An Update on Doppler Ultrasound of Vertebral Arteries: Subclavian Steal Syndrome

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Abstract

The subclavian steal syndrome refers to a vascular disorder in which there is reversal of blood flow to the ipsilateral vertebral artery, caused by a stenosis proximal to its origin, usually an occlusion of the subclavian artery or, more rarely, of the brachiocephalic trunk. It is a relatively rare disease, reported in approximately 6% of asymptomatic patients with cervical murmurs. Pulsed Doppler (PW) is useful in the analysis of the vertebral artery, capable of providing information to identify the presence of the subclavian steal syndrome. Based on the hemodynamic changes of the vertebral artery assessed by spectral Doppler, there are three types of subclavian steal: latent, intermittent and complete (permanent). With the advent of transluminal percutaneous angioplasty, and then, the stents, many specialists advocate this combination of procedures such as the treatment of choice for symptomatic cases of this disease.

Introduction

The subclavian steal syndrome occurs when there is reversal of flow in the ipsilateral vertebral artery distal to a stenosis or occlusion of the proximal subclavian, or, more rarely, the innominate artery. Arteriosclerosis is the leading cause for occlusive disease involving the subclavian artery.[1] Smoking is present in 78% to 100% of the cases and concomitant coronary artery disease in 27% to 65% of cases.[2] The most common location of atherosclerotic lesions that cause reverse flow in the vertebral artery is in the proximal portion of the left subclavian artery.[1] Zimmerman reported a 3:1 ratio between the symptomatic lesions in the left subclavian artery and the right subclavian artery[3] The right subclavian artery and the innominate artery are less common sites for atherosclerotic lesions that can result in subclavian steal[1]. Kirsanov et al.[4] reported three cases of deformities in the subclavian arteries associated with subclavian steal syndrome.

Because of the reduction of pressure in the subclavian artery distal to the obstruction, blood flows antegradely up the contralateral vertebral artery, into the basilar artery, and retrogradely down the ipsilateral vertebral artery to supply collateral circulation to the upper extremity (Figure 1). Thus, blood supply is "stolen" from the basilar system and may compromise cerebral blood flow.[5] Approximately 20% of the cerebral blood is supplied by cerebral arteries.[1]

Keywords

Ultrasonography, Doppler, Pulsed/methods; Vertebral Artery/physiopathology; Subclavian Steal Syndrome; Angioplasty; Stents.

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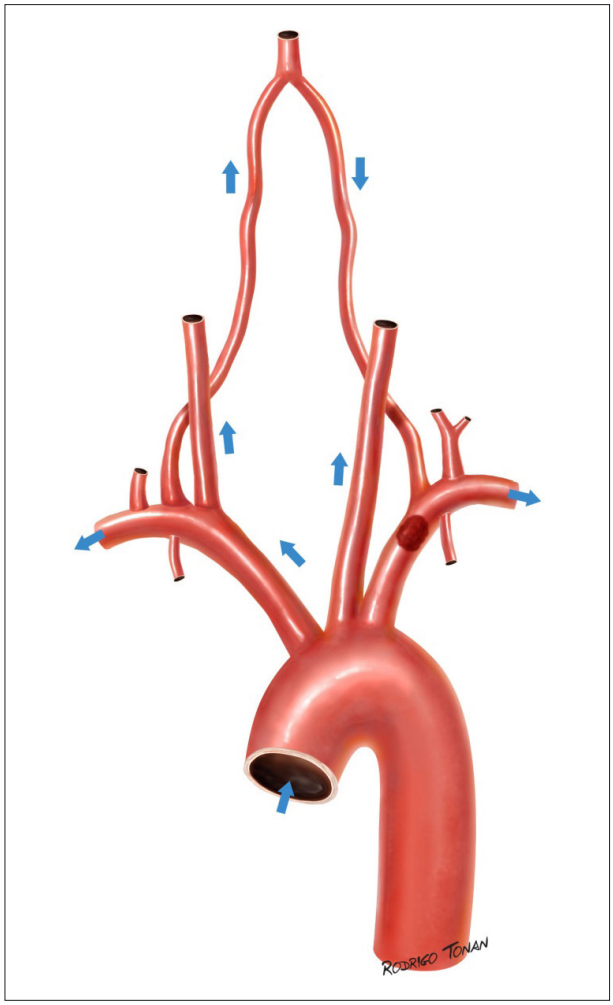

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Figure 1 – *Schematics showing the blood flow from the left vertebral artery to the ipsilateral subclavian artery.*

Contorni is credited with reporting the first angiographic visualization of subclavian steal in 1960.[6] Reivichi et al.[7] reported, in 1961, about two patients with clinical signs of cerebral vascular insufficiency associated with reversal of flow through the vertebral artery secondary to subclavian obstruction. However, it was Fisher who coined the term *subclavian steal syndrome* in a subsequent editorial published in the New England Journal of Medicine.[8] Contorni[9] reported that as early as 1829, Harrison had realized the importance of vertebral artery circulation in occlusions of the first segment of the subclavian artery, and eventually calling it Harrison and Smith Syndrome. However, this term, suggested by Contorni, failed to stick. It is slightly more prevalent in men than in women, at an average age of around 60.[2,10]

Symptoms

It is a relatively rare disease, reported in approximately 6% of asymptomatic patients with cervical murmurs.[11] The most common symptoms in the subclavian steal syndrome are vertigo, syncope, and intermittent claudication of the ipsilateral upper extremity. [1] The reversal of the blood flow in the vertebral artery rarely results in permanent neurological damage. It is mostly asymptomatic.[12] Many of the reported symptoms may be associated with severe carotid artery disease.[1] In 1996, Lacey[2] reported that symptomatic lesions in the subclavian artery were also associated with concomitant lesions in the contralateral vertebral artery and one or both carotid arteries for 35% to 85% of the patients.

Although widely used, the term *subclavian steal syndrome* should be applied when the reverse flow in the vertebral artery causes symptoms of vertebrobasilar hypoperfusion and/or upper limb ischemia.[1] In its asymptomatic forms, usually hidden and intermittent, or partial, the most correct would be to delete the word *syndrome*, leaving only the expression *subclavian steal*.

Diagnosis

The pulsed Doppler (PW) is useful in the analysis of the vertebral artery, as it is capable of providing information to identify the presence of the subclavian steal syndrome. One of the main objectives of the Doppler imaging of the vertebral arteries is to detect the reversed blood flow, thus indicating the subclavian steal phenomenon.[13] The vertebral artery is identified by locating the right common carotid artery in a sagittal plane and moving the transducer laterally toward the transverse processes of the cervical spine, where it can be displayed using a color Doppler.[14] It is noteworthy, however, that ultrasound imaging is not accurate for identification of focal stenosis.[15]

Classification

Based on the hemodynamic changes in vertebral artery assessed by the study with spectral Doppler, three types of subclavian steal may be identified.[16]

Type 1 – Latent Steal[16] (Minimum hemodynamic changes)

The spectral Doppler analysis of the vertebral artery may show a anterograde flow with a mid-systolic deceleration (Figure 2), which can convert temporarily to a wave pattern even more abnormal in response to reactive hyperemia in the ipsilateral upper limb after exercise.[13,16] Figure 3 shows the relationship between the spectral curve (PW) of the vertebral artery with the heart cycle.

Type 2 – Intermittent or Partial Steal[16] – Moderate hemodynamic changes

The spectral Doppler analysis of the vertebral artery shows a partially reversed flow (Figure 4). In both the latent steal and intermittent or partial steal, Doppler spectrum can form an image that resembles the profile of a "rabbit"[13] the so-called "*bunny waveform*".[14] Figure 5 shows the relationship between the spectral curve (PW) of the vertebral artery and the heart cycle.

Type 3 – Complete (Permanent) Steal[16] – (Significant hemodynamic changes)

The spectral Doppler analysis of the vertebral artery shows a completely reversed flow (Figure 6). It may be associated with symptoms in the ipsilateral upper limb.[13]

Treatment

The subclavian steal syndrome has traditionally been treated with surgery. However, with recent advances in percutaneous transluminal angioplasty (PTA), this has been a reasonable alternative to surgical treatment. Other methodologies, such as atherectomy, are also applicable. This aims to permanently restore the anterograde flow in the affected vertebral artery, eliminating the cerebral hypoperfusion and thus the symptoms. The treatment of asymptomatic cases of subclavian steal is questionable.

Modalities

Carotid-subclavian bypass

Subclavian carotid transposition

Axillary-axillary bypass

Carotid endarterectomy

Atherectomy

Percutaneous transluminal angioplasty (PTA) with stent placement.

The extrathoracic extra-anatomic bypass has been the traditional surgical treatment of choice, but it poses a significant risk of morbidity and mortality. With the advent of PTA, in 1980, and then, followed by the stents, many claim this combination of procedures as being of choice.[15]

Authors' contributions

Manuscript writing: Passos MD, Alves LM, Jesus PC, Junqueira Jr LF, Vasconcelos DF; Critical revision of the manuscript for major intellectual content: Passos MD, Alves LM, Jesus PC, Junqueira Jr LF, Vasconcelos DF; Revision of bibliography: Passos MD, Alves LM, Jesus PC, Junqueira Jr LF, Vasconcelos DF.

Potential Conflicts of Interest

No relevant conflicts of interest.

Academic association

This study is not associated to graduate programs.

Sources of funding

This study had no external funding sources.

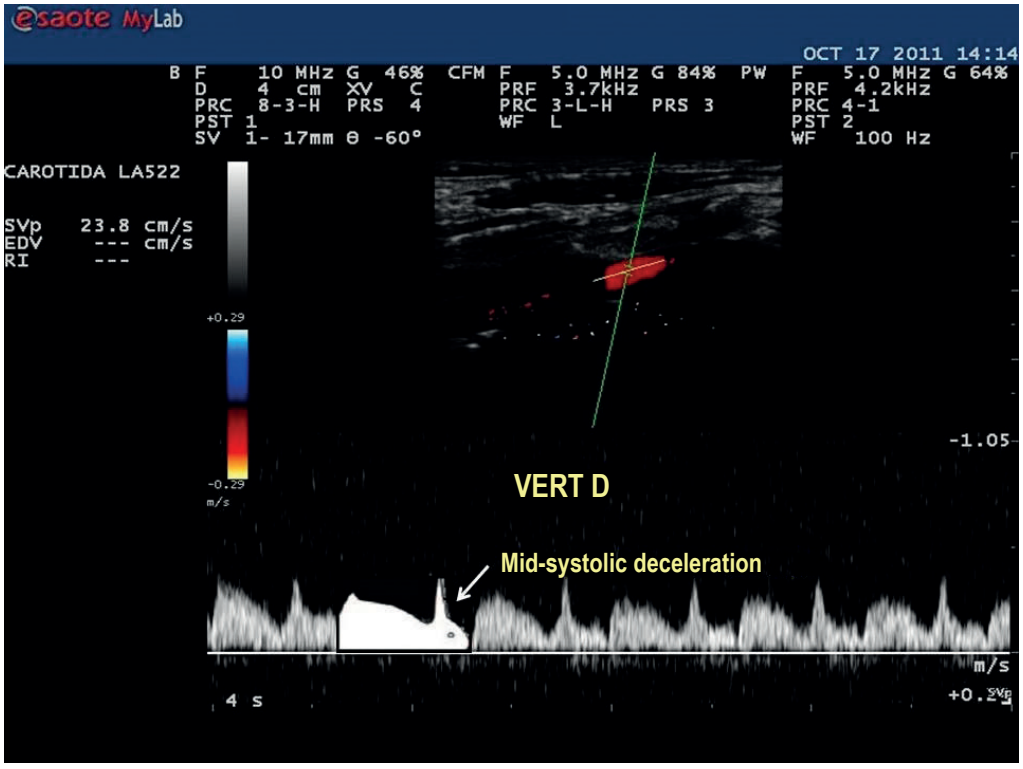

Figure 2 – *Spectral Doppler (PW) imaging of the right vertebral artery showing mid-systolic deceleration ("Bunny Waveform") consistent with type 1 steal (latent),[15] also known as hidden subclavian steal. Reactive hyperemia maneuvers may intensify the phenomenon.[12,15]*

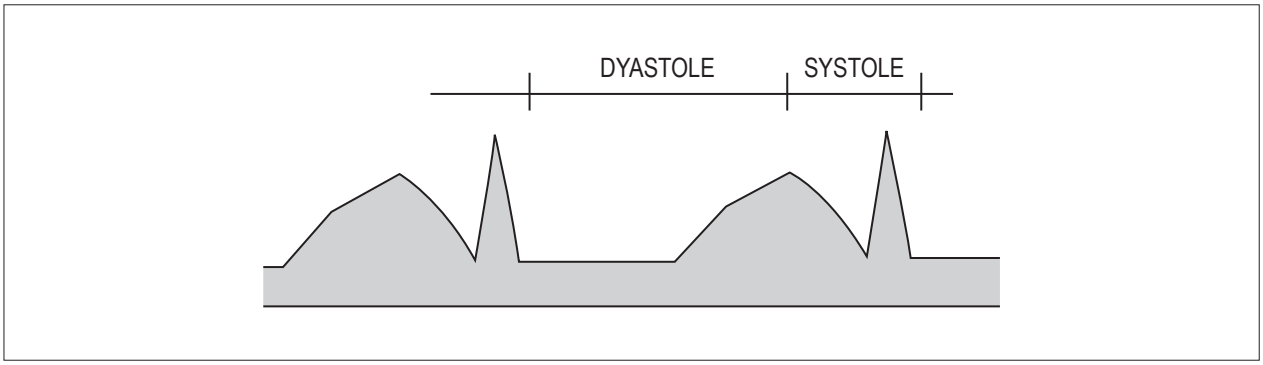

Figure 3 – *Relationship between the spectral curve (PW) of the vertebral artery and the heart cycle. This waveform shows a sharper and deeper "cleft" between the two systolic peaks. Nadir of mid-systolic cleft is at or slightly below the end-diastolic velocity. Modified from Kliewer et al.[12]*

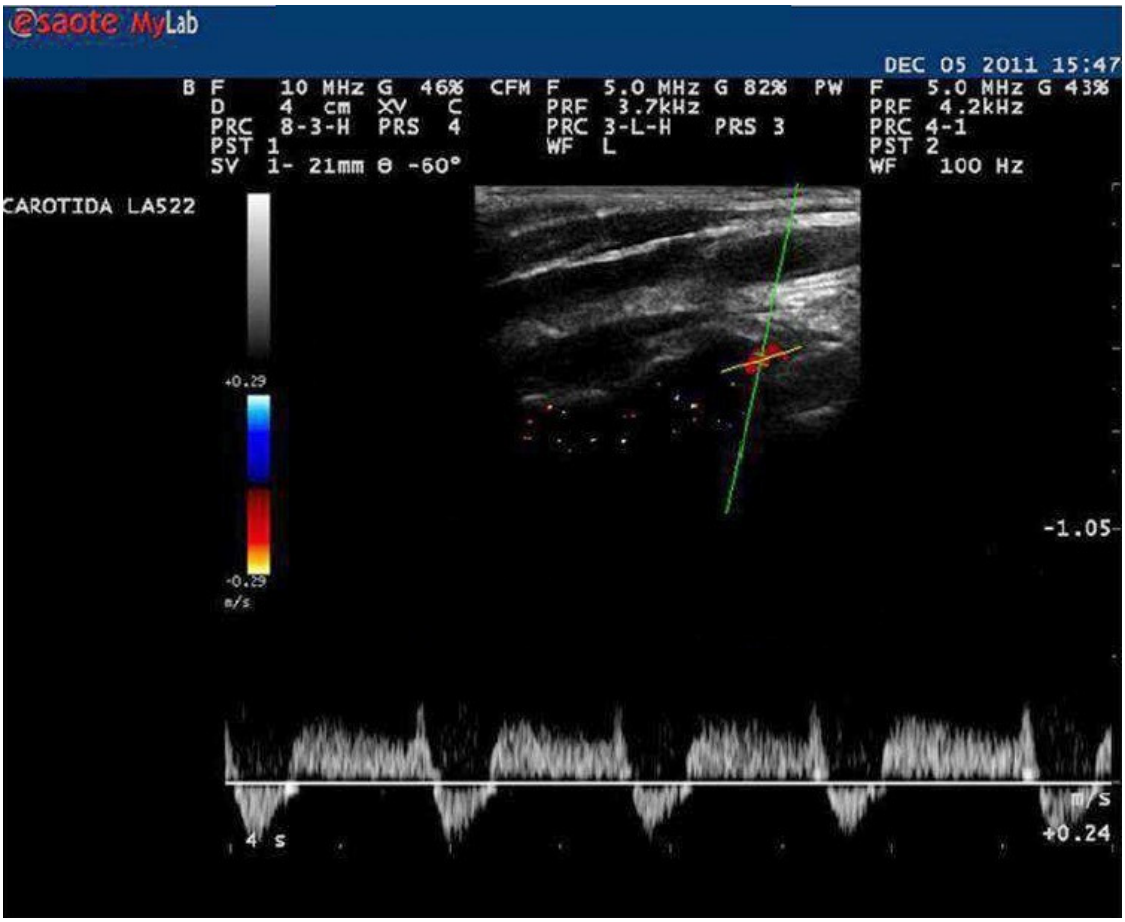

Figure 4 – *Spectral Doppler (PW) imaging of the right vertebral artery shows partially reversed flow, consistent with type 2 steal (intermittent or partial).*[15]

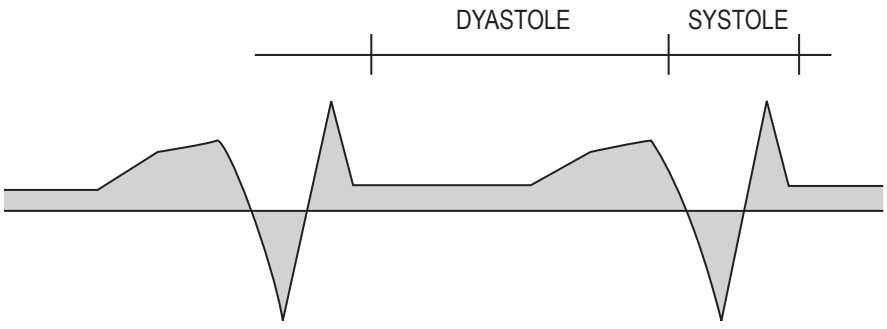

Figure 5 – *Relationship between the spectral curve (PW) of the vertebral artery and the heart cycle. Nadir of mid-systolic cleft falls well below baseline, which means a higher reversal of blood flow during systole. Modified from Kliewer et al.*[12]

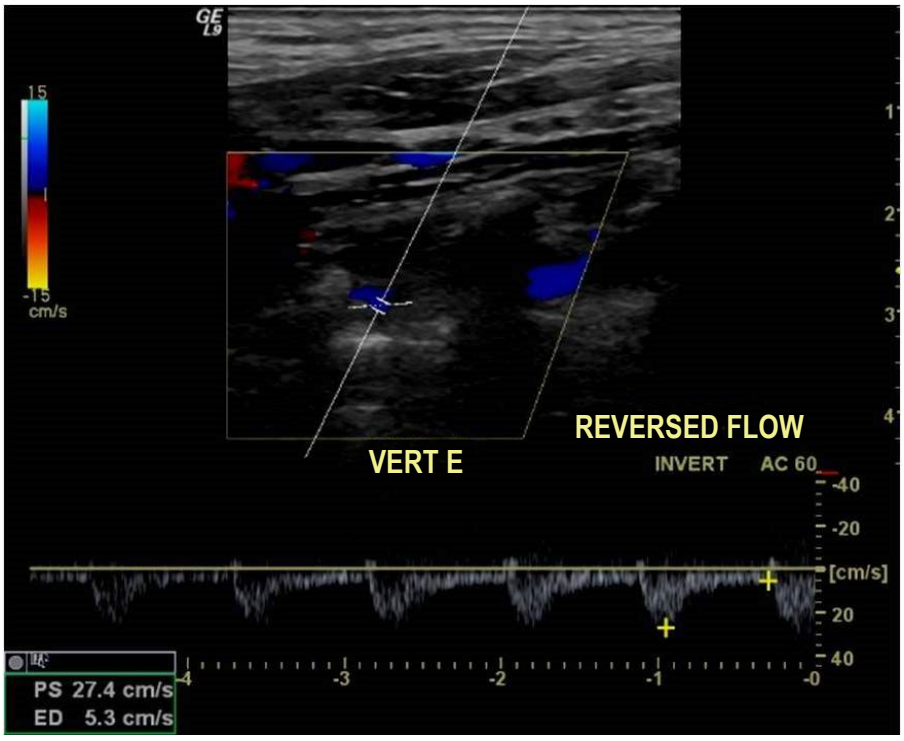

Figure 6 – *Spectral Doppler (PW) imaging of the left vertebral artery shows completely reversed flow, which is consistent with type 3 steal (complete).*[15]

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