



“SUBCLAVIAN STEAL SYNDROME” EMBRYOLOGICAL BASIS AND ITS CLINICAL SIGNIFICANCE

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ABSTRACT

The Subclavian Steal Syndrome is a condition in which the subclavian artery proximal to the origin of the vertebral artery is affected with stenosis or blockage. The blockage causes the reverse blood flow in the vertebral artery which is termed the "steal", because it steals blood from the cerebral circulation. Blood is drawn from the contralateral vertebral, basilar or carotid artery regions into the low-pressure ipsilateral upper limb vessels. The term subclavian steal syndrome is applied when reversed vertebral artery flow causes cerebral ischemia with associated symptoms of vertebrobasilar hypo perfusion and/or symptoms of brainstem or arm ischemia. This syndrome exists as an important consideration in the differential diagnosis of cerebral and brachial ischemia.

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Introduction

The Subclavian Steal Syndrome (SSS), also called subclavian steal phenomenon or subclavian steal stenocclusive disease, is due to a reverse blood flow in the vertebral artery or the internal thoracic artery [3]. This is due to the association with a proximal subclavian artery stenosis or blockage. It is a condition where both signs and symptoms are prevalent.

The clinical representation of the Subclavian Steal Phenomenon often involves high-grade stenosis or obstruction of the subclavian artery. This leads to a decrease in the Sino-Atrial pressure, distal to the lesion. If the stenosis is severe and if the affected arm is exerted, this pressure drop can cause the blood flow in the ipsilateral vertebral artery to reverse and thus hardening the blood from the unaffected SA node via the contralateral vertebral artery. This happens in order to ensure adequate blood supply to the involved arm is provided. Forceful exercise of the arm and a sudden turning of the head in the direction of the affected side, have so far been shown to worsen the symptoms [1].

Subclavian steal syndrome is frequently asymptomatic. It can be discovered on ultrasound, angiographic examination or it may be impelled by a clinical examination finding of reduced unilateral upper limb pulse or blood pressure [5]. In some cases, patients may present with development of upper limb ischemic symptoms, due to reduced arterial flow. This happens in the region of a subclavian artery blockage, or it can be due to the development of neurologic symptoms. This in turn is caused by the posterior circulation ischemia, associated with exercise of the ipsilateral arm [2].

Subclavian steal syndrome can be traditionally treated by open subclavian artery revascularization, typically via subclavian artery transportation or carotid-subclavian bypass. These are generally time consuming procedures. Newer, less

invasive options include: Endovascular intervention with recanalization, angioplasty and stenting [44].

Incidence

The clinical relevance of the subclavian steal syndrome was discovered in 1961 by Reivich, Holling and Roberts. Contorni was the first to recognize and describe this retrograde flow in 1961 using angiography in a patient who had an absent radial pulse [6-9]. A year later, Reivich associated this phenomenon with transient ischemic attack (TIA) and hence became the first scientist to correlate it with neurological symptoms. The term "subclavian steal", however, was coined by Fisher in 1961. This was after he reviewed Reivich's article and observed that the anomaly caused the ipsilateral subclavian artery to receive retrograde flow from the contralateral circulation, at the expense of the vertebrobasilar circulation [15].

Although peripheral arterial disease affects about 20-25% of individuals older than 70 years, the vessels of the upper extremity are affected much less often than those of the lower extremity are. Because, most of the patients are do not seek medical advices unless the symptoms occur. the true prevalence of subclavian artery occlusive disease and subclavian steal syndrome is unknown [10].

The left subclavian artery is the aortic arch branch vessel most commonly affected by atherosclerosis; therefore, it is not surprising that the left subclavian artery is involved with subclavian steal three times more frequently than the right subclavian artery [11-15].

In the joint Study of Extracranial Arterial Occlusion, Fields and Lemak found that 17% of the 6534 patients admitted In the joint Study of Extracranial Arterial Occlusion, Fields and Lemak found that 17% of the 6534 patients admitted to the study had arteriographic evidence of subclavian or innominate stenosis greater than 30% or occlusion.

However, only 168 patients had symptoms of subclavian steal syndrome. Berguer et al found that only half of their patients with significant subclavian occlusive lesions manifested reversal of blood flow in the ipsilateral vertebral artery [15].

Ontogenesis for the normal development of Subclavian artery and embryological basis for the Subclavian Steal Syndrome (SSS)

The aorta develops during the third week of gestation. The aorta develops in a complex process related to the formation of the endocardial tube at day 21. A primitive aorta is formed consisting of ventral and a dorsal segment that runs continuously through the first Aortic arch [16]. Both the ventral aortae fuse to form aortic sac and the dorsal aortae fuse to form midline descending Aorta. The six paired aortic arches develop between the dorsal and ventral aortae and in addition many intersegmental arteries are given off by dorsal aorta [36].

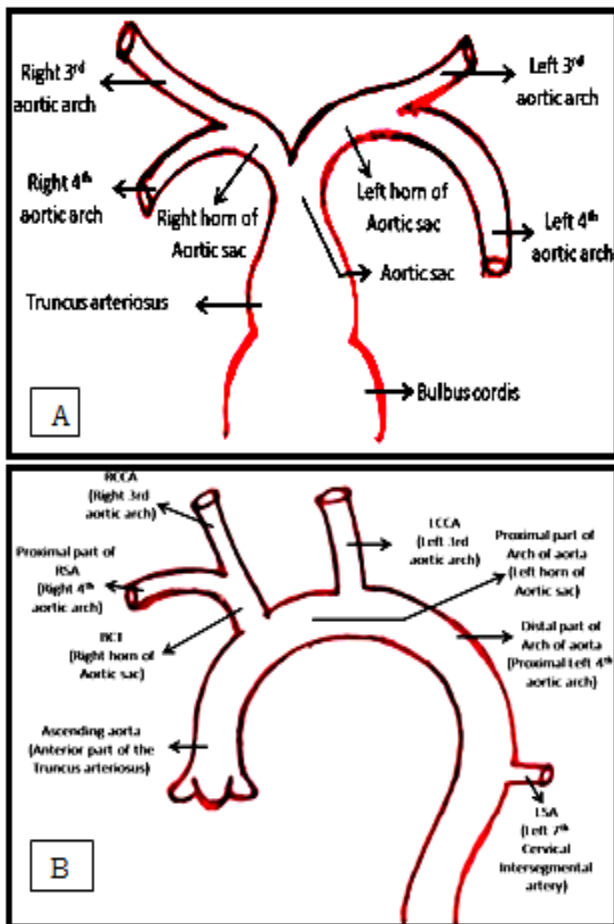


Fig 1. The derivatives of aortic arch arteries. A diagrammatic representation showing the Truncus arteriosus receives the third (III) and fourth (IV) sets (right and left) of Aortic arch arteries, ultimately it opens into the right and left horns of the Aortic sac and B. Derivatives of the Aortic sac horns and third (III) and fourth (IV) sets (right and left) of Aortic arch arteries. (BCT-Brachiocephalic trunk, RSA- Right subclavian artery, RCCA- Right Common carotid artery, LCCA- Left Common carotid artery and LSA-Right subclavian artery).

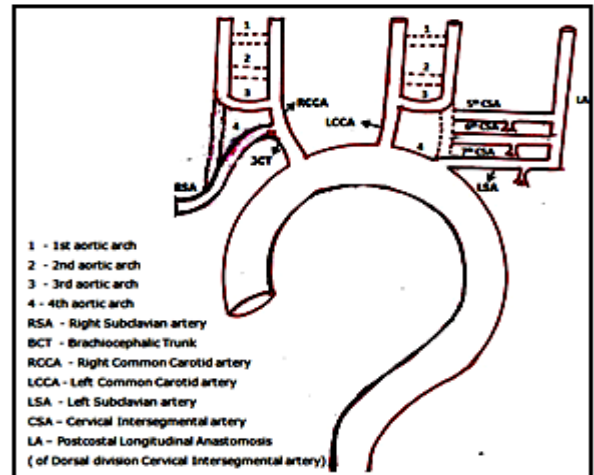


Fig 2. Diagrammatic representation of Aortic Arch and its branches.

The blood vessels derived from each of arch are as follows:

The first pair of blood vessels is assigned to formation of both the external carotid and maxillary arteries [18]. The second pair of blood vessels contributes to formation of the stapedial arteries. The third aortic arch presents the commencement of the internal carotid artery and is known as the carotid arch [19-22].

Proximal parts of the third pair form the common carotid arteries. Together with sections of the dorsal aortae, the distal portions provide to formation of the internal carotid arteries [11].

The left arch of the fourth pair produces the sections of normal left aortic arch between the left common carotid and subclavian arteries. The right fourth arch forms the proximal right subclavian artery and the distal part of the right fourth arterial arch gets regressed. The distal right subclavian artery is derived from a portion of the right dorsal aorta and the right seventh intersegmental artery [23].

Rudimentary blood vessels that regress early develop out of the fifth pair. The left arch of the sixth pair provide to the formation of the main and left pulmonary arteries and ductus arteriosus, this duct obliterates a few days after birth has taken place [25]. The right sixth arch provides to formation of the right pulmonary artery. With the caudal migration of the heart in the second fetal month, the seventh intersegmental arteries increase in size and migrate cephalic to form the distal subclavian arteries [9].

In normal embryological development, the left subclavian artery arises from the 7th intersegmental artery, while right subclavian artery arises from the following sources (i) right 4th aortic arch, (ii) right dorsal aorta and (iii) right 7th intersegmental artery [26].

Malformations of the aortic arch system can be defined by enduring nature of sections of the aortic arches that usually continue or disappearance of sections that normally remain it can be possible both [27].

In congenital anomalies, severe proximal subclavian artery stenosis or blockage, results insufficient flow may be present to sustain the ipsilateral arm. The greatest relevance for present purposes is the confluence of the vertebral arteries at the basilar artery and its subsequent communication with the circle of Willis, which allows the ipsilateral vertebral artery to provide flow in a reversed manner from the contralateral vertebral artery or from the anterior cerebral circulation [32].

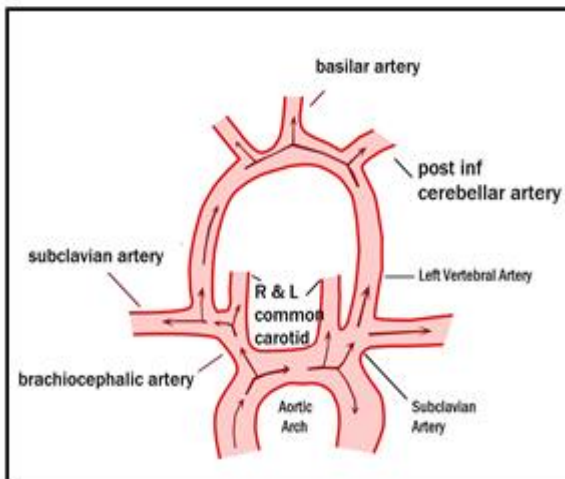


Fig 3. Schematic representation of normal development of subclavian artery.

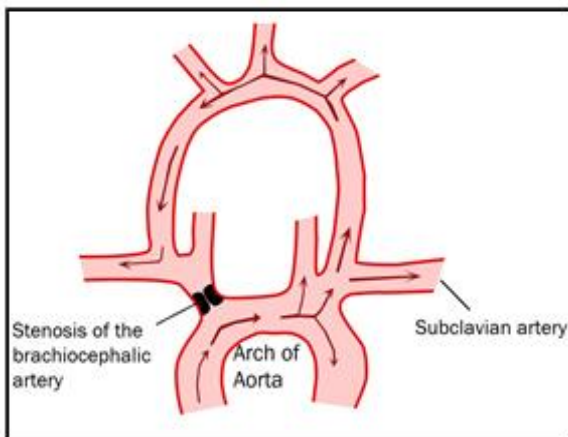


Fig 4. Schematic representation of stenosis of the brachiocephalic artery leading to retrograde flow.

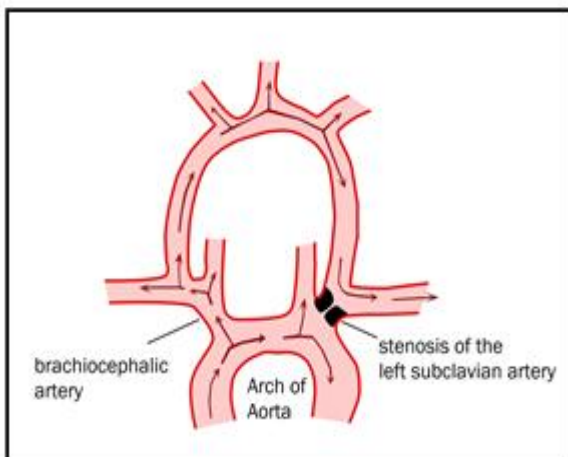


Fig 5. Schematic representation of stenosis of the subclavian artery leading to retrograde flow of left vertebral artery.

Discussion

Subclavian Steal syndrome refers to subclavian artery steno-occlusive disease proximal to the origin of the vertebral artery and is associated with reverse flow in the vertebral artery. Anatomically, there is an obstruction in the subclavian artery just before the origin of the vertebral artery [33]. This clinical entity is associated with neurological symptoms of vertebrobasilar insufficiency that occur during exercise of the ipsilateral arm. Symptoms of dizziness or vertigo occur in more than half of the patients, and syncope and dysarthria have been noticed in 18% and 12.5%, respectively.

Since most patients do not seek medical advice unless symptoms manifest, the prevalence of subclavian artery occlusive disease and subclavian steal syndrome is unknown. Arteriosclerosis is the most common cause of proximal subclavian artery occlusive lesion. Some of the risk factors are cigarette smoking, hypercholesterolemia, type 2 Diabetes Mellitus, hypertension, and hyperhomocysteinemia. Subclavian steal syndrome mostly occurs on the left side [29]. When the arm is exercised, dilation of the blood vessels enhances perfusion to the ischemic muscle, thus lowering the shunt in the outflow vessels [33]. The increased demand for blood by the left arm, results in the shunting of blood into the left subclavian artery. Blood crosses the basilar artery from the contralateral intracranial vertebral artery and flows retrograde down the ipsilateral vertebral artery towards the left arm. This bypasses the stenosis in the left subclavian artery [31]. When arm exercise ceases, the resistance in the outflow vessels of the arm increases, thereby reducing retrograde blood flow in the vertebral artery [12].

The clinical relevance of the subclavian steal syndrome was discovered in 1961 by Reivich, Holling and Roberts. Contorni was the first to recognize and describe this retrograde flow in 1961 using angiography in a patient who had an absent radial pulse. A year later, Reivich associated this phenomenon with transient ischemic attack (TIA) and hence became the first scientist to correlate it with neurological symptoms. The term "subclavian steal", however, was coined by Fisher in 1961 [33-35]. This was after he reviewed Reivich's article and observed that the anomaly caused the ipsilateral subclavian artery to receive retrograde flow from the contralateral circulation, at the expense of the vertebrobasilar circulation [38]. If the blood flow demand in the arm increases, more arterial flow is siphoned from the cerebral circulation, satisfying increased oxygen demand through the exercising muscles of the upper extremity. This causes partial ischemia of the brain stem and posterior cerebral cortex and symptoms could be manifested. Indirectly, because of anastomoses between the carotid system and vertebrobasilar system at the circle of Willis may be affected during times of heightened activity [40-42]. Numerous symptoms are associated with posterior circulation cerebral ischemia. Visual symptoms secondary to vestibular dysfunction and/or nystagmus include a sensation of objects moving or the inability to focus as well as monocular or binocular visual loss. Diplopia occurs in 19% of the cases [43]. The most frequent neurologic symptom is dizziness or vertigo, usually described as a sensation of lightheadedness, rocking, swaying, or tilting. On our examination, there was a blood pressure difference between the arms; usually this difference is at least 20mmHg lower on the involved side in SSP [45]. The pulse is usually weak and the arms and feet may feel cool. Diagnosis is possible through non-invasive testing. SSP most commonly is diagnosed incidentally during carotid and vertebral artery color Doppler US, discovering abnormalities of blood flow direction in the vertebral artery. Angiography remains the definitive diagnostic test for confirming this condition [11].

Conclusion

The Subclavian Steal Syndrome is a vascular disorder that retrograde cerebral blood flow to the subclavian artery affected by blockage or occlusion, causing a reduction in blood flow to territories supplied by the carotid and vertebrobasilar systems [48]. Hypo-perfusion to the optic nerve and ciliary body can potentially create normal tension glaucoma.

Increasing evidences are showing that vascular factors leading to ischemia may have a fundamental role in the disease initiation or progression. It is important to recognize the Subclavian Steal Syndrome and its effects on ocular and systemic level, in order to make an early intervention, referral and an adequate follow-up of the disease [46-47].

References

- [1] Ajit Kumar, E.Ganesh, T.Malarvani, Manish Kr. Singh. Bilateral supernumerary heads of biceps brachii. *Int J Anat Res.* 2014; 2(4):650-52.
- [2] Ajit Kumar, Ganesh Elumalai, Malarvani Thangamani, Nirmala Palayathan, Manish Kr Singh. A Rare Variation in Facial Artery and Its Implications in Facial Surgery: Case Report. *Journal of Surgery.* 2014; 2(5): 68-71.
- [3] Ganesh Elumalai, Sushma Chodisetty. Anomalous "Mutilated Common Trunk" Aortic Arch Embryological Basis and its Clinical Significance. *Texila International Journal of Basic Medical Science.* 2016; 1(1): 1-9.
- [4] Ganesh Elumalai, Emad Abdulrahim Ezzeddin. "The sudden soul reaper" - hypertrophic cardiomyopathy – its embryological basis. *Elixir Embryology.* 2016; 99: 43284-43288.
- [5] Ganesh Elumalai, Muziwandile Bayede Mdletshe. "Arteria lusoria"- aberrant right subclavian artery embryological basis and its clinical significance. *Elixir Embryology.* 2016; 99: 43289-43292.
- [6] Ganesh Elumalai, Sushma Chodisetty, Pavan Kumar D. 2016. Ganesh Elumalai et al Classification of Type - I and Type - II "Branching Patterns of the Left Arch Aorta". *Imperial Journal of Interdisciplinary Research.* 2(9): 161-181.
- [7] Ganesh E, Sushma C. The deer horn aortic arches" embryological basis and surgical implications. *Anatomy Journal of Africa.* 2016; 5(2): 746 – 759.
- [8] Ganesh Elumalai, Sushma Chodisetty. Teratological Effects of High Dose Progesterone on Neural Tube Development in Chick Embryos. *Elixir Gynaecology.* 2016; 97: 42085-42089.
- [9] Ganesh Elumalai, Sushma Chodisetty. "The True Silent Killers" - Bovine and Truncus Bicaroticus Aortic Arches its Embryological Basis and Surgical Implications. *Elixir Physio. & Anatomy.* 2016; 97: 42246-42252.
- [10] Ganesh Elumalai, Sushma Chodisetty, Bridget Omo Usen and Rozminabanu Daud Patel. "Patent Ductus Caroticus" - Embryological Basis and its Clinical significance. *Elixir Physio. & Anatomy.* 2016; 98: 42439-42442.
- [11] Ganesh Elumalai, Sushma Chodisetty, Eliza Arineta Oudith and Rozminabanu Daud Patel. Common anomalies origin of left vertebral artery and its embryological basis. *Elixir Embryology.* 2016; 99: 43225-43229.
- [12] Ganesh Elumalai, Sushma Chodisetty, Sanjoy Sanyal. Common Nasal Anomalies and Its Implications on Intubation in Head and Neck Surgeries. *Journal of Surgery.* 2016; 4 (4): 81-84.
- [13] Ganesh Elumalai, Malarvani Thangamani, Sanjoy Sanyal, Palani Kanagarajan. Deficient sacral hiatus cause mechanical low back pain: a radiological study. *Int J Anat Res.* 2016; 4(1):1758-64.
- [14] Borenstein M, Minekawa R, Zidere V et-al. Aberrant right subclavian artery at 16 to 23 + 6 weeks of gestation: a marker for chromosomal abnormality. *Ultrasound Obstet Gynecol.* 2010;36 (5): 548-52.
- [15] Bayford D. An account of a singular case of obstructed deglutition. *Memoirs Med Soc London* 1794;2:275–86.
- [16] Gross RE. Surgical treatment for dysphagia lusoria. *Ann Surg* 1946;124:532–4.
- [17] Cina CS, Arena GO, Bruin G, Clase CM. Kommerell's diverticulum and aneurysmal right-sided aortic arch: a case report and review of the literature. *J VascSurg* 2000;32:1208–14.
- [18] Cloud GC, Markus HS. Diagnosis and management of vertebral artery stenosis. *QJM.* 2003; 96:27–54.
- [19] Daoud AS, Pankin D, Tulgan H, Florentin RA. Aneurysms of the coronary artery. Report of ten cases and review of literature. *Am J Cardiol.* 1963;11:228–37.
- [20] Habel RE, Budras KD. Thoracic cavity. In: *Bovine Anatomy: An Illustrated Text.* Hanover, Germany: Schlütersche GmbH & Co; 2003:62–65.
- [21] Hausegger KA, Oberwalder P, Tiesenhausen K, Tauss J, Stanger O, Schedlbauer P, et al. Intentional left subclavian artery occlusion by thoracic aortic stent-grafts without surgical transposition. *J Endovasc Ther* 2001;8:472–6.
- [22] Jakanani GC, Adair W. Frequency of variations in aortic arch anatomy depicted on multidetector CT. *Clin Radiol* 2010; 65(6): 481-7.
- [23] Jeng JS, Yip PK. Evaluation of vertebral artery hypoplasia and asymmetry by color-coded duplex ultrasonography. *Ultrasound Med Biol* 2004;30:605–609.
- [24] Mok CK, Cheung KL, Kong SM, Ong GB. Translocating the aberrant right subclavian artery in dysphagia lusoria. *Br J Surg* 1979;66:113–6.
- [25] Orvald TO, Scheerer R, Jude JR. A single cervical approach to aberrant right subclavian artery. *Surgery* 1972;71:227–30.
- [26] Peker O, Ozisik K, Islamoglu F, Posacioglu H, Demircan M. Multiple coronary artery aneurysms combined with abdominal aortic aneurysm. *Jpn Heart J.* 2001;42:135–41.
- [27] Phan T, Huston J 3rd, Bernstein MA, Riederer SJ, Brown RD Jr. Contrast-enhanced magnetic resonance angiography of the cervical vessels: experience with 422 patients. *Stroke.* 2001;32(10):2282-6.
- [28] P. M. Hunauld, "Examen de quelques parties d'un singe," *Histoire de l'Académie Royale des Sciences*, vol. 2, pp. 516–523, 1735.
- [29] Stone WM, Brewster DC, Moncure AC, Franklin DP, Cambria RP, Abbott WM. Aberrant right subclavian artery: varied presentations and management options. *J VascSurg* 1990;11:812–7.
- [30] Taylor M, Harris KA, Casson AG, DeRose G, Jamieson WG. Dysphagia lusoria: extrathoracic surgical management. *Can J Surg* 1996;39:48
- [31] Valentine RJ, Carter DJ, Clagett GP. A modified extrathoracic approach to the treatment of dysphagia lusoria. *J VascSurg* 1987;5:498–500.
- [32] van Son JA, Mierzwa M, Mohr FW. Resection of atherosclerotic aneurysm at origin of aberrant right subclavian artery. *Eur J CardiothoracSurg* 1999;16:576–9.
- [33] Weissleder R, Wittenberg J, Harisinghani MM et-al. *Primer of Diagnostic Imaging, Expert Consult- Online and Print.* Mosby. 2011;144 -157
- [34] W.M Stone, D.C Brewster, A.C Moncure. Aberrant right subclavian artery: varied presentations and management options. *J Vasc Surg.* 1990;11: 812–817
- [35] Donnelly LF, Fleck RJ, Pacharn P, Ziegler MA, Fricke BL, Cotton RT. Aberrant subclavian arteries: cross-sectional imaging findings in infants and children referred for

evaluation of extrinsic airway compression. *Am J Roentgenol* 2002;178:1269-1274

[36] Weinberg PM. Aortic arch anomalies. *Journal of Cardiovascular Magnetic Resonance* 2006; 8:633-643

[37] Baudet E, Roques XF, Guibaud JP, Laborde N, Choussat A. Isolation of the right subclavian artery. *Ann Thorac Surg* 1992;53:501-503

[38] Smith JA, Hirschklau MJ, Reitz BA. An unusual presentation of isolation of the right subclavian artery. *Cardiology in the Young* 1994;4:181-183

[39] Carano N, Piazza P, Agnetti A, Squarcia U. Congenital pulmonary steal phenomenon associated with tetralogy of Fallot, right aortic arch, and isolation of the left subclavian artery. *Pediatric Cardiology* 1997;18:57-60

[40] Nath PH, Castaneda-Zuniga W, Zollikofer C et al. Isolation of a subclavian artery. *Am J Roentgenol* 1981;137:683-688

[41] McMahon CJ, Thompson KS, Kearney DL et al. Subclavian steal syndrome in anomalous connection of the left subclavian artery to the pulmonary artery in D-transposition of the great arteries. *Pediatric Cardiology* 2001;22:60-62

[42] Chen MR, Cheng KS, Lin YC et al. Isolation of the subclavian artery: 4 cases report and literature review. *Int J Cardiovasc Imaging* 2007;23:463-467

[43] Mathieson JR, Silver SF, Culham JA. Isolation of the right subclavian artery. *Am J Roentgenol* 1988;151:781-782

[44] Mosieri J, Chintala K, Delius RE et al. Abnormal origin of the right subclavian artery from the right pulmonary artery in a patient with D-transposition of the great vessels and left juxtaposition of the right atrial appendage: an unusual anatomical variant. *J Card Surg* 2004;19:41-44.

[45] Subclavian Steal Syndrome: Background, Pathophysiology, Etiology. *Emedicine.medscape.com*. 2016 [cited 14 October 2016]. Available from: <http://emedicine.medscape.com/article/462036-overview>

[46] Subclavian artery. *En.wikipedia.org*. 2016 [cited 10 October 2016]. Available from: https://en.wikipedia.org/wiki/Subclavian_artery

[47] Subclavian steal syndrome: a review. *ResearchGate*. 2016 [cited 11 October 2016]. Available from: https://www.researchgate.net/publication/5856457_Subclavian_steal_syndrome_a_review

[48] Subclavian Steal Phenomenon. SSP / SSS information page | Patient [Internet]. *Patient*. 2016 [cited 28 October 2016]. Available from: <http://patient.info/doctor/subclavian-steal-phenomenon>

[49] ScienceDirect.com | Science, health and medical journals, full text articles and books. [Internet]. *Scencedirect.com*. 2016 [cited 28 October 2016]. Available from: [http:// www. Science direct .com/science/article](http://www.Science direct .com/science/article).