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"PATENT DUCTUS CAROTICUS" EMBRYOLOGICAL BASIS AND ITS CLINICAL SIGNIFICANCE

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ABSTRACT

Ductus Caroticus, the embryonic dorsal aorta between points of junction with the third and fourth branchial arch arteries normally disappears in early embryonic life. If persist, it forms a thin strand of tissue without lumen, called a "ligamentum caroticum" or a short communicating vessel with lumen, a ductus, as a fair-sized artery, called the "arteria muscularis cervicis". In anomalous condition, it persisted as a wide open vessel, between the third and fourth branchial arch arteries and it is treated as "Clinical significant anomalies" in the branchial arch arteries. The present study aimed to through insight knowledge about this unusual variant.

Introduction

The human aortic arch normally branching into three vessels patterns called the brachiocephalic trunk (BCT) or innominate artery, the left common carotid artery (LCCA) and the left subclavian artery (LSA) [Jakanani et al., 2010; Natsis et al., 2009; Boyaci et al., 2015; Budhiraja et al., 2013; Ogeng'o JA et al., 2010; Patil et al., 2012]. The adult archetype of the Aortic arch and its branches are formed, due to the different growth pattern of the aortic or branchial arch arteries and their associated "migration" and "merging" of their branches [Osborn, 1999]. The anomalous branching patterns in the aortic arch are due to the deviations or disturbances the normal growth pattern of the aortic or branchial arch arteries during the embryonic period.

Ductus Caroticus was a portion of the embryonic dorsal aorta between points of junction with the third and fourth branchial or aortic arch arteries, usually, it disappears in early embryonic development. If persist, it forms a connection, communicating the carotid and systemic arches, and it usually situated somewhat laterally, where both these arteries are bending around the esophagus. It is actually a persisted as a portion of the embryonic dorsal aorta, and may be represented merely by a thin strand of tissue with no lumen, termed as a "ligamentum caroticum". Sometimes it may present as a short communicating vessel with a lumen, a ductus, as a fair-sized artery, called the "arteria muscularis cervicis". In anomalous condition, it persisted as a wide open vessel, at the point of junction between the third and fourth branchial or aortic arch derivatives. The ontogenesis for these anomalous anatomical configurations and its clinical significance still remains unclear.

The implication of these patent ductus caroticus anomalous, has not been properly signified in the literature till now. Till today the patent ductus caroticus anomalous arteries are commonly regarded as an unusual variant so, very little direct data are available. Generally, the patients with patent ductus caroticus anomalous arteries are clinically normal and asymptomatic. Currently, the clinicians claimed the patent ductus caroticus anomalous arteries are common in patients with Internal-carotid artery insufficiencies, may lead to anterior and middle cerebral hypoplasia. Recently, it is well identified that the suspicion exists with patent ductus caroticus anomalous arteries, leads to sudden severe neurological complications due to the wide range of cerebral hypoplasia due to aneurysms, it may cause fatal. Since the patent ductus caroticus anomalous arteries are treated as "Clinical significant anomalies" in the aortic arches. The present study aimed to through insight knowledge about this unusual variant.

Incidence

The congenital anomalies are the most important cause of death in infants under one year of age [Ganesh Elumalai and Sushma Chodisetty, 2016]. In some serious anomalous conditions, the ductus caroticus may persist as a wide open vessel, at the point of junction between the third and fourth branchial or aortic arch derivatives. As a result, the left internal carotid artery arises directly from the arch of the aorta, and the right internal carotid from the right subclavian. Suspicion exists with patent ductus caroticus anomalous arteries, leads to sudden severe neurological complications due to the Internal-carotid artery (ICA) insufficiencies. The reported incidence of congenital ICA anomalies ranges approximately, 4 – 66% [Koskas et al., 1993]. The bilateral anomalous ICA demonstrates deficiencies in the filling of both Anterior and Middle cerebral arteries, also in the ophthalmic vessels [Caldemeyer et al., 1998].

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Ontogenesis for the normal aortic arch branching pattern:

During development, in the primitive heart tube, the Truncus arteriosus (aortic sac) receives six sets (right and left) of Aortic or branchial arterial arch [10]. These arterial arches undergo selective apoptosis, and the residual branch vessels constitute the formation of Aortic arch and its great vessels. Any deviations in this normal process will result in the anatomical variance.

The first and second sets (right and left) arterial arches (I and II) are usually gets regressed. Initially, the ductus caroticus connects the third and fourth branchial arches. The ductus caroticus normally disappears at an embryo size of 12 to 14mm.The third pair (right and left) arterial arches (III), forms the proximal part of the common carotid arteries bilaterally. The proximal part of the right fourth arterial arch (IV) persists as the right subclavian artery up to the origin of the internal thoracic (mammary) artery, whereas the distal part of the right fourth arterial arch gets regressed. The distal part of the left fourth arterial arch (IV) regresses and its proximal part form a small segment of the adult Aortic arch between the origin of the left common carotid artery and the left subclavian arteries. The right and left, fifth arterial arch (V) either regresses or incompletely formed. The proximal part of the right and left sixth arterial arch (VI) forms the pulmonary arteries. The distal part of the right side sixth arch (VI), becomes ductus arteriosus, whereas in the left side distal part will regress completely [Bogousslavsky et al., 1998]. The right horn of the Aortic sac forms the brachiocephalic trunk (BCT) or innominate artery and the left horn of the Aortic sac, normally forms the part of the Aortic arch intervenes between the origins of the brachiocephalic trunk (BCT) or innominate artery and the left common carotid (LCCA) arteries [Ganesh E and Sushma C, 2016].

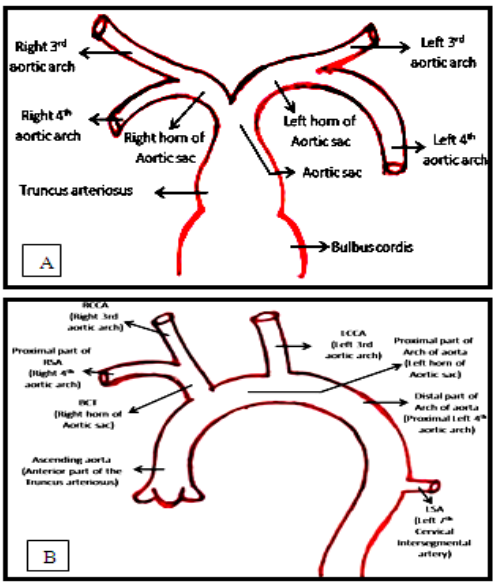

Fig 1. The derivatives of aortic arch arteries A. schematics showing the Truncus arteriosus receives the third (III) and fourth (IV) sets (right and left) of Aortic arch arteries, ultimately it is opens into the right and left horns of the Aortic sac and B. Derivatives of the Aortic sac horns and third (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)

Normally, the anterior part of the Truncus arteriosus receives the third (III) and fourth (IV) sets (right and left) of arterial arches; eventually, it opens into the right and left horns of the Aortic sac. The posterior part of the Truncus arteriosus receives the sixth (VI) sets (right and left) of arterial arches, and forms the right and left pulmonary arteries. The formation of the spiral or Conotruncal septum divides the Truncus arteriosus into the anterior ascending aorta and the posterior pulmonary trunk. The anterior part of the Truncus arteriosus continuous above as the Aortic sac, where it connects with the third (III) and fourth (IV) sets (right and left) of Aortic or branchial arch arteries. Ultimately, the aortic sac and its horns receive, all the derivatives of third (III) and fourth (IV) sets (right and left) of Aortic or branchial arches (Fig-1).

Embryological basis for the "Patent Ductus Caroticus" and anomalous Internal Carotid arteries:

The normal embryonic development, the CCA, ECA, and the ICA are arises from the third branchial arch. The definitive fourth branchial arch gives the arch of the aorta in the left and the proximal portion the subclavian artery in the right. Initially, the ductus caroticus connects the third and fourth branchial arches on the both side. The ductus caroticus normally disappears at an embryo size of 12 to 14mm. The root of the ECA originates from the proximal portion of the third arch (which normally becomes the CCA). If the ductus caroticus remains patent, as wide lumen vessels, the ECA and ICA will have separate origins directly from the arch of the aorta on the left side and from the subclavian artery on the right side. It may be involved bilateral or unilateral, either from the right or the left (Fig-2).

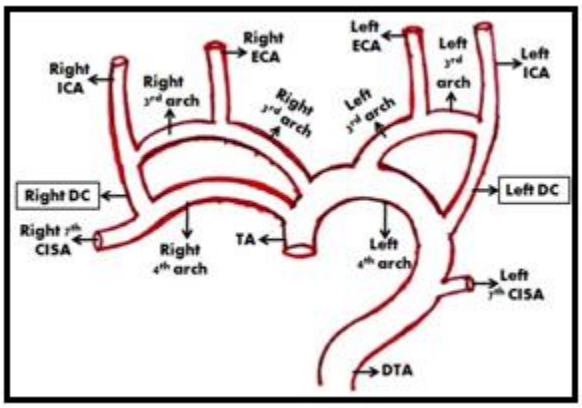

Fig 2. The 3rd and 4th aortic arch arteries are opens into the right and left horns of the Truncus arteriosus. (TA-Truncus Arteriosus; DTA-Dorsal Thoracic Aorta; ICA-Internal Carotid artery; ECA-External Carotid artery; CISA-Cervical Intersegmental artery and DC- Ductus Caroticus)

The blood directly flows to the persisting patent ductus caroticus from the aortic arch on the left side and subclavian artery to the persisting patent ductus caroticus on the right side, forming the aortic arch origin of the left ICA and the subclavian origin of the right ICA. This preferential blood flows through the persisting patent ductus caroticus channels, results in diminishes the normal flow through the third branchial arteries, which ultimately disappear.

The anomalous absent of the Common carotid artery (CCA), with separate origins of the External Carotid artery (ECA) and the Internal Carotid artery (ICA), from the arch of

the aorta on the left side and the subclavian artery from the right [Andrews et al., 1963; Lie,1968; Bryan et al.,1978].

As normally, the distal portions of the ECA developed from the remnants of the first and second branchial arches. The proximal aspects of the ECA represent the vessel that would have been the CCA (had normal development occurred), and the proximal ICA represents, what was the originally patent ductus caroticus (Fig-3).

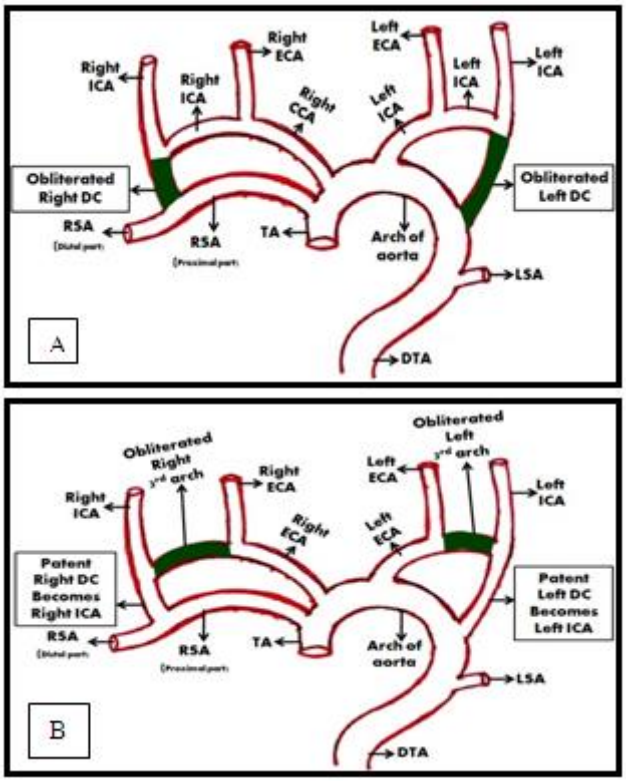

Fig 3. Normal derivatives of the 3rd and 4th aortic arch arteries are opens into the right and left horns of the Truncus arteriosus. A. Ductus caroticus Obliterated B. Patent Ductus Caroticus. (TA-Truncus Arteriosus; DTA-Descending Thoracic Aorta; ICA-Internal Carotid artery; ECA-External Carotid artery; RSA- Right subclavian artery; LSA- Left subclavian artery and DC- Ductus Caroticus)

Discussion

The human aortic arch, normally branching into three vessels patterns called the brachiocephalic trunk (BCT) or innominate artery, the left common carotid artery (LCCA) and the left subclavian artery (LSA) [Jakanani et al., 2010; Natsis et al., 2009; Boyaci et al., 2015; Budhiraja et al., 2013; Ogeng'o JA et al., 2010; Patil et al., 2012]. The adult archetype of the Aortic arch and its branches are formed, due to the different growth pattern of the aortic or branchial arch arteries and their associated "migration" and "merging" of their branches [Osborn, 1999]. The anomalous branching patterns in the aortic arch are due to the deviations or disturbances the normal growth pattern of the aortic or branchial arch arteries during the embryonic period.

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In some serious anomalous conditions, the ductus caroticus may persist as a wide open vessel, at the point of junction between the third and fourth branchial or aortic arch derivatives. As a result, the left internal carotid artery arises directly from the arch of the aorta, and the right internal carotid from the right subclavian. Suspicion exists with patent ductus caroticus anomalous arteries, leads to sudden severe neurological complications due to the Internal-carotid artery (ICA) insufficiencies. The reported incidence of congenital ICA anomalies ranges approximately, 4 – 66% [Koskas et al., 1993]. The bilateral anomalous ICA demonstrates deficiencies in the filling of both Anterior cerebral artery (ACA) and Middle cerebral artery (MCA), also in the ophthalmic vessels [Caldemeyer et al., 1998].

Currently, the clinicians claimed, the anomalous origin of internal carotid arteries due to the patent ductus caroticus leads to atheromatic hypoperfusion and aneurysms. The large diameter Left ICA receives the high-pressure blood from the arch of the aorta, results in the increased blood pressure. The increased in the pressure of the ICA causes dilatations of ACA and MCA vessels up to the one and a half to two times that of a normal diameter, so called as ectasia, if the dilatations occur more than the twice of the normal diameter, results in an aneurysm. These aneurysms (ACA and MCA aneurysms) should be repaired to avoid possible life-threatening tribulations. The pressure increases in the Left ICA resulting from asymmetric cerebral blood flow might influence the disturbances in the cerebral arterial system, cause cerebral infarctions.

An atherosclerotic lesion was the most common (60%) cause, for an aneurysm. The arterial bifurcations are the most common site for the atheromatous plaque formations. Atheromatous plaques are developed in the crucial regions with intricate blood flow patterns with fluctuation lateral pressure on the blood vessels as in the regions such as bifurcations, bends and junctions [Daoud et al., 1963; Stajduhar et al., 1993; Bryan et al., 2001]. According to the previous observations, only 20% of strokes are due to the hemorrhagic origin. Although the hemorrhagic strokes are less common than ischemic strokes, it causes more severe lesions than the ischemic type. The ischemia is often resulting from the high blood pressure or lateral wall pressure on the blood vessels which are before now damaged by the atherosclerotic lesions. The ischemic strokes are the more common (80%) type of all strokes.

The implication of these patent ductus caroticus anomalous, has not been properly signified in the literature till now. Till today the patent ductus caroticus anomalous arteries are commonly regarded as an unusual variant so, very little direct data are available. Generally, the patients with patent ductus caroticus anomalous arteries are clinically normal and asymptomatic. Currently, the clinicians claimed the patent ductus caroticus anomalous arteries are common in patients

with Internal-carotid artery insufficiencies, may lead to anterior and middle cerebral hypoplasia [Agrawal et al., 2014; O'Donoghue, 1917].

Conclusion

Knowledge about the branching pattern of the aortic arches was utmost significant during supra-aortic angiography, aortic instrumentation, thoracic, head and neck surgeries [Ganesh Elumalai et al., 2016]. Recently, it is well identified that the suspicion exists with patent ductus caroticus anomalous arteries, leads to sudden severe neurological complications due to the wide range of cerebral hypoplasia due to aneurysms, it may cause fatal. Since the patent ductus caroticus anomalous arteries are treated as "Clinical significant anomalies" in the aortic arches. The present study aimed to through insight knowledge about this unusual variant. In general, knowledge about the development and morphology of angio-architecture contributes to skilful segmentectomies, helping to preserve tissue, perform better surgery, and reduce both anesthesia and hemorrhage [Ajit Kumar et al., 2014]. The present case may provide useful information in the different fields of Anesthesia, Head & neck and thoracic surgeries, Emergency and Critical care units [Ganesh Elumalai and Sushma Chodisetty, 2016].

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