What are the characteristics of the normal blood supply of the esophagus?

D. Liebermann-Meffert, M. Allgower, JR. Siewert (Munich)

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The increasing range of operative procedures for diverticula, stenosis and malignancy of the esophagus, problems arising with leaking esophageal anastomoses and the supposition that the integrity of the anastomosis and the viability of the organ depends on an intact circulation required an accurate consideration of the related vascular anatomy. One might be concerned about fatal mediastinal bleeding from esophageal vessels, however, "blunt stripping" of the esophagus without thoracotomy for carcinoma has been shown to be relatively safe [1-3]. The remarkably low blood loss during the procedure and the frequency of postoperative anastomotic leaks suggested a primarily poor esophageal vascularization. Nevertheless, the surgically mobilized esophagus retained viability over a long distance when carefully handled [4-7].

Evaluations of previous workers were largely based on dissection specimens using a more or less coarse injection material. Neglecting the striking species differences in the vascular anatomy [3,8], results from experiments using animals were included which also produced apparent confusion in the various descriptions. More recently the smaller vessels, and in particular those entering the esophageal wall, could be clearly demonstrated by means of vascular corrosion casts [3]. The casts display the multidimensional arrangement of the extramural and intramural esophageal blood vessels [3,8]. They reproduce the macroscopic features of the esophagus by presenting vessels within the submucosa and down to microscopic dimensions [3]. The contours provided by the vascular network reflect the esophageal shape. The absence of tissues around the vascular casts and the ability to examine stereo pairs exclude potential misinterpretation of closely overlaying vessels [3,9],

Esophageal dimensions

The esophagus measured from the cricoid cartilage and cardiac notch, ranged from 21 to 34 cm (average of 27 cm) in 52 corpses in accordance with the height of the body (153 to 187 cm). It was 23 cm ± 2 SD in the female and 28 cm ± 3 SD in the male. The cervical portion was 3-4 cm, the thoracic 20-26 cm and the abdominal 3-6 cm in length.

Extramural arteries

The cervical esophagus is supplied via the paired superior and inferior thyroid arteries (Figs. 1 and 2) which derive from the right and left exterior carotid artery and the thyreocervical trunk of subclavian artery, respectively. The blood of both the **cranial trachea and cervical esophagus** is mainly provided by the inferior thyroid arteries [3,10-13] each giving off a 2 to 3 cm long branch called the tracheoesophageal artery, that travels on each side towards caudal and medial to approach the tracheoesophageal grove. The vessels of both sides are "joined by anastomotic twigs along the trachea [10]"

and divide into three to four tracheal branches with two to three tributaries to the esophagus, which in turn subdivide within the periesophageal tissue into vessels of less than 500 µm luminal diameter, before entering the esophageal wall. Variants such as, direct esophageal branches from the subclavian artery, the superior thyroid artery, the thyroidea ima and the common carotid artery are infrequent and rather insignificant [3,8,10,11,13,14].

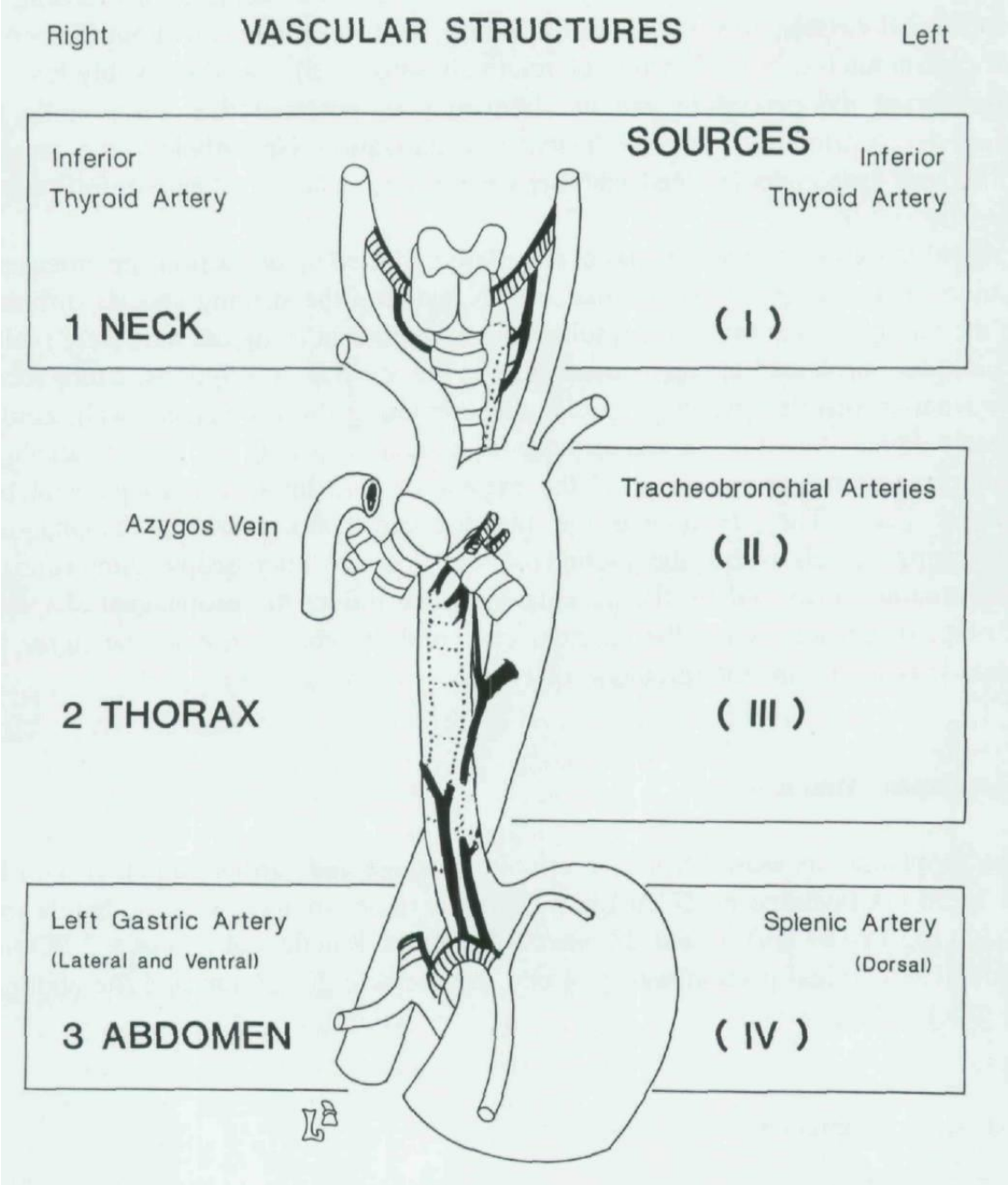

Figure 1. .Standard pattern of the angio-architecture of the esophagus. Size out of scale. Stem vessels are striped, esophageal branches black and the larger intramural vessels dotted.

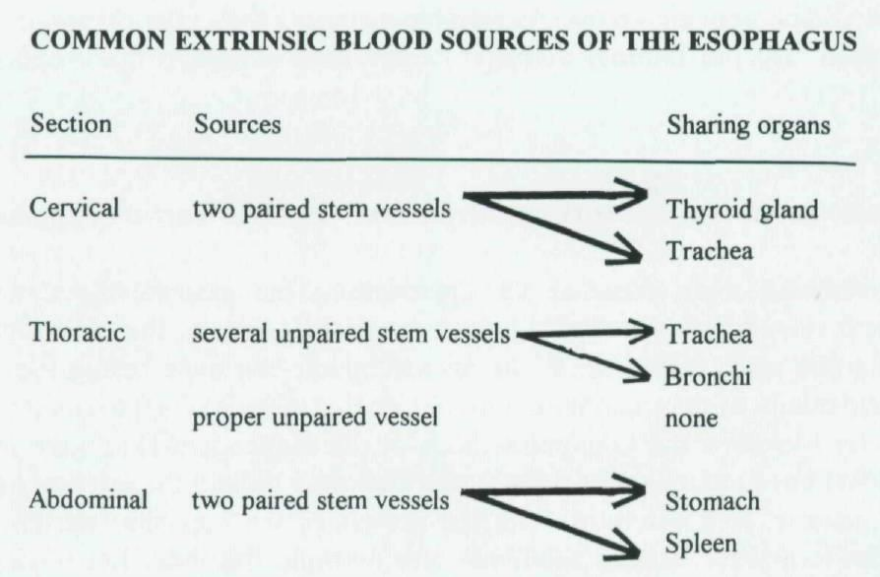

Figure 2. .Vessels of organs with which the esophagus shares its characteristic extramural pattern.

** The **intrathoracic esophagus receives blood from two** origins (Figs. 1 and 2), which are described below:

- **Up to four unpaired tracheobronchial arteries** [3,8,11,12,14,15] which derive as a bundle from the inflexion of the aortic arch [3]. These give off several small branches to the esophagus which subdivide within the periesophageal tissue to vessels of 350-500 µm in diameter. **Frequently one bronchoesophageal artery originates 1-3 cm caudal to the vascular bundle from the anterolateral aspect of the descending aorta** [3]. In this area, which relates to the tracheal bifurcation, all the vessels are straight and short **(less than 1.5 cm)** and form a firm connection between the aorta, trachea and esophagus [3,8,14,15]. Variants, such as branches from intercostal arteries (if there are any) [3,8,11], seem to be insignificant for the blood supply of the human esophagus.

- One (or seldom two) unpaired proper esophageal artery with luminal diameter between 1-2 mm may arise more caudally from the anterior aspect of the descending aorta as an exclusive source (Fig. 2) for the esophagus [3,8,12,14-16]. If present, this vessel travels obliquely down towards the esophagus within the mediastinum, to divide into a recurrent ascending and a descending branch [12,14]. Both subdivide into several periesophageal vessels of less than 500 urn in diameter.

The **abdominal esophagus and gastric cardia** are supplied by the unpaired left gastric artery [3,8,12,14,15] and the splenic artery [3], which derive from the celiac axis (Figs. 1 and 2). With up to 11 arterial branches the left **gastric artery** supplies mainly the anterior and right lateral aspect of the esophageal wall, while the **splenic artery** is the source of blood for mainly the posterior and left lateral aspect (cardiac notch) by either one or two direct branches or via vessels of the gastric fundus including connections with the short

gastrics. The branches from both stem vessels that supply the esophagus (Fig. 1) run straight up for 4-6 cm, within the periesophageal tissue

across the diaphragmatic hiatus. At variable distances they give off small tributaries of less than 500 μm internal diameter before they penetrate the esophageal wall [3,15].

The dense continuous network of intramural vessels: structural appearance

Having reduced their diameter by approaching the periesophageal tissue, the extramural vessels pass perpendicularly through the layers of the tunica muscularis, give off a few small tributaries to the muscle bundles en route before they divide at the muscular side of the submucosa into one or two vessels of approximately 400 μm in diameter to follow the longitudinal axis of the esophagus. They give off vessels of 200-300 μm in diameter at right angles that pass around the circumference, in a circular manner, to anastomose with the vessels of the opposite site. During their course the transverse vessels subdivide into multiple fine branches throughout the submucosa. This pattern of supply is characteristic of the entire esophagus [3,10,16]. All these vessels form an uninterrupted, minute and dense network in the submucosa (Fig. 3) to supply the musculature and mucosa. The submucosal vasculature connects the extramural vessels with the intramural vessels in the esophagus without any visible segmental demarcation.

The microvascular connections are evident in detail after injection of low particle size resin and at a higher magnification. Scanning electron microscopy of the complete cast revealed a submucosal network of small arteries and arterioles down to capillary diameter. The venous system (venules and veins) is filled by retrograde infusion and is also displayed. The arteries may or may not be accompanied by veins. Their respective characteristically different endothelial (nuclear) impressions allow a ready distinction. In principle, the submucous network arteries are approximately 50 μm in diameter and the veins 60-80 μm. The arteries give off short arterioles which display a variety of vessel size (40-20 μm) and break up into capillaries of 5-20 μm in diameter. The capillary part revealed a complex polygonal meshwork of vessels that were connected to others, principally of similar diameter.

All together, this vascular intramural network provides a subtle but luxurious vascular supply to the esophagus.

Conclusion

The esophageal vascular casts provide the morphological basis for circulation. Sources of blood supply to the esophagus concern mainly three areas: from the neck by the paired inferior thyroid arteries; in the chest by the unpaired aortic arch arteries; from the abdomen by the unpaired left gastric and splenic artery. According to the dominant size of the extramural vessels, however, it is evident that the cervical and abdominal sources provide the major blood supply to the esophagus, while the small stem vessels at the level of the carina seem to be of minor importance.

The vascular pattern is developed in such a manner that with the exception of one

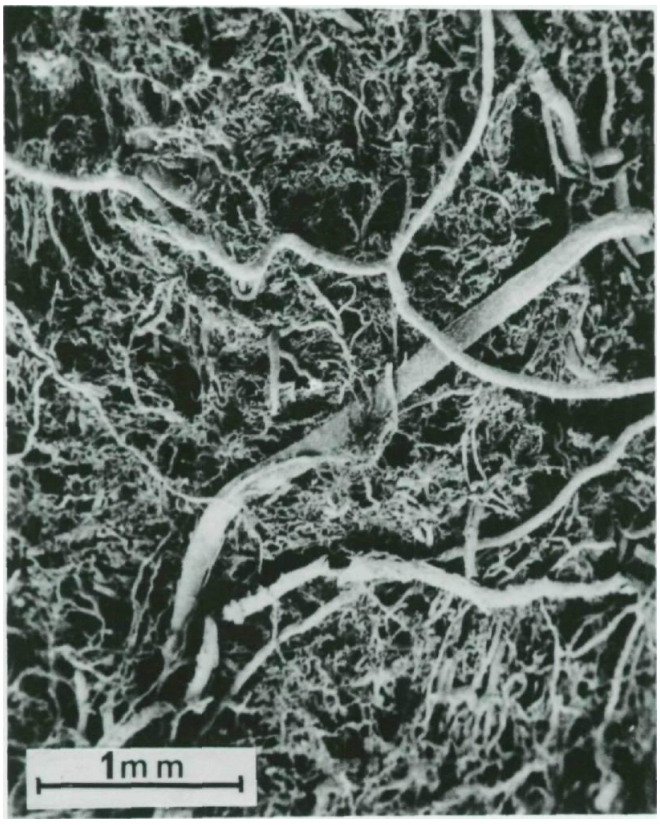

Figure 3. .Scanning electron microscopy of a vascular cast of the human intramural, submucosal blood supply. Vascular network in healthy human tissue. Sagittal section from the external to the luminal surface aspect showing the whole range of microvessels.

vessel of direct aortic origin, all others derive from the larger stem vessels of different organs (Fig. 2) which signifies that the esophagus depends on "a shared vasculature".

Branching subdivides the already primarily small esophageal vessels to be minute in the periesophageal tissue, before entering the wall of the esophagus. They, therefore, may undergo contractile hemostasis when torn.

A continuous regular network located in the submucosa connects all the extramural vessels. There is no short supplied or avascular zone. Besides, surgical experience has clearly shown that problems due to circulatory disturbances are by far, overestimated. Anastomotic failures practically always arise from the visceral substitute.

It is crucial that the esophagus itself is provided with an excellent blood supply through longitudinally oriented intramural vessels that permit the anastomosis being

placed at which ever level. The intramural network thus provides a luxurious, although fine vascularity for the esophagus, by a system of small arteries, arterioles and capillaries which nevertheless needs careful surgical handling.

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