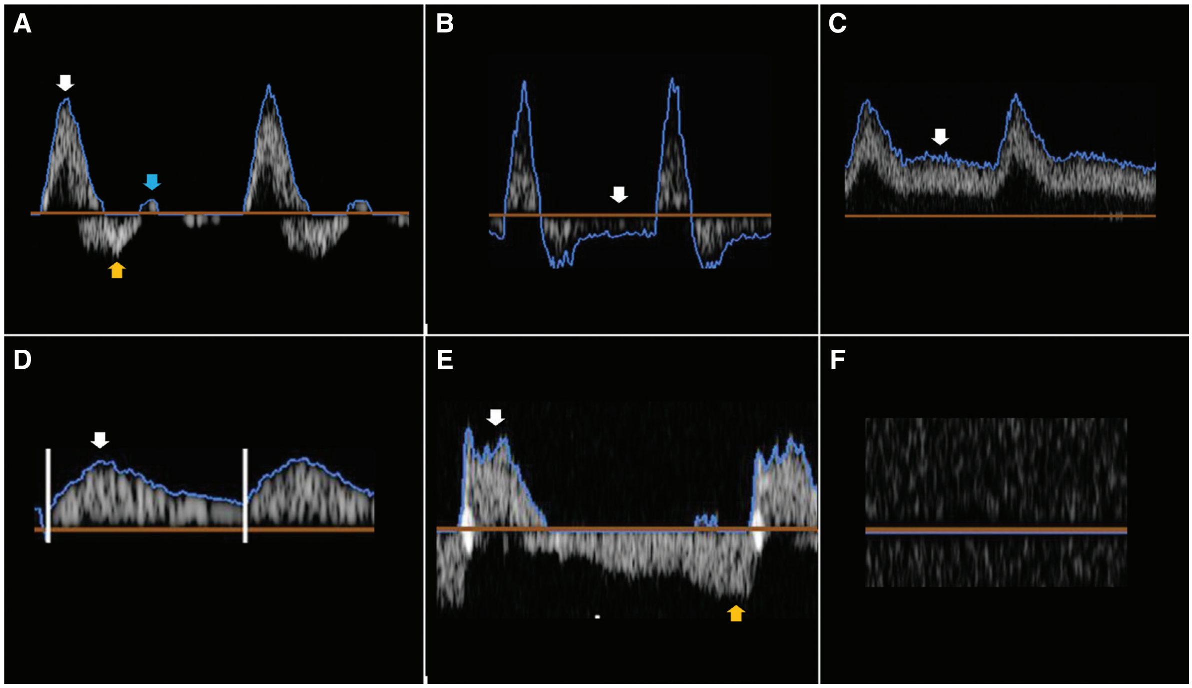

Figure 2. Arterial spectral pattern analysis of extremities with blunt, penetrating, or gunshot wounds. **A:** triphasic pattern: normal findings due to three hemodynamic events consisting of acceleration of blood flow during systole through the peripheral arteries with anterograde flow (white arrow), subsequent closure of the aortic valve with early retrograde diastolic flow (yellow arrow), and final antegrade diastolic flow (blue arrow), which depends on arterial wall elasticity, peripheral resistance, and transmural gradient. View at the site proximal to, at the level of, and distal to the lesion. **B:** high-resistance biphasic pattern demonstrates loss of anterograde diastolic flow (arrow) due to increased peripheral resistance and transmural gradient, suggesting adjacent soft tissue edema due to traumatic limb injury. **C:** low-resistance monophasic or biphasic pattern characterized by normal PSV with anterograde diastole during the cardiac cycle (white arrow), with decreased peripheral resistance and transmural gradient due to distal injury. **D:** monophasic "tardus parvus" pattern: anterograde systolic and diastolic flow with reduced velocities and delayed systolic acceleration (arrow) due to a proximal lesion. **E:** bidirectional pattern of flow through the neck of an arterial pseudoaneurysm. The waveform shows rapid ascending systole with exaggerated deceleration (white arrow) and a pronounced prolonged reflux component (yellow arrow). **F:** obstructive spectral pattern: lack of flow on spectral CDUS assessment.

CDUS: color Doppler ultrasound; PSV: peak systolic velocity.

There were 1124 studies of the extremities, and 582 (51.8%) corresponded to patients evaluated in the emergency department with blunt, penetrating, or gunshot wounds (Table 1). Spectral patterns were classified according to the definitions, and the findings observed in our patients are presented below.

Table 1. Clinical referral diagnoses for spectral CDUS and grayscale ultrasound of the extremities in 1124 patients evaluated at our center

Description	n (%)
Diabetic arterial disease	513 (45.6)
Traumatic blunt, penetrating, gunshot wounds	582 (51.8)
AVF maturation	18 (1.6)
Clinical suspicion of arterial thrombosis	6 (0.5)
Snake bite	3 (0.3)
Dog bite	1 (0.1)
Spider bite	1 (0.1)
Total	1124 (100)

AVF: arteriovenous fistula; CDUS: color Doppler ultrasound.

High-resistance biphasic spectral pattern

In spectral CDUS, anterograde flow with high resistance is observed in which PSV remains constant and comparable at proximal, at level, and distal to the injury site, leading to the diagnosis of soft tissue edema (Figure 3). This pattern can also be found in compartment syndrome[10] or when the operator performs excessive compression on the site.

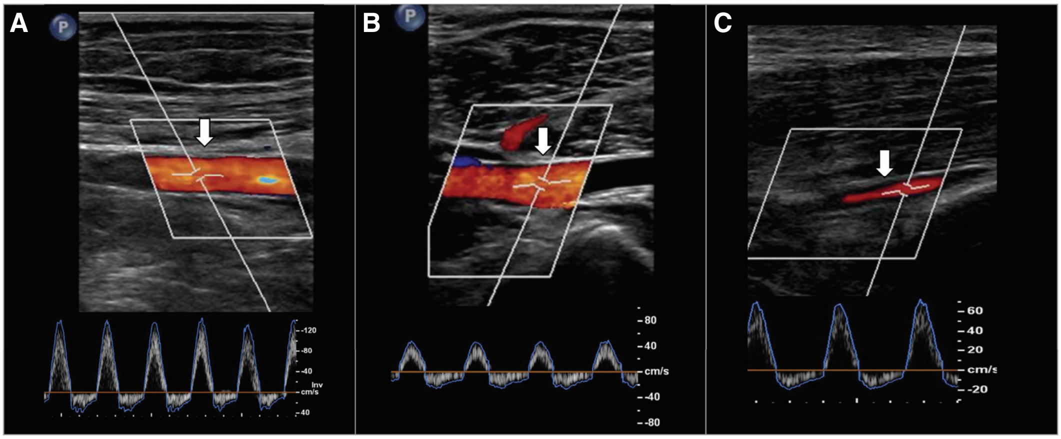

Figure 3. Spectral CDUS and grayscale ultrasound in a 34-year-old man with a penetrating soft tissue wound of the right thigh and leg. **A:** image proximal to the wound of the femoral artery (arrow). **B:** popliteal at the level of the lesion (arrow). **C:** anterior tibial artery spectral doppler distal to the lesion (arrow). The wall was intact with anterograde flow and a biphasic spectral pattern with high resistance throughout the arterial tract with anterograde flow in systole and retrograde flow in diastole. No intraluminal filling defects were found. The vascular features were suggestive of changes due to adjacent soft tissue edema.

CDUS: color Doppler ultrasound.

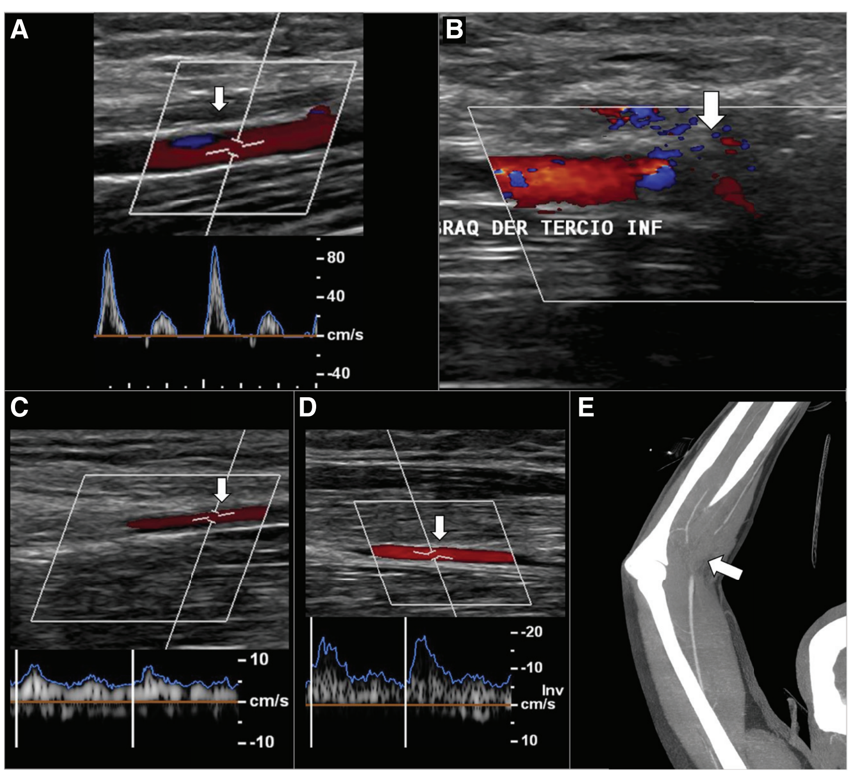

Figure 4. Spectral CDUS and CTA in a 57-year-old man with a gunshot wound in the right forearm. **A:** image proximal to the site of a brachial artery lesion; patency of the brachial artery (arrow) with triphasic spectral pattern. **B:** image at the site of a brachial artery lesion with thrombosis in the distal third corresponding to an obstructive pattern (arrow). **C–D:** image of the radial and ulnar arteries, distal to the lesion site, permeable with decreased PSV in the spectral pattern and anterograde diastole throughout the cardiac cycle ("*tardus parvus*" spectral pattern), suggesting recanalization by collateral circulation. **E:** coronal CTA with multiplanar reformation of the right arm in the arterial phase showing thrombosis of the distal brachial artery (arrow) with distal recanalization of the radial and ulnar arteries.

CDUS: color Doppler ultrasound; PSV: peak systolic velocity; CTA: computed tomography angiography.

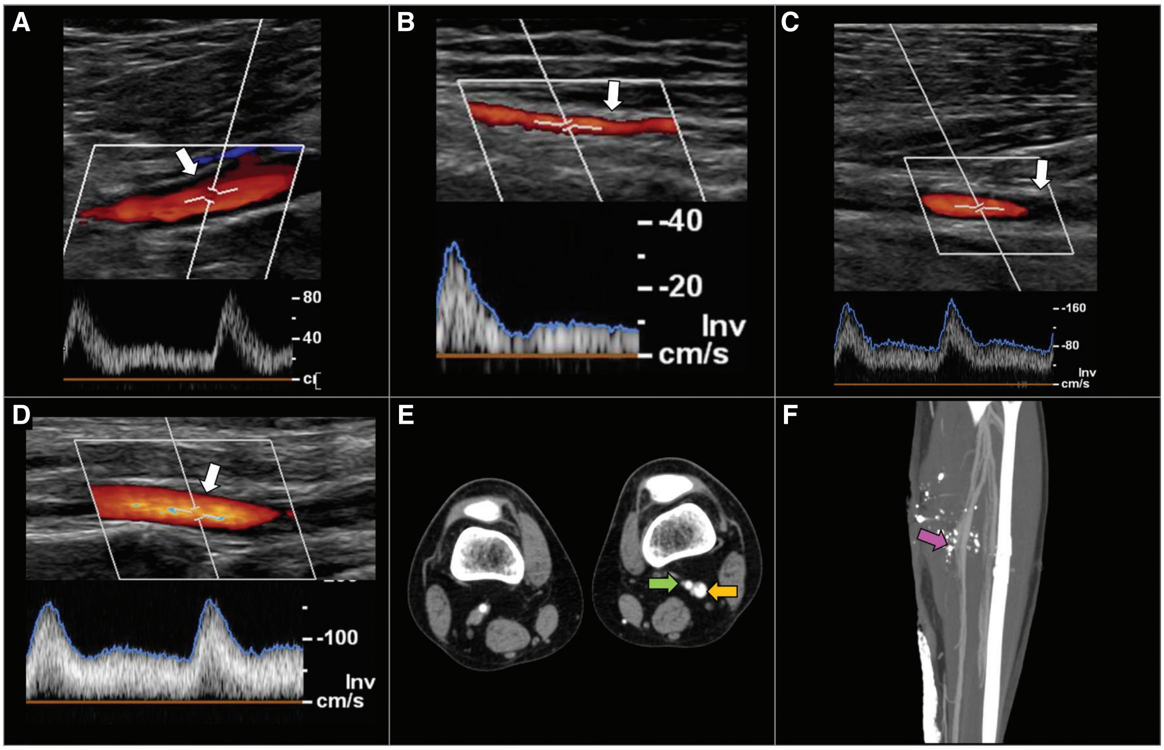

Figure 5. Spectral CDUS in a 21-year-old man with a gunshot wound to the left leg and decreased peripheral pulses. **A:** image of the proximal popliteal artery (arrow). **B–D:** at the site of injury (arrows) both arteries showed patency and a biphasic spectral pattern with low resistance characterized by anterograde blood flow throughout the cardiac cycle, indicating vascular injury. **E:** axial pelvic CTA in the arterial phase showing iodinated contrast in the artery (green arrow) and left popliteal vein (yellow arrow). **F:** coronal CTA with multiplanar reformation of the left leg showing AVF of the tibial vessel (pink arrow).

CDUS: color Doppler ultrasound; CTA: computed tomography angiography; AVF: arteriovenous fistula.

Obstructive spectral pattern

Grayscale ultrasound shows intraluminal echogenic material at the level of the lesion, suggesting thrombosis. Proximal to the lesion, anterograde flow with high resistance, a triphasic spectral pattern, and increased acceleration time is observed on spectral CDUS (Figure 4). No flow is seen at the site of the lesion. Distal to the lesion, when recanalized, the spectral pattern is attenuated with decreased PSV and persistent flow during diastole ("*tardus parvus*"). When this pattern is found, it is advisable to perform CTA or surgical evaluation.

Low-resistance monophasic or biphasic spectral patterns

In arteriovenous fistulas (AVF), grayscale ultrasound is usually normal. On spectral CDUS, the connection between the arterial and the venous system results in a change from the normal arterial triphasic pattern to a biphasic pattern with low resistance and increased PSV at the level of the fistula (Figure 5). False-positive findings may be due to moderate to severe atheromatous disease or an inflammatory or infectious process distal to the lesion. CTA assessment shows contrast medium in the venous system during the arterial phase, suggesting an AVF.

"Tardus parvus" low-resistance monophasic pattern

A monophasic pattern distal to the traumatic injury, represented by increased acceleration time and decreased PSV, indicates significant stenosis or obstruction (Figure 6). This characteristic pattern is called "*tardus parvus*." If this pattern is seen, the contralateral limb must be assessed as an additional evaluation. If the spectral analysis of the contralateral limb is normal, a vascular lesion of the injured limb is likely; in contrast, if the spectral analysis is abnormal, then central vascular disease should be suspected. In any case, CTA should be considered to identify arterial injury, atheromatous disease, or central vascular disease – the latter presents as a false positive for traumatic arterial injury on spectral CDUS.

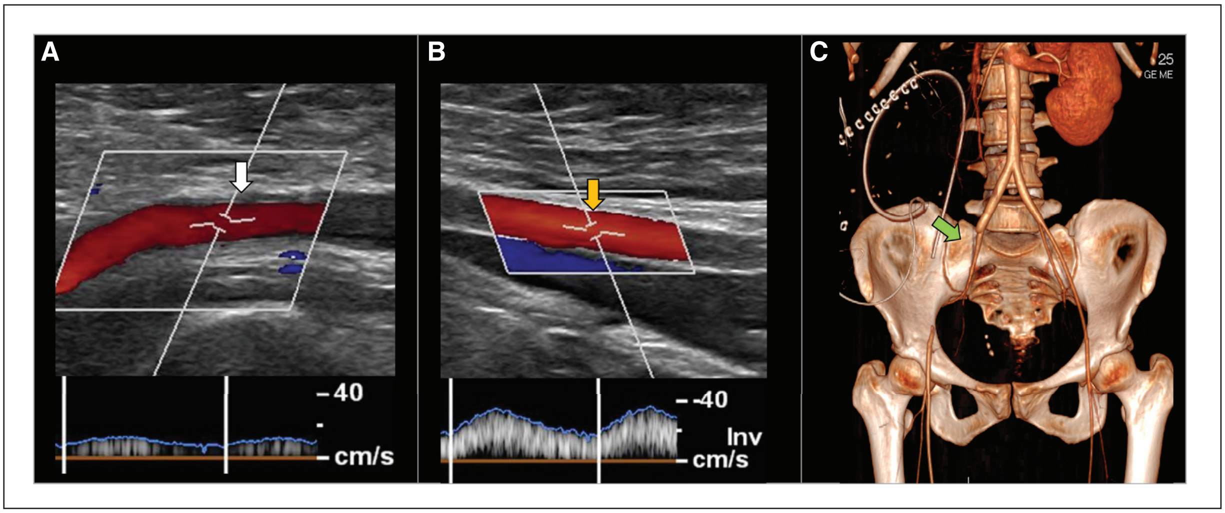

Figure 6. Spectral CDUS in a 45-year-old woman PO right nephrectomy who had decreased temperature and absence of distal pulses in the ipsilateral lower extremity. **A:** image of the common femoral artery (white arrow). **B:** right femoral artery (yellow arrow) permeable with low-resistance monophasic spectral "*tardus parvus*" type, compatible with severe stenosis or proximal obstruction. **C:** CTA with multiplanar reformation of the abdomen showed absence of contrast in the right external iliac artery, compatible with a complete obstruction at this level (green arrow).

CDUS: color Doppler ultrasound; PO: post-operative; CTA: computed tomography angiography.

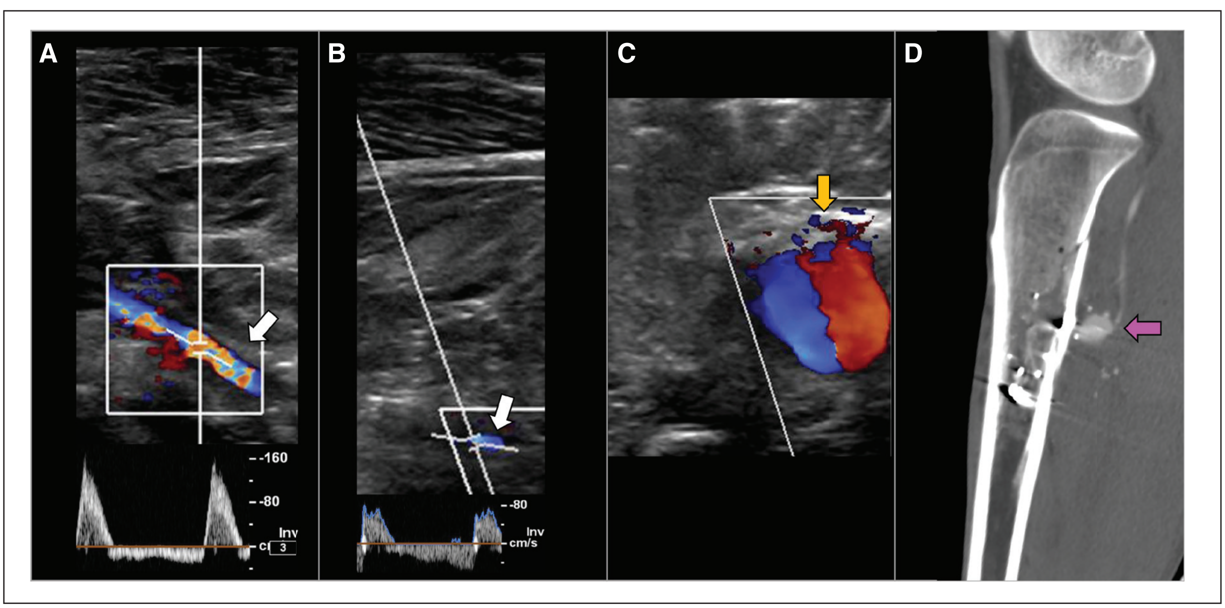

Figure 7. Spectral CDUS in a 27-year-old man with a gunshot wound in the upper third of the left leg. **A:** image of the patent PTA (arrow) at the level of the injury showing high-resistance biphasic spectral pattern. **B:** patent PTA at the level of the lesion with bidirectional spectral pattern (arrow). **C:** saccular image distal to the lesion site with "yin-yang" sign (yellow arrow). **D:** CTA in arterial phase with sagittal reconstruction showing a PTA with saccular image consistent with pseudoaneurysm (pink arrow).

CDUS: color Doppler ultrasound; PTA: Posterior tibial artery; CTA: computed tomography angiography.

"To and fro" bidirectional spectral pattern

Pseudoaneurysms are usually complications of traumatic lesions. On grayscale ultrasound, a saccular and anechoic image is found (not shown). On spectral CDUS, a turbulent bidirectional flow known as a "yin-yang" sign is observed, corresponding to a pseudoaneurysm (Figure 7). The spectral pattern at the neck of the pseudoaneurysm is characteristic and conditioned by anterograde systole resulting from blood

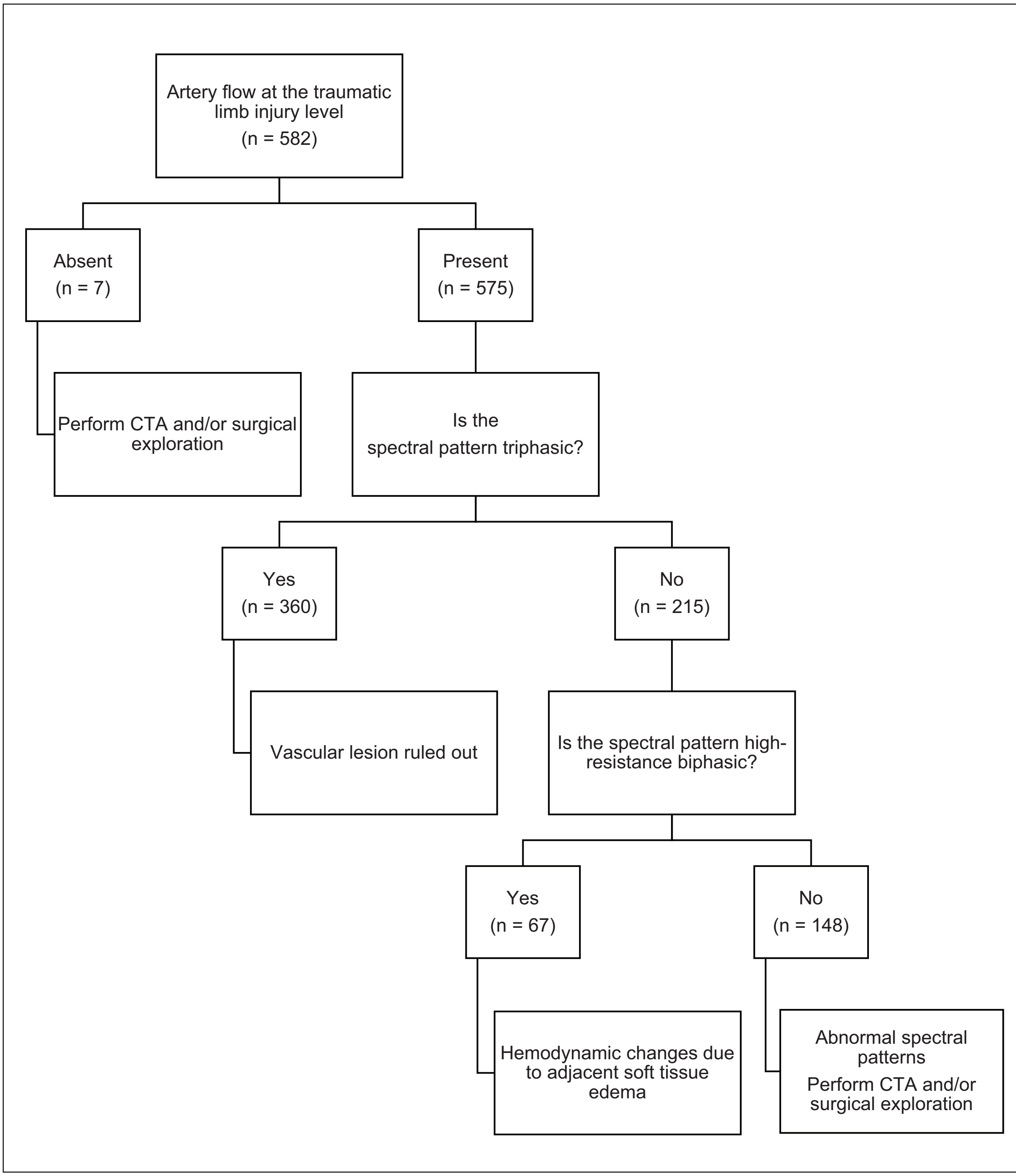

Figure 8. ALTUA diagnostic algorithm using spectral CDUS to identify the spectral pattern in 582 patients with gunshot, blunt, or penetrating limb wounds. Arterial flow at the injury site is assessed; if absent, CTA or surgical exploration is performed (n = 7). If arterial flow is present and has a triphasic spectral pattern which reflects normal vessel wall integrity, then a vascular injury is ruled out and CTA is not required (n = 360). If the pattern is not triphasic, the arterial flow spectrum is analyzed (n = 215). A high-resistance biphasic pattern suggests changes due to adjacent tissue edema and does not require CTA and/or vascular surgery (n = 67). If it is not a high-resistance biphasic pattern, traumatic arterial injury to the extremities should be suspected and the vascular flow spectrum analyzed to identify the type of abnormal spectral patterns, such as low-resistance monophasic or biphasic, "*tardus parvus*" monophasic, bidirectional, or obstructive pattern. CTA and/or surgical exploration were indicated in these patients (n = 148) for probable traumatic arterial limb lesion.

ALTUA: Arterial Limb Trauma Ultrasonographic Assessment; CDUS: color Doppler ultrasound; CTA: computed tomography angiography.

flow entering the lumen of the pseudoaneurysm and retrograde diastole representing blood flow exiting the neck of the pseudoaneurysm[11].

Arterial Limb Trauma Ultrasonographic Assessment (ALTUA)

The ALTUA diagnostic algorithm is proposed for evaluating patients with suspected arterial injuries from blunt, penetrating, or gunshot wounds to the extremities attended in the emergency department (Figure 8). The ALTUA algorithm is based on the spectral patterns described in this pictorial essay, according to our experience in 582 evaluated cases. Seven (1.2%) patients had no arterial flow, and CTA or surgical exploration was indicated. An arterial spectral pattern was found in 575 patients, and in 360 (61.8%), the spectral pattern was triphasic (normal), ruling out an arterial limb injury, and no further imaging studies were indicated. In 215 (36.9%) of the 575 cases, no triphasic spectral pattern was observed, so the type of spectral pattern was analyzed: in 67 (11.7%) of the 575 cases, a high-resistance biphasic spectral pattern was observed, which was attributed to hemodynamic changes due to edema of adjacent soft tissues from blunt, penetrating, or gunshot injuries; additional imaging studies were not indicated. Abnormal spectral patterns, such as low-resistance monophasic or biphasic, "tardus parvus" monophasic, obstructive, or bidirectional patterns, were found in 148 (25.7%) of the 575 patients. In these cases, a probable arterial traumatic limb injury was suspected, and a CTA scan and/or surgical exploration were indicated.

DISCUSSION

For the first time, the ALTUA diagnostic algorithm based on spectral CDUS is proposed to classify three categories of spectral waves: the triphasic pattern, which is normal reflecting vessel wall integrity in the absence of arterial injury, a high-resistance biphasic pattern, which is associated with soft tissue edema without arterial vessel injury, and abnormal spectral patterns, such as a low-resistance monophasic or biphasic, "*tardus parvus*" monophasic, obstructive, or bidirectional patterns, for probable traumatic arterial limb lesion in patients with blunt, penetrating, or gunshot injuries assessed in the emergency department. Triage with the ALTUA algorithm allows the identification of patients with abnormal spectral patterns requiring CTA and/or surgical exploration and avoids exposure to ionizing radiation in patients without arterial traumatic limb injury.

Delayed diagnosis and treatment of arterial limb injury impact morbidity in patients with blunt, penetrating, or gunshot injuries[3]. Spectral CDUS is recommended as an initial approach for diagnosis in the emergency department. Knudson et al.[12] found that spectral CDUS examination has the same sensitivity as angiography in detecting vascular injury with the advantage of being noninvasive. Montorfano et al.[3] compared spectral CDUS with 2-Point Fast Doppler (2PFD) assessment in two distal arteries (pedal and posterior tibial) in 149 extremities with penetrating vascular injuries of 140 patients. The diagnosis was confirmed by angiography and/or surgical exploration. The authors reported 100% specificity of the 2PFD protocol and spectral CDUS for detecting vascular lesions. Identification of the triphasic pattern showed 100% sensitivity to exclude arterial lesions in the extremities. In contrast, the obstructive pattern with absent flow and the monophasic or biphasic spectral pattern were associated with a traumatic arterial lesion of the extremity[3]. The 2PFD protocol may have limitations because of false-positive results due to preexisting or chronic changes such as diabetic angiopathy and atherosclerosis. In a study by Fry et al.[5], spectral CDUS was compared with conventional angiography and/or surgical exploration in 175 injured extremities of 150 patients. Spectral CDUS was performed in 133 (88.7%) patients. An arterial lesion was identified in 19 (10.8%) injured extremities; 17 were confirmed by angiography and/or surgical exploration. Spectral CDUS showed a sensitivity of 100%, a specificity of 97.3%, and a diagnostic accuracy of 98.5% compared with angiography and/or surgery. In our study, 148 (25.7%) of 575 patients had an abnormal spectral pattern on spectral CDUS examination in which evaluation by CTA and/or surgical exploration was indicated. The high diagnostic sensitivity of spectral CDUS, previously reported as up to 100% in identifying arterial traumatic lesions of the extremities[5] allows the implementation of the diagnostic approach using the ALTUA algorithm to identify the spectral pattern and may reduce the number of patients requiring additional imaging studies such as CTA and/or surgical exploration. This can be useful in the context of health services with limited infrastructure and resources, as in Mexico.

Spectral CDUS allows real-time assessment of blood flow velocities and spectral patterns[5]. In the literature, there are differences in the description of spectral patterns in traumatic limb injuries[13]. It is important to standardize the nomenclature of normal spectral patterns to identify vessel wall integrity in the absence of arterial injury versus abnormal spectral patterns for probable traumatic arterial limb lesion in patients with blunt, penetrating, or gunshot injuries evaluated in the emergency department. Three categories of spectral waves were defined in the ALTUA algorithm[14,15]: the triphasic pattern, which reflects normal vessel wall integrity in the absence of arterial injury; the high-resistance biphasic pattern, which is associated with soft tissue edema without arterial vessel injury; and any other abnormal spectral pattern suggestive of a traumatic arterial injury of the extremities, which may be a low-resistance monophasic or biphasic, "tardus parvus" monophasic, obstructive, or bidirectional patterns due to AVF, hemorrhage, pseudoaneurysm, or traumatic thrombotic arterial obstruction. Identifying abnormal spectral patterns in patients with blunt, penetrating, or gunshot wounds with suspected arterial extremity injuries in the emergency department may avoid delays in deciding whether to perform CTA or surgical exploration.

The study's strength is related to the size of the study sample and the population, which includes patients with blunt, penetrating, or gunshot wounds with suspected traumatic arterial injuries. Spectral CDUS can be performed at the patient's bedside in the emergency department without transfer to radiology facilities, reducing the risks of mobilization and shortening the time required to perform the imaging examination. On the other hand, our study has several limitations, such as the lack of a reference standard for confirming a traumatic arterial lesion of the extremities. Information on clinical evolution and follow-up until patient discharge was not included because of the study's cross-sectional design; therefore, a clinical correlation with the spectral CDUS imaging findings was not possible. Additionally, the need for radiologists with training in vascular ultrasound may limit the use of the ALTUA algorithm because emergency departments often lack personnel with this training.

CONCLUSION

The ALTUA algorithm allows an imaging approach to traumatic arterial lesions of the extremities to define the spectral pattern based on proximal, at the level, and distal examination of the lesion. The triphasic or high-resistance biphasic pattern reflects vessel wall integrity in the absence of arterial injury. In contrast, abnormal spectral patterns, such as a low-resistance monophasic or biphasic, monophasic "*tardus parvus*," bidirectional or obstructive patterns suggest a probable vascular lesion, and CTA or surgical exploration should be performed. Our proposed ALTUA algorithm with standardization of the diagnostic approach based on spectral patterns is not ready for wide application. The clinical usefulness of the ALTUA algorithm needs to be validated in other populations and prospective cohort studies with the gold standard for confirming traumatic extremity artery injury to define the sensitivity and specificity of the ALTUA algorithm.

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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 they followed their center's protocol for sharing patient data.

Right to privacy and informed consent. Informed consent was not required for this observational study of information collected during routine clinical care.

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