Subclavian Artery Stenosis: A Case Series and Review of the Literature

Javier Reyna, MD,[1] Julio G. Peguero, MD,[1] Hany M. Elmahdy, MD,[2] Orlando Santana, MD,[1] Cesar Conde, MD[1]

[1]Columbia University Division of Cardiology at Mount Sinai Heart Institute, Miami Beach, FL; [2]Department of Medicine, Mount Sinai Medical Center, Miami Beach, FL

Subclavian artery stenosis (SAS) is a significant form of peripheral artery disease, which may be a marker of diffuse atherosclerosis and increased risk for cardiovascular events. SAS can lead to symptomatic ischemia affecting the upper extremities, the brain, and, in some cases, the heart. In general, asymptomatic subclavian artery disease is treated with medical therapy and invasive treatment is reserved for the more symptomatic patients. This article discusses the evaluation of four patients with varying presentations of subclavian artery disease.

[Rev Cardiovasc Med. 2014;15(2):189-195 doi: 10.3909/ricm0723]

KEY WORDS

Subclavian artery stenosis • Subclavian steal syndrome • Coronary steal syndrome

The assessment of peripheral artery disease typically focuses on the evaluation of the lower extremities as clinically significant ischemic disease is less frequent in the upper extremities. However, subclavian artery stenosis (SAS) is a significant form of peripheral artery disease, which may be a marker of diffuse atherosclerosis and increased risk for cardiovascular events. The incidence of SAS in the general population is approximately 2% to 7%,[1] with atherosclerosis being the most common cause of this condition.[2,3] SAS can lead to symptomatic ischemia affecting the upper extremities, the brain, and (in some cases) the heart, when the left internal mammary artery (LIMA) is used as a graft during coronary artery bypass graft surgery (CABG).[3]

Variations of SAS include subclavian steal syndrome (SSS) and coronary-subclavian steal syndrome (CSS). SSS is defined as a clinical manifestation of hemodynamically significant SAS. SSS

arises due to reversal of flow in the vertebral artery as blood is shunted to the upper extremity circulation. In CSS there is reversal of flow within the LIMA because of proximal subclavian stenosis. The diagnosis may be suspected on physical examination when there is a blood pressure difference between both arms (typically > 15 mm Hg), and/or the pulses are absent or significantly diminished, but the definitive diagnosis is typically based on imaging. In general, asymptomatic subclavian artery disease is treated with medical therapy and invasive treatment is reserved for the more symptomatic patients. Herein, we present a case series of four patients evaluated at our institution with varying presentations of subclavian artery disease. A review of the literature is discussed with emphasis on the pathophysiology, presenting symptoms, diagnosis, and treatment options.

Case 1: Subclavian Artery Stenosis

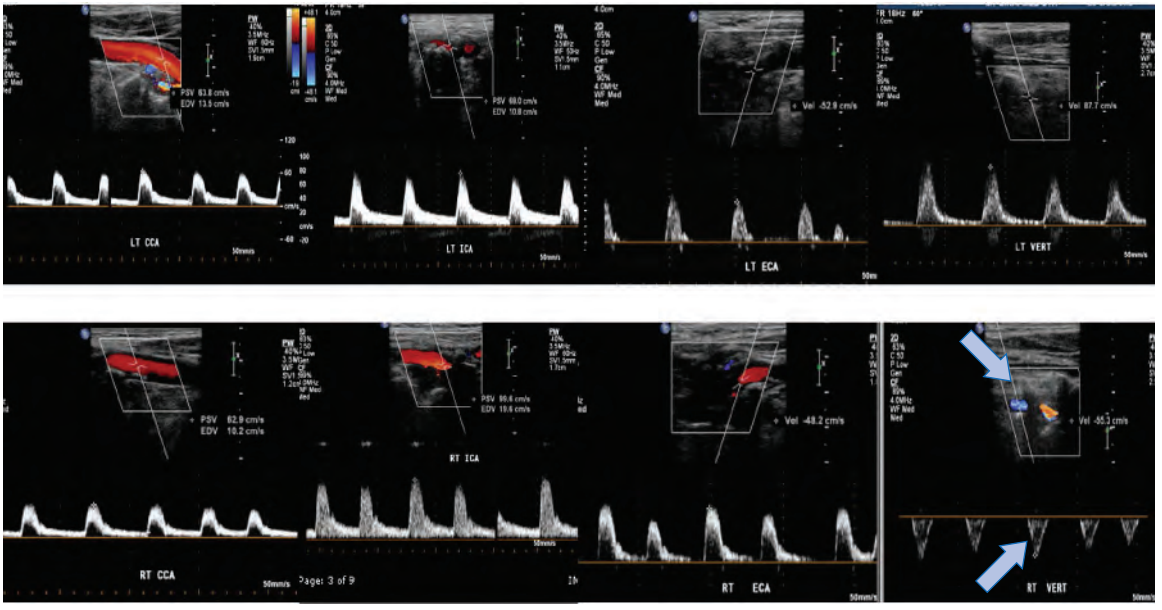
A 92-year-old woman with a history of hypertension presented with recurrent episodes of flash pulmonary edema. Occlusive coronary artery disease was excluded, but significant right renal artery stenosis was identified by renal artery angiography. Stenting of this lesion resolved the episodes of acute pulmonary edema. She was stable for 2 years until her primary care physician diagnosed low blood pressure in the right upper extremity. Hypertension medications were initially reduced and eventually discontinued. She subsequently developed dyspnea on exertion, edema of the lower extremities, and headaches, and was found to have low blood pressure in the right upper extremity but elevated blood pressure in the left upper extremity (100/70 mm Hg and 180/100 mm Hg, respectively). A Doppler ultrasound of the upper extremities was performed, which revealed a right-sided SAS (Figure 1). The decision was to adjust her antihypertensive therapy accordingly, which controlled her symptoms without invasive intervention.

In general, asymptomatic subclavian artery disease is treated with medical therapy and invasive treatment is reserved for the more symptomatic patients.

Etiology, Epidemiology, and Initial Clinical Diagnosis

The subclavian arteries are two major vessels derived from the arch of the aorta. They supply blood to the left and the right arm, with some branches supplying the head and thorax. On the left side of the body, the subclavian artery comes directly off the arch of aorta whereas on the right, it arises from the relatively short brachiocephalic artery, which bifurcates into the subclavian and the right common carotid artery. The branches of the subclavian on both sides of the body are the vertebral artery, the internal thoracic artery, the thyrocervical trunk, the costocervical trunk, and the dorsal scapular artery. The subclavian artery becomes the axillary

Figure 1. Carotid ultrasound Doppler demonstrates upright forward flow in all left cerebrovascular vessels in the *top panel*. The *bottom panel* illustrates upright flow in all vessels, except the retrograde right vertebral artery flow (*arrow*).



artery at the lateral border of the first rib.

The reported prevalence of SAS varies. Aboyans and colleagues[2] described a cross-sectional analysis that included 6814 subjects aged 45 to 84 years who were free of clinical cardiovascular disease at baseline, and determined that the prevalence of SAS was approximately 4.5%. This study also demonstrated that SAS is more common in women and in African Americans, and that a close relationship exists between SAS and other cardiovascular risk factors. In another cross-sectional analysis, the incidence of SAS was reported to be between 2% and 7%, as just mentioned.[1]

. . . SAS is more common in women and in African Americans, and a close relationship exists between SAS and other cardiovascular risk factors.

The main etiology of SAS is atherosclerotic disease. Other, less frequent causes include Takayasu arteritis, postsurgical or postradiation stenosis, and anatomic anomalies.[4-6] SAS usually develops in the elderly, due to the higher prevalence of atherosclerotic disease in this population. It is more common in the left subclavian artery with a ratio of 3:1 to 4:1,[3,7] which is attributed to a sharper origin of the artery leading to an increased flow turbulence that results in accelerated plaque formation.[8]

On physical examination, blood pressure difference between both arms is the hallmark for subclavian artery disease. A blood pressure difference of 10 to 15 mm Hg indicates the need for further evaluation, whereas a blood pressure difference $>$ 15 mm Hg is a better indicator for vascular disease and death, with a sensitivity of 15% and a specificity of 96% for diagnosing significant lesions.[9] A greater blood pressure difference $>$ 40-50 mm Hg) between arms is associated with more severe symptoms, and correlates with the need for intervention.[10] The physical examination should also include palpation of distal pulses, skin examination for signs of distal embolization, supraclavicular auscultation, and thoracic outlet maneuvers to rule out other possibilities of subclavian obstruction. Dynamic exercise and reactive hyperemia can also be used to induce the symptoms and aid in the diagnosis.[11] Significant SAS may lead to limb ischemia, muscle pain, fatigue, and numbness in the arm.[12,13]

Case 2: Subclavian Steal Syndrome

A 78-year-old woman with history of hypertension complained of weakness, lightheadedness, and worsening left upper extremity discomfort over the past few months. The initial physical examination revealed a systolic blood pressure difference of 40 mm Hg between the upper extremities. Doppler ultrasound demonstrated a near total occlusion of the left subclavian artery with stage III retrograde flow (Figure 2). A computed tomography angiogram of the arch of the aorta showed severe left SAS with subsegmental disease (Figure 3). Due to the complex anatomy, a carotid to subclavian graft was performed, which resolved all of the patient's symptoms.

Pathophysiology and Diagnosis of Subclavian Steal Syndrome

When there is a significant obstruction at the proximal segment of the subclavian artery, the pressure drops distal to the obstruction. This leads to change in the blood flow direction and blood being "stolen" from the proximal branches of the artery to the distal vascular beds.[14] Reversal of flow throughout the vertebral artery of the subclavian artery and its associated symptoms is referred to as SSS. However, if there is SAS with reversal of flow but no clinical manifestation of the disease, it is referred to as subclavian steal phenomenon.[3]

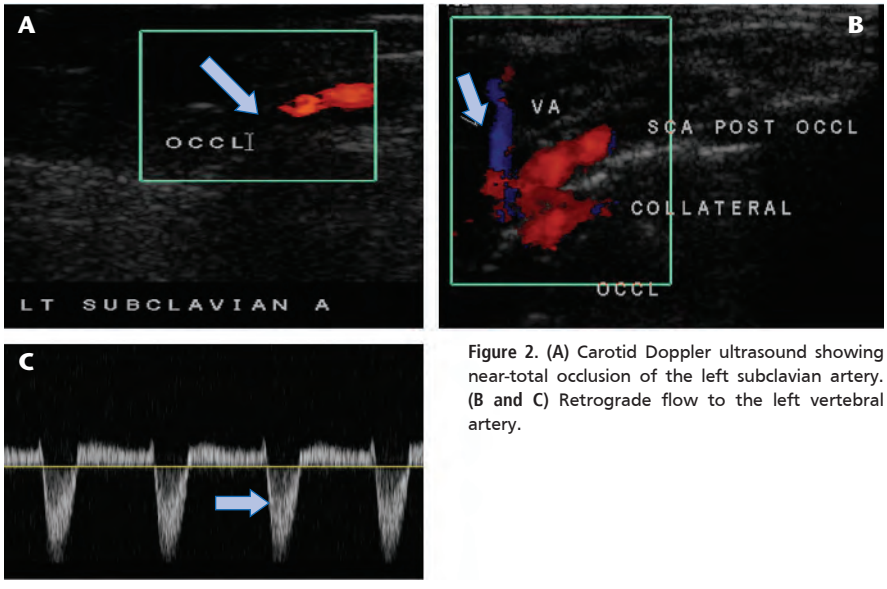


Figure 2. **(A)** Carotid Doppler ultrasound showing near-total occlusion of the left subclavian artery. **(B and C)** Retrograde flow to the left vertebral artery.

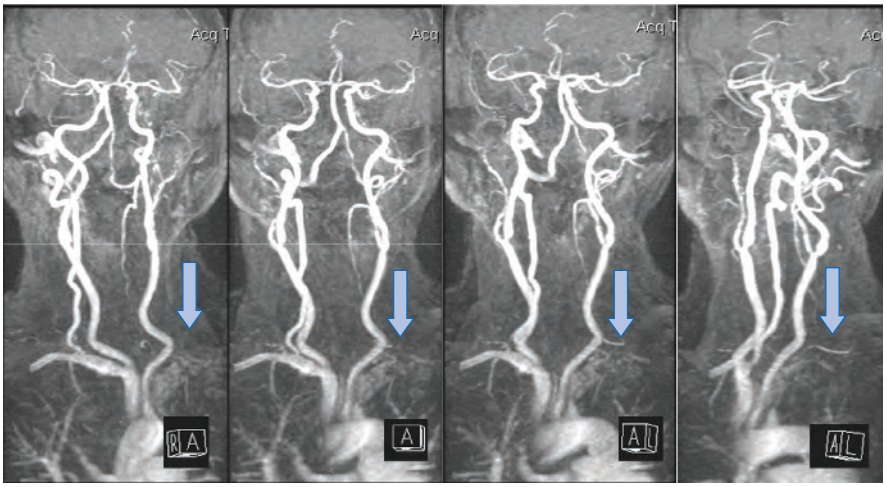


Figure 3. Computed tomography angiogram illustrating different angles of severe proximal and segmental left subclavian artery stenosis.

The clinical manifestations of SSS depend on several factors, including the etiology, degree of the obstruction, and the vessel from which the subclavian artery is receiving major retrograde flow. The frequency of symptoms directly correlates with the severity of the stenosis. They are usually symptoms related to poor posterior cerebral circulation perfusion (vertebrobasilar ischemia), which can manifest with various symptoms, including dizziness, vertigo, and ataxia,[15] but it can also manifest with arm claudication if the blood supply to the arm is inadequately compensated, especially during arm exercise.

Walker and colleagues[16] made the interesting observation that the presence of symptoms is not entirely based on SAS and reversal of vertebral blood flow, and there needs to be another vascular lesion; the presence of neurologic symptoms requires another intracranial arterial defect as the circle of Willis is not always complete, whereas arm claudication can be secondary to another coexisting anatomic abnormality such as aberrant vertebral artery origin. SSS or CSS can also be seen when there is increased blood flow to the ipsilateral arm where the lesion is located, as is seen in patients with arteriovenous fistulas for hemodialysis.[17,18]

When the blood flow is coming from the ipsilateral vertebral artery, the severity of the disease can be classified into three different stages that correlate with the degree of stenosis. Stage I is referred to as pre-subclavian steal, which is defined as reduced anterograde vertebral flow with complete interruption during hyperemia test. Stage II is referred to as intermittent or latent SAS, which is defined as alternating flow to and from, during diastole and systole. Stage III is defined as permanent retrograde flow throughout the cardiac cycle.[19]

Doppler and duplex ultrasonography are the tests of choice to diagnose SAS and steal phenomenon.[20] These techniques provide accurate information about the flow of the vertebral artery. Doppler ultrasound can also be combined with hyperemia testing to induce flow reversal if suspicion is high and retrograde flow is not found in the initial evaluation.[21]

Computed tomography or magnetic resonance angiography may be used as confirmatory tests after SAS has been suggested by clinical examination and/or Doppler ultrasound. In addition to confirming the presence of the stenosis, they add valuable information about the detailed anatomy of the vessels, and the presence of other lesions in the posterior and anterior circulation of the brain.[8,22]

Case 3: Coronary Steal Syndrome

A 74-year-old man with a history of abdominal aortic aneurysm and CABG surgery presented to the hospital with an acute coronary syndrome. In the emergency department his right upper extremity blood pressure was 130/30 mm Hg whereas the left upper extremity blood pressure was 70/40 mm Hg. A cardiac catheterization demonstrated severe disease of all venous bypass grafts, and reversal of flow from the LIMA graft to the subclavian artery (Figure 4). Angiography of the aortic arch identified a significant segmental occlusion of the left subclavian artery (Figure 5). The patient underwent a reoperative CABG surgery but did not survive. In retrospect, a possible alternative in the treatment of this patient may have been to restore anterograde flow of the LIMA by treating the SAS.

Doppler and duplex ultrasonography are the tests of choice to diagnose SAS and steal phenomenon.

Besides the vertebrobasilar steal phenomenon seen in SAS, the blood can also be stolen from the internal mammary arteries, and is usually asymptomatic. However, if the mammary artery is used as a bypass graft, retrograde blood flow can steal blood from the coronary

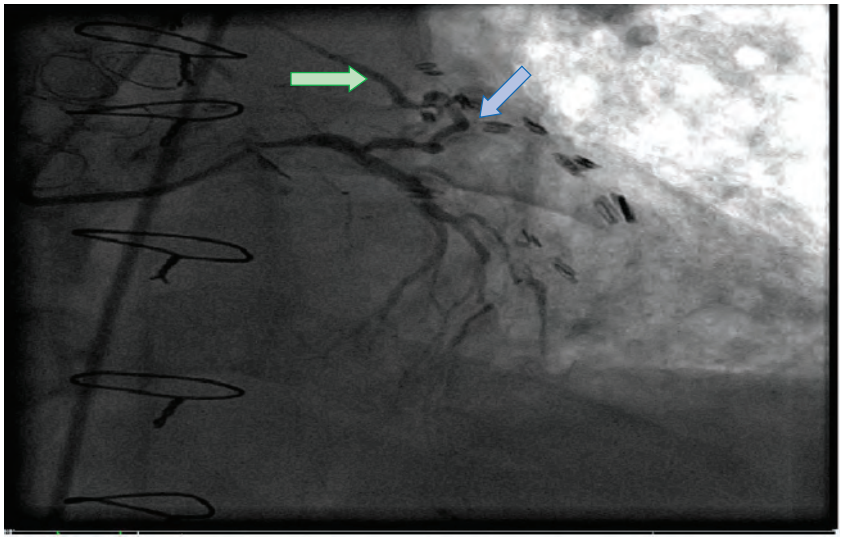


Figure 4. Left coronary artery angiogram with retrograde flow from left anterior descending (LAD) coronary artery to left internal mammary artery (LIMA) graft. *Blue arrow:* LIMA to LAD anastomosis. *Green arrow:* retrograde flow from LAD to LIMA.

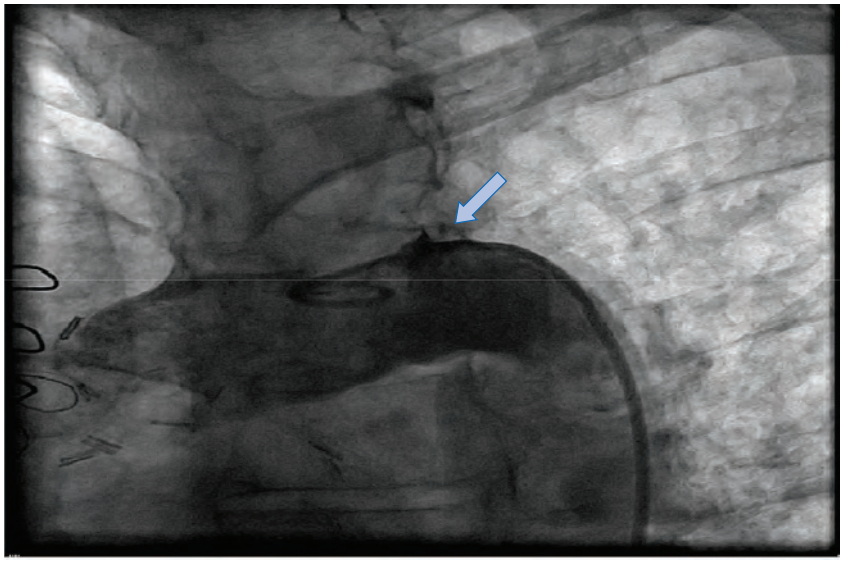


Figure 5. Aortogram showing left subclavian artery stenosis (*arrow*).

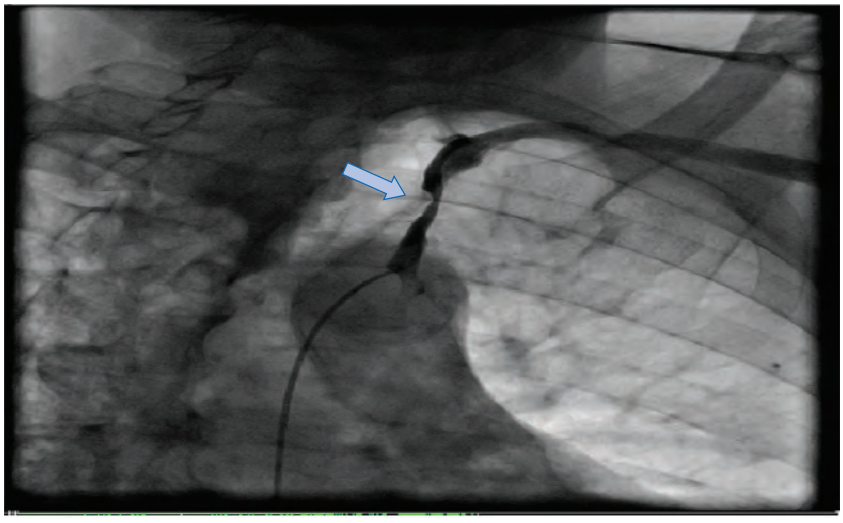


Figure 6. Left subclavian artery angiogram showing severe stenosis (*arrow*).

circulation, causing angina and myocardial ischemia, and is termed CSS.[23,24] After its first description by Harjola and Valle,[25] the importance of this entity has led some institutions to screen for SAS before using the mammary arteries for CABG surgery.[13,23]

Case 4: Prevention of Coronary Artery Steal Syndrome

A 72-year-old man, who was a smoker with hypertension and peripheral vascular disease, presented to the emergency department with an acute coronary syndrome. Coronary angiography showed severe multivessel coronary artery disease and CABG surgery was recommended. Because he had a history of peripheral vascular disease, an aortic arch angiogram was performed during coronary angiography, and a moderate to severe left-sided SAS was diagnosed (Figure 6). He underwent stenting of the left subclavian artery (Figure 7) and the LIMA was then used successfully as part of his CABG surgery.

Treatment of Subclavian Artery Stenosis

If SAS is asymptomatic, medical therapy to control the risk factors and avoid progression of the disease is recommended. Invasive treatment may be necessary in symptomatic patients in whom symptoms cannot be controlled by medical therapy alone. As discussed, the degree of stenosis, symptomatology, and blood pressure difference play a role in the treatment course. The aim of invasive treatment is to restore anterograde flow of the vertebral or mammary artery, thus avoiding steal and ischemia to the distal organs. The different modalities of surgical repair include carotid-subclavian

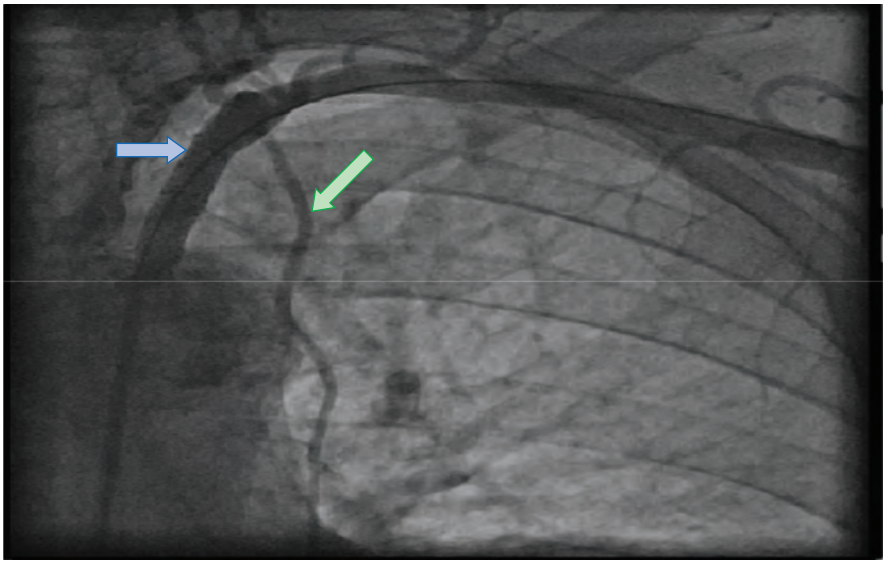


Figure 7. Left subclavian artery angiogram after stent placement (*blue arrow*) with restored flow to the left internal mammary artery graft (*green arrow*).

bypass, subclavian-carotid transposition, axilloaxillary bypass, and subclavian-subclavian bypass.[26] Percutaneous strategies utilized include angioplasty and/or stenting; stenting after angioplasty has the advantage of improving the long-term patency without significant increase in major complications.[27] Surgical approaches have been traditionally the treatment of choice and are associated with decreased restenosis at the expense of slightly increased perioperative mortality. Angioplasty has gained increased attention due to safety and availability, but is associated with a 10.3% restenosis rate at a mean follow-up period of 27 ± 20 months,[28] with a rate of restenosis between 6% and 21%.[29] When performed in conjunction with stenting, a higher success rate and low complications are achieved with reasonable patency.[30] This approach is an acceptable option in patients with a short stenotic segment at the origin of the subclavian artery, whereas surgical correction is preferred if there is a more extensive lesion or multiple lesions.[8]

Conclusions

Awareness of SAS and its clinical presentations is important. The diagnosis may be suspected by physical examination and confirmed by noninvasive tests. Asymptomatic SAS can be treated medically. However, SAS and CSS may benefit from more invasive interventions. Prompt diagnosis and adequate treatment of SAS can prevent significant morbidity, and possibly mortality, in these patients. ■

References

1. Shadman R, Criqui MH, Bundens WP, et al. Subclavian artery stenosis: prevalence, risk factors, and association with cardiovascular diseases. *J Am Coll Cardiol*. 2004;44:618-623.
2. Aboyans V, Kamineni A, Allison MA, et al. The epidemiology of subclavian stenosis and its association with markers of subclinical atherosclerosis: the Multi-Ethnic Study of Atherosclerosis (MESA). *Atherosclerosis*. 2010;211:266-270.
3. Osiro S, Zurada A, Gielecki J, et al. A review of subclavian steal syndrome with clinical correlation. *Med Sci Monit*. 2012;18:RA57-RA63.
4. Yoneda S, Nukada T, Tada K, et al. Subclavian steal in Takayasu's arteritis. A hemodynamic study by means of ultrasonic Doppler flowmetry. *Stroke*. 1977;8:264-268.
5. Saalouke MG, Perry LW, Breckbill DL, et al. Cerebrovascular abnormalities in postoperative coarctation of aorta. Four cases demonstrating left subclavian steal on aortography. *Am J Cardiol*. 1978;42:97-101.

MAIN POINTS

- Subclavian artery stenosis (SAS) is a significant form of peripheral artery disease, which may be a marker of diffuse atherosclerosis and increased risk for cardiovascular events. It can lead to symptomatic ischemia affecting the upper extremities, the brain, and, in some cases, the heart.
- Variations of SAS include subclavian steal syndrome (SSS) and coronary-subclavian steal syndrome (CSS). SSS is defined as a clinical manifestation of hemodynamically significant SAS and arises due to reversal of flow in the vertebral artery as blood is shunted to the upper extremity circulation; the diagnosis of CSS may be suspected on physical examination when there is a blood pressure difference between both arms.
- Medical therapy to control the risk factors of SAS and avoid progression of the disease is recommended; invasive treatment may be necessary in symptomatic patients in whom symptoms cannot be controlled by medical therapy alone.
- Surgical approaches have been traditionally the treatment of choice and are associated with decreased restenosis at the expense of slightly increased perioperative mortality; angioplasty has gained increased attention due to safety and availability, but is associated with a 10.3% restenosis rate at a mean follow-up period of 27 ± 20 months.

6. Kajinami K, Mori K, Masuda S, et al. Asymptomatic congenital subclavian steal in a young male patient with right aortic arch. *Chest*. 1990;97:481-482.
7. Zimmerman NB. Occlusive vascular disorders of the upper extremity. *Hand Clin*. 1993;9:139-150.
8. Spittell PC. Subclavian steal syndrome. UpToDate Web site. http://www.uptodate.com/contents/subclavian-steal-syndrome. Accessed April 20, 2014.
9. Clark CE, Taylor RS, Shore AC, et al. Association of a difference in systolic blood pressure between arms with vascular disease and mortality: a systematic review and meta-analysis. *Lancet*. 2012;379:905-914.
10. Labropoulos N, Nandivada P, Bekelis K. Prevalence and impact of the subclavian steal syndrome. *Ann Surg*. 2010;252:166-170.
11. Sharon M, Asinger RW, Hodges M. Reactive hyperemia for the clinical diagnosis of subclavian steal syndrome: report of a case. *Stroke*. 1981;12:369-371.
12. Hennerici M, Klemm C, Rautenberg W. The subclavian steal phenomenon: a common vascular disorder with rare neurologic deficits. *Neurology*. 1988;38:669-673.
13. Ochoa VM, Yeghiazarians Y. Subclavian artery stenosis: a review for the vascular medicine practitioner. *Vasc Med*. 2011;16:29-34.
14. Toole JF, McGraw CP. The steal syndromes. *Ann Rev Med*. 1975;26:321-329.
15. Lord RS, Adar R, Stein RL. Contribution of the circle of Willis to the subclavian steal syndrome. *Circulation*. 1969;40:871-878.
16. Walker PM, Paley D, Harris KA, et al. What determines the symptoms associated with subclavian artery occlusive disease? *J Vasc Surg*. 1985;2:154-157.
17. Bron C, Hirt L, Halabi G, et al. Asymptomatic high flow subclavian steal in a patient with hemodialysis access. *J Vasc Access*. 2010;11:63-65.
18. Crowley SD, Butterly DW, Peter RH, Schwab SJ. Coronary steal from a left internal mammary artery coronary bypass graft by a left upper extremity arteriovenous hemodialysis fistula. *Am J Kidney Dis*. 2002;40:852-855.
19. Branchereau A, Magnan PE, Espinoza H, Bartoli JM. Subclavian artery stenosis: hemodynamic aspects and surgical outcome. *J Cardiovasc Surg (Torino)*. 1991;32:604-612.
20. Kaneko A, Ohno R, Hattori K, et al. Color-coded Doppler imaging of subclavian steal syndrome. *Intern Med*. 1998;37:259-264.
21. Kliewer MA, Hertzberg BS, Kim DH, et al. Vertebral artery Doppler waveform changes indicating subclavian steal physiology. *Am J Roentgenol*. 2000;174:815-819.
22. Lum CF, Ilsen PF, Kawasaki B. Subclavian steal syndrome. *Optometry*. 2004;75:147-160.
23. Takach TJ, Beggs ML, Nykamp VJ, Reul GJ Jr. Concomitant cerebral and coronary subclavian steal. *Ann Thorac Surg*. 1997;63:853-854.
24. Nguyen NH, Reeves F, Therasse E, et al. Percutaneous transluminal angioplasty in coronary-internal thoracic-subclavian steal syndrome. *Can J Cardiol*. 1997;13:285-289.
25. Harjola PT, Valle M. The importance of aortic arch or subclavian angiography before coronary reconstruction. *Chest*. 1974;66:436-438.
26. Salam TA, Lumsden AB, Smith RB 3rd. Subclavian artery revascularization: a decade of experience with extrathoracic bypass procedures. *J Surg Res*. 1994;56:387-392.
27. Chatterjee S, Nerella N, Chakravarty S, Shani J. Angioplasty alone versus angioplasty and stenting for subclavian artery stenosis-a systematic review and meta-analysis. *Am J Ther*. 2013;20:520-523.
28. Li Y, Yin Q, Zhu W, et al. Endovascular stenting for atherosclerotic subclavian artery stenosis in patients with other craniocervical artery stenosis. *J Thromb Thrombolysis*. 2013;35:107-114.
29. Rogers JH, Calhoun RF 2nd. Diagnosis and management of subclavian artery stenosis prior to coronary artery bypass grafting in the current era. *J Card Surg*. 2007;22:20-25.
30. Crowe KE, Iannone LA. Percutaneous transluminal angioplasty for subclavian artery stenosis in patients with subclavian steal syndrome and coronary subclavian steal syndrome. *Am Heart J*. 1993;126:229-233.