Surgical Anatomy of the Deep Fascia of the Neck

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The term "great arteries" refers to the major intrathoracic arterial structures and includes the aorta - ascending aorta, aortic arch, and descending thoracic aorta - and its major branches, the innominate, left common carotid, and left subclavian arteries; and the pulmonary artery trunk with its two branches. The success of any surgical procedure upon these vessels and the ease with which the procedure will be performed depends to a great degree on the operator's thorough knowledge of their courses and relationships and how to obtain good exposure of these vascular structures. The purpose of this communication is to review briefly the gross surgical anatomy of these arteries, their main embryological malformations, and the best possible surgical approaches to them.

Aorta

The aorta arises from the left ventricle at approximately the level of the third left sternocostal joint. It first courses upward, forward, and to the right to approximately the level of the right second sternocostal joint, then arches obliquely to the left and posteriorly to a point just to the left of the vertebral column at the level of the lower border of the fourth thoracic vertebra. From this point on, it descends caudally and slightly to the right to penetrate the diaphragm at the level of the twelfth thoracic vertebra.

The ascending aorta is completely encased within pericardium and lies posterior and to the right of the pulmonary artery trunk. The right pulmonary artery is directly posterior to it and the superior vena cava lies immediately on the right. The only branches of the ascending aorta are the right and left coronary arteries which arise from the respective sinuses of Valsalva.

The arch of the aorta lies behind the lower half of the manubrium. Its right posterior aspect is related to the trachea, esophagus, left recurrent laryngeal nerve, and thoracic duct, as well as several nerves to the deep cardiac plexus that descend with the trachea. The left anterior surface is covered by the left mediastinal pleura and is crossed by four nerves, the left phrenic, left vagus, and two cardiac nerves. Within the concavity of the arch lie the main pulmonary trunk and its two branches, the ligamentum arteriosum and the left recurrent laryngeal nerve as it curves under the arch from its origin from the left vagus nerve. The superior aspect of the aortic arch usually gives rise to three branches, the innominate, left common carotid, and left subclavian arteries. The arch and the origins of its branches are crossed anteriorly by the left brachiocephalic vein which descends obliquely from left to right.

The descending thoracic aorta is continuous with the arch and begins at the lower level of the fourth thoracic vertebra. As it descends caudally, it first lies on the left side of the bodies of the fifth through seventh thoracic vertebrae. Below this level, the aorta lies directly anterior to the remaining thoracic vertebrae. Throughout this course, the thoracic duct and azygous vein lie on its right and the hemiazygous veins on its left posterolateral side. In its upper portion it crosses posterior to the root of the left lung and lies to the left of the
esophagus. Since the aorta angles slightly to the right in its descent to the abdominal cavity, and the esophagus angles slightly to the left, the latter structure comes to lie to the left of the aorta near the diaphragm. The branches of the descending aorta are the bronchial, esophageal, and intercostal arteries, as well as small branches to the pericardium and diaphragm.

**Branches of the Aortic Arch**

The innominate (brachiocephalic) artery is the first branch of the aortic arch. It arises behind the center of the manubrium, ascends cephalad in a course which is slightly oblique to the right, and divides behind the right sternoclavicular joint into its branches, the right subclavian and right common carotid arteries. Its total length is approximately 5 cm. The trachea lies immediately posterior to it and the left brachiocephalic vein crosses directly anterior to its origin.

The left common carotid arises immediately after the innominate artery and is followed by the left subclavian artery, and both ascend cephalad behind the left sternoclavicular joint. They originate from the more posterior portion of the aortic arch and follow a semispiral course to reach the left neck. In the groove between these two branches, the left vagus descends to reach the aortic arch and behind them are the left recurrent laryngeal nerve, thoracic duct, and left side of the trachea and esophagus. The left brachiocephalic vein crosses in front of both arteries but is closely related only to the left common carotid due to the more posterior origin of the left subclavian.

**Pulmonary Artery**

The main pulmonary artery trunk originates from the infundibular portion of the right ventricle and passes cephalad and slightly to the left. It is approximately 2 inches long and most of its length is within the pericardium. Shortly after leaving the investment of the pericardium and within the concavity of the aortic arch, it bifurcates into its two branches, the right and left main pulmonary arteries. The pulmonary trunk lies anterior to the left of the aortic root, anterior to the left coronary artery, and anterior medially to the left atrial appendage.

The right and left pulmonary arteries course directly transversely from their origin from the pulmonary artery trunk, thus resembling the horizontal portion of the letter "T". The right pulmonary artery, which is slightly longer, lies directly posterior to the ascending aorta and superior vena cava and the left pulmonary artery lies directly anterior to the descending aorta. The right and left mainstem bronchi and inferior tracheobronchial lymph nodes lie directly posterior to both pulmonary arteries and thus separate them from the esophagus. The ligamentum arteriosum, a fibrous band of tissue which represents the remnants of the ductus arteriosus, runs from the left pulmonary artery to the concave surface of the arch of the aorta just distal to the origin of the left subclavian artery and around it the left recurrent laryngeal nerve makes its loop.

**Congenital Anomalies of Great Arteries**

The above description of the aortic arch and its branches represents the normal embryologic development of the left aortic arch and its branches, which is estimated to be
encountered 83 per cent of the time. In addition, various anomalies of the great arteries have been seen. These include anomalies of the left aortic arch, the right aortic arch, and double aortic arch.

The presence of these various anomalies can be explained by the location at which, during the embryonic life, interruption of the embryonic arches occurs in the Edwards hypothetical double aortic arch.

**Left Aortic Arch**

Left aortic arch with aberrant right subclavian artery is considered to be the most common malformation of the aortic arch, one in every 200 persons. In this anomaly, the right subclavian artery arises as the fourth branch from the aortic arch and, crossing behind the esophagus, extends to the right arm. Usually the patients with this anomaly are asymptomatic but symptoms due to esophagealcompression have occasionally been observed during childhood and in adults with aneurysm of this anomalous artery. This malformation is formed as a result of interruption of the right aortic arch in the hypothetical double aortic arch between the right common carotid and the right subclavian arteries.

Left aortic arch with right descending aorta results from the interruption of the embryonic right aortic arch in the hypothetical double aortic arch between the right subclavian artery and the descending aorta. The branching of the vessels of the arch in this anomaly is normal, and it is a very rare malformation and results in no airway or esophageal problems.

**Right Aortic Arch**

The right aortic arch anomalies can be divided into five types. Type I occurs when, in the hypothetical double aortic arch, interruption takes place in the embryonic arch between the descending aorta and left ductus arteriosus. This results in a persistent right aortic arch giving off first the innominate artery, then the right common carotid, and finally the right subclavian artery. The left innominate artery crosses the midline over the trachea and then branches to the left common carotid and left subclavian arteries. This anomaly does not form a vascular ring and is not accompanied by symptoms of compression of the trachea and esophagus. It is almost always associated with cyanotic congenital heart disease.

Type II right aortic arch results from the interruption of the left embryonic arch in the hypothetical double aortic arch between the left subclavian artery and the ductus arteriosus. Again the right aortic arch gives off first the left innominate artery, then the right common carotid, and finally the right subclavian artery. The left innominate artery crosses the midline over the trachea and forms, with the left ligamentum arteriosum, a vascular ring which may be symptomatic.

Type III right aortic arch gives off first the left common carotid, then the right common carotid, the right subclavian, and finally an aberrant left subclavian artery from a posterior aortic diverticulum. The ligamentum arteriosum originates from the left subclavian at its origin forming a vascular ring which may cause significant compression symptoms. This anomaly results from interruption of the left embryonic arch in the hypothetical double aortic arch between the left subclavian and the left common carotid arteries.
Type IV right aortic arch occurs when interruption of the left embryonic arch in the hypothetical double aortic arch takes place between the ascending aorta and the left common carotid artery. The right aortic arch gives off first the right common carotid artery, then the right subclavian, and finally an aberrant retroesophageal left innominate artery. A left ligamentum arteriosum joins the pulmonary artery to the descending aorta at the origin of the left innominate artery, thus forming a vascular ring, which may be symptomatic.

Type V right aortic arch gives off first the left common carotid artery, then the right common carotid, and last the right subclavian artery. The left subclavian artery does not originate from the aorta but it is connected only to the pulmonary artery by the ligamentum arteriosum. The occurrence of this anomaly can be explained when interruption of the left embryonic arch occurs in the hypothetical double aortic arch at two places, between the left common carotid and left subclavian arteries and between the descending aorta and the left subclavian artery. The patients with this malformation, when symptomatic, have symptoms of subclavian steal syndrome.

Double Aortic Arch

When both aortic arches persist, the anomaly of double aortic arch occurs with the right common carotid and subclavian arteries arising independently from the right arch and the left common carotid and left subclavian arteries arising from the left arch. Depending upon the patency of either of the two arches, the double aortic arch can be classified according to two types.

In Type I double aortic arch, both arches are patent and form a constricting ring around the trachea and esophagus, commonly producing symptoms of compression of these two structures, but this anomaly may go unrecognized and be discovered during incidental aortography. Due to the fact that it frequently produces symptoms of tracheal compression, this malformation is the most important of all vascular ring anomalies.

Type II double aortic arch is the anomaly which has both aortic arches in continuity, but one of them, almost always the left one, is partially atretic. The atresia may occur between the descending aorta and left ductus arteriosus, between the ductus arteriosus and left subclavian artery, between the left common carotid and left subclavian artery, or between the ascending aorta and left common carotid artery, or between the ascending aorta and left common carotid artery, resulting in the following respective anomalies. Regardless of the location of the atresia, a diverticulum of the descending aorta at the point of junction of the two arches is always present, as well as a complete ring around the esophagus and trachea, resulting commonly in compression of these structures.

Cervical Aortic Arch

It is a very rare anomaly in which the ascending aorta arises normally from the left ventricle and extends higher so that the aortic arch is located in the neck. The origin of the arch vessels in this anomaly varies - it might be normal, or the external and internal carotids might originate separately from the arch and the right subclavian artery may be aberrant, or the left may originate as a last branch of the right aortic arch from the retrosternal segment of the aorta. Symptoms of tracheal and esophageal compression may be present in the cases
with cervical aortic arch and all of them have a pulsatile mass in the neck which can be mistaken for aneurysm of the innominate, subclavian, or carotid artery.

Coarctation of the Aorta

Coarctation is constriction of the aortic lumen of varying degree and length and occurs anywhere along the aorta, but in 95 per cent of the subjects it is a localized stenosis just distal to the subclavian artery near the site of the ligamentum arteriosum. When the coarctation is located below the ductus arteriosus, it is referred to as a postductal coarctation and when it is located above the ductus arteriosus, it is referred to as a preductal coarctation. The ductus may remain open or closed in each type, although it is more likely to be open in the preductal coarctation. The coarctation is characterized by deformity of the aortic media involving the superior, anterior, and posterior wall, frequently at the origin of the descending aorta, forming a curtain-like infolding of the wall which causes eccentric stenosis of the lumen. The remainder of the aorta may be normal or a segment, commonly the isthmus, may be hypoplastic. The development of the aortic hypoplasia may be explained by the relationship of the coarctated aortic segment to the aortic insertion of the ductus arteriosus. ie, when the ductus arteriosus enters the aorta distal to the coarctation, blood flow during fetal life is through the ductus arteriosus to the descending aorta. Thus, due to the diminished blood flow through the aortic isthmus and arch, varying degrees of hypoplasia of these segments occur. This phenomenon is not expected to occur when the ductus arteriosus enters the aorta proximal to the coarctation.

In the patients with coarctation of the aorta, varied degrees of collateral circulation are formed between the branches of the subclavian arteries - vertebral, thyrocervical, costocervical, internal mammary, and the intercostal arteries - which may result in considerable bleeding during surgical repair of the lesion. Occasionally, an anomalous artery arising from the back of the aorta immediately proximal to the coarctation, the so-called Abbott's artery, is encountered in these patients, which courses medially beneath the aortic arch or the left common carotid artery which may be as large as 1 cm in diameter and aneurysmally dilated. This vessel with the aneurysmally dilated and fragile intercostal arteries can make the dissection for repair of coarctation of the aorta hazardous.

Coarctation of the aorta usually manifests with heart murmur, hypertension of the upper extremities and its complications, and congestive heart failure, particularly during infancy.

Surgical Exposure of the Great Arteries

The ascending aorta, the main pulmonary artery trunk, the first portion of the aortic arch, the innominate artery, and the left common carotid artery are best exposed through midsternotomy incision, which can be extended into the neck if needed to expose the common carotid arteries. For concomitant exposure of the second and third portion of the subclavian arteries, the incision should be extended in the supraclavicular fossa parallel to the clavicle, the median portion of the clavicle should be resected, and the sternocleidomastoid, sternohyoid, sternothyroid, and scalenus anticus muscles should be divided. During this maneuver, special attention should be paid not to injure all the vital structures located in this
area, especially the phrenic nerve which is lying over the latter muscle and, on the left side, the thoracic duct as it joins the left subclavian vein.

Exposure of the ascending aorta with the innominate artery or with the aortic arch, left common carotid, and left subclavian arteries can also be gained through an ipsilateral anterior thoracotomy through the fourth intercostal space and a midsternotomy extending from the level of the fourth intercostal space to the sternal notch, with an ipsilateral supraclavicular incision and excision of the medial portion of the clavicle. This incision, the "trap door," exposes all these vascular structures but is more taxing to the patient and to the surgeon alike.

The best exposure for the first portion of the subclavian artery, such as is needed for the creation of a subclavian to pulmonary artery shunt, is best accomplished by a lateral thoracotomy through the fourth intercostal space. Exposure of the proximal portion of the descending aorta for repair of coarctation of the aorta is best done through a posterolateral thoracotomy through the fourth intercostal space; exposure of the whole descending aorta, such as will be needed for aneurysmectomy, is best accomplished through a posterolateral thoracotomy but through the fifth intercostal space or the bed of the fifth rib. In mobilizing the descending aorta, care should be exercised to protect all the neighboring structures, esophagus, trachea, etc, and particularly the intercostal veins, because after injury their medial end retracts medially and far to the right and is very difficult to gain control; the intercostal arteries, especially in the presence of coarctation of the aorta, when they are thin and aneurysmally dilated; and the recurrent laryngeal nerve during the division of the ligamentum arteriosum.

The surgical repair of aortic arch anomalies is best accomplished through a left posterolateral thoracotomy through the fourth intercostal space. In the case of double aortic arch, the smaller of the two should be divided. The division of the arch should be performed distally to the origin of the common carotid artery so that this vessel will be left to receive blood from the ascending aorta rather than from the descending aorta, where the orifice at the point of junction of the arch to the descending aorta might be small. In the case of an aberrant subclavian artery, ligation of this vessel should be done at its origin from the aorta, whereas symptoms of trachea compression by an anomalously originating innominate artery can be relieved by lifting this vessel against the chest wall after its adventitia is sutured to the sternum. Because of the possibility of trachea collapse with the loss of external support following surgery for relief of the airway compression by an aortic arch anomaly, dissection around the trachea should be minimal so that sufficient support tissue is left around it.

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