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THE ANATOMY, PHYSIOLOGY AND SURGICAL CONSIDERATION OF THE OESOPHAGUS

By A. K. MONRO, M.D., F.R.C.S.

(*Surgical Registrar, Southend General Hospital*)

ANATOMY.

The oesophagus is a muscular tube connecting the laryngo-pharynx with the stomach. Commencing behind the lower border of the cricoid cartilage it descends successively through the neck, the superior mediastinum and the posterior part of the inferior mediastinum, to the diaphragm. This it traverses through the oesophageal hiatus, passing on for a further half-inch into the abdomen to end at the cardiac orifice of the stomach behind a point half an inch to the left of the sterno-xiphoid junction. Its average length is ten inches. From the incisor teeth, its commencement, guarded by the cricopharyngeus sphincter, is at a distance of seven inches; it is crossed by the left bronchus at eleven inches, whilst the cardiac sphincter lies at a distance of seventeen inches. The cricopharyngeus sphincter, usually described as the lower circular portion of the inferior constrictor muscle of the pharynx, is a thick ring of muscular fibres normally keeping the upper end of the oesophagus tightly closed. The cardiac sphincter guarding the lower end of the oesophagus consists merely of its lower muscular fibres, and presents no thickening to the naked eye. It is thus a physiological, rather than an anatomical, sphincter. Below, its fibres merge into the muscular layers of the stomach wall.

In the neck the oesophagus lies at first in the midline between the trachea in front and the vertebral column behind, but tending slightly to the left as it descends it comes into relation with the posterior surface of the left lobe of the thyroid gland. On its left the thoracic duct ascends and arches forward; on either side the recurrent laryngeal nerve lies in the groove between the oesophagus and the trachea.

In the superior mediastinum the oesophagus maintains its close posterior relationship to the trachea, both being crossed in front and on the left by the arch of the aorta, and on the right by the vena azygos. Owing to its slight deviation to the left the oesophagus is here in direct relation with the left parietal pleura; posteriorly, but not in direct relation with it, lies the thoracic duct. Again, owing to its inclination to the left, the oesophagus is an immediate posterior relation of the left bronchus.

In the inferior mediastinum the oesophagus lies behind the pericardium, having the thoracic aorta at first on its left side. In this region it returns to the midline, and is in direct relation with both right and left parietal pleurae. As it descends the aorta insinuates itself behind the oesophagus, which is thus enabled to incline forwards and to the left, losing its relation to the right pleura, and reaching the oesophageal hiatus of the diaphragm at the level of the tenth thoracic vertebra.

In the abdomen the last half-inch of the oesophagus lies in a groove on the posterior surface of the left lobe of the liver, being covered by peritoneum anteriorly and on its left side, and terminates by opening into the cardiac orifice of the stomach.

In the upper part of the thorax, therefore, the oesophagus is in close relation to the left parietal pleura. The arch of the aorta then comes between the two, opposite the third and fourth thoracic vertebrae, just as on the right side the vena azygos arches forward between the oesophagus and the right parietal pleura. In the centre of the thorax the oesophagus returns to the midline and is equally in relation to the two pleurae. In the lower part the oesophagus returns to its more intimate relation with the left pleura.

The vagi come into relation with the oesophagus below the roots of the lungs, the left nerve as it descends coming to lie anteriorly, the right posteriorly. Each divides into a number of branches, on the right commonly three, on the left two, forming an oesophageal plexus of nerves which tends, however, to reunite into two trunks before piercing the diaphragm, each trunk containing a proportion of fibres from both vagi.

The arterial supply of the oesophagus is derived from the following sources (Ohsawa, 1933):—

RIGHT SIDE	LEFT SIDE
Branches from inferior thyroid arteries.	
Br. costocervical trunk (not constant).	Br. left subclavian artery (not constant)
Br. right bronchial artery	*Br. superior and inferior left bronchial arteries*

Oesophageal Br. of Thoracic Aorta (3 *to* 5 *in number*).
Br. posterior intercostal arteries (variable).
Br. left gastric artery.
Br. left inferior phrenic artery.

The venous system corresponds, draining mainly to the thyroid veins above, to the azygos and hemiazygos veins in the thorax and to the left gastric vein below. Its chief interest lies in the fact that the anastomosis between the left gastric vein and the lower oesophageal veins draining to the azygos and hemiazygos veins represents one of the four important sites of communication between the portal and systemic venous circulations.

It is thus evident that the oesophagus receives its blood supply at each end and in the middle, the intervening areas being supplied only by vessels which run along the oesophageal wall.

The lymphatics of the oesophagus drain to the following groups of glands:—

1. Lower deep cervical (in relation to the common carotid artery).
2. Glands lying with the recurrent laryngeal nerves.
3. Bronchial.
4. Posterior mediastinal (along the aorta).
5. Left gastric.

Studies of operative and post-mortem material have shown how commonly in cases of carcinoma of the oesophagus the left gastric glands are involved (Churchill and Sweet, 1942). They would suggest that the left gastric glands play a major role.

The nerve supply of the oesophagus is derived from two sources, sympathetic and parasympathetic. Both have been the subject of minute enquiry (Mitchell, 1938). With the dissecting microscope it has been shown that the sympathetic supply comes from three sources:—

1. Branches from the ganglionated sympathetic trunks, both right and left (Thoracic 6–10).
2. Branches from the greater and sometimes the lesser splanchnic nerves.
3. Branches from the plexuses on the left gastric and inferior phrenic vessels, from the coeliac plexus.

From these studies it would appear that denervation of the left gastric artery by no means deprives the cardia of all its sympathetic supply, and is therefore unlikely on theoretical grounds to relieve cardiospasm. The parasympathetic supply comes directly from the vagal plexuses which lie on the oesophagus.

PHYSIOLOGY.

The wall of the oesophagus consists of four coats. The inner mucosal layer, lined by stratified squamous epithelium, is demarcated by a well-developed muscularis mucosae from the submucous coat which is the toughest layer of the wall and contains the larger blood vessels and a plexus of nerves corresponding to Meissner's plexus in the intestine. Throughout the oesophagus small mucous glands lie in the submucous layer, their ducts passing through the muscularis mucosae to open on the surface. Commonly each duct passes through a small nodule of lymphoid tissue. At the upper and lower ends of the oesophagus there are also present small tubulo-racemose glands which lie entirely within the mucosa, not penetrating the muscularis mucosae, and are similar in character to the cardiac glands of the stomach. Round the mouths of these glands the lining of the oesophagus often consists of columnar epithelium, closely resembling that of the stomach. Its presence may explain the occurrence of adenocarcinomata in the oesophagus (19 of 267 carcinomata, or 7 per cent, reported by Watson, 1933).

The muscular coat consists of an inner circular and an outer longitudinal layer. The fibres of the outer longitudinal coat are divided into bundles with intervening strands of connective tissue. In approximately the upper one-third the muscle is striated; in the lower two-thirds

it is non-striated. Between the layers is a nerve plexus corresponding to that of Auerbach found elsewhere in the intestine.

The outer coat of the oesophagus, often referred to as the "fibrous" coat, is in reality a thin layer of areolar tissue, blending directly with the surrounding areolar tissue of the neck and mediastinum. It has no strength value.

The process of swallowing, which can be studied by means of X-rays after the ingestion of a mouthful of barium cream, is seen to be originated by the forceful impelling of the fluid into the upper end of the oesophagus in the act of deglutition. The fluid then passes straight down the oesophagus as if purely under the influence of gravity, but slows up momentarily in the lower oesophagus before passing through the cardia 2–3 seconds after deglutition. The process is a reflex set up by the voluntary act of deglutition. Sensitive spots can be demonstrated on the posterior pharyngeal wall and on the soft palate (Alvarez, 1929), the glossopharyngeal nerves and palatine branches of the 2nd division of the 5th nerve being the receptor fibres by which impulses are conveyed to nuclei in the floor of the fourth ventricle of the brain. The effector nerve is the vagus.

Interruption of this reflex arc at any point may interfere with swallowing, as is seen:—

(*a*) When the receptor organs in the mucous membrane of the pharynx are put out of action by cocainisation, or by inflammation, as in diphtheria.
(*b*) When the nuclei in the bulb are involved, as in progressive bulbar palsy, in botulism and in hydrophobia, in all of which difficulty in swallowing is a prominent symptom.
(*c*) When the nerves of the reflex arc are involved as, for instance, by secondary malignant deposits.

In dogs, division of both vagi has resulted in slow death from inanition. This does not occur in man, nutrition remaining good, though gastric motility has been shown to be impaired, with some temporary pyloric spasm and regurgitation of food into the oesophagus, especially on lying down (Churchill and Sweet, 1942). It appears, therefore, that man's oesophagus, being composed in two-thirds of its length of non-striated muscle, can function satisfactorily by means of its own nerve plexuses as can more distal parts of the intestine.

Again, in carnivora who swallow their food largely unchewed, in gulps, the oesophagus is a powerful muscular organ. A dog has been shown to be able to swallow a wooden ball supporting, by a thread over a pulley, a weight of 250 grammes, and even at times up to 450 grammes (15 ounces). Man's oesophagus is not nearly so powerful, and has been shown to be able to swallow against a maximum weight of 70 grammes (2½ ounces). (Alvarez, 1929.)

SURGICAL CONSIDERATIONS.

The evolution of the surgery of the oesophagus forms one of the most fascinating chapters in the history of surgery. It is as yet very far from complete.

Owing to its inaccessibility the oesophagus for long defied even the most enterprising surgeons. In its early stages surgery of the oesophagus was limited to cervical oesophagotomy for the removal of foreign bodies. In 1871 we find that Billroth was experimenting on oesophageal resection in dogs. In 1877 Czerny first excised a portion of the cervical oesophagus for carcinoma in man, leaving the patient with a fistula. Mikulicz (1886) went further and closed the resulting fistula by means of skin flaps from the neck. Interestingly enough, he used silver wire sutures in the skin. The wound healed by the first intention. In the same year Richardson removed a dental plate from the lower end of the oesophagus by introducing two fingers through the cardia from a gastrotomy. He also showed that a finger introduced down the oesophagus from a cervical incision could be made to reach another finger introduced from below, a fact later utilised in the "tunnelling" operation.

During the remaining years of the last century the extra-pleural approach to the oesophagus by means of a posterior mediastinotomy was developed. Through a large flap incision in the posterior thoracic wall, with division or resection of four or five ribs, access was gained to the posterior mediastinum without opening the pleura. A number of successful oesophagotomies by this route were recorded in the early years of the present century. Approach through the anterior mediastinum (Milton, 1897) held out no hope. The transpleural route was first used experimentally by Biondie (1895), but was not applicable to human surgery until after the advances made by the thoracic surgeons, particularly in the matter of differential pressures and of intratracheal anaesthesia.

In the early years of this century progress was made in the treatment of benign strictures of the oesophagus in the shape of extra-thoracic oesophagoplasty, although this had been suggested by Bircher in 1894. It consisted of transection of the oesophagus in the neck, the divided ends being sutured to the skin, the upper end being brought down over the sternum. A tubular gastrostomy was also performed, using a flap of stomach to form a tube as devised first by Depage (1901), but later improved by others, particularly by Beck and Jianu (1912), who used a flap consisting of almost the whole greater curvature of the stomach, hinged near the fundus. This tube was brought up and fixed as high as possible to the skin of the chest, or even anastomosed directly to the cut upper end of the oesophagus. If this junction could not be effected directly, it was achieved later by the interposition of a buried skin tube made from the skin of the anterior chest wall. Lotheissen (1922) reported four successful cases using this method, in two of which the Beck-Jianu gastrostomy was lax enough to reach the cut upper end of the oesophagus; in the other two cases he found it necessary to interpose skin tubes 10 cm. in length.

Other methods were devised for effecting a junction between the divided oesophagus and the stomach by antethoracic transposition of a viscus, using either the whole stomach (Kirschner, 1920), a loop of jejunum (Roux, 1907, Herzen, 1908), or the transverse colon (Kelling, Vulliet, 1911). Up to 1927 there were 144 recorded oesophagoplastic operations for benign stricture with a mortality of 20·8 per cent (Saint, 1929). Many of the writers mention ulceration and leakage at the sites of the junction between oesophagus, skin or viscus tube and stomach, which, besides the many stage operations necessary for the completion of the procedure, are its main disadvantages.

Since that time, however, Plummer (1910) and Vinson (1924) have shown that almost all strictures of the oesophagus can be dilated by making the patient swallow a fine thread and by using this thread as a guide for dilators. The treatment of oesophageal stricture was thereby largely removed from the hands of the surgeon.

Progress in the treatment of carcinoma of the oesophagus was slower. In the early years of this century resection of the cervical oesophagus was being extended and ingenious methods of the repair devised (von Hacker, 1908, Trotter, 1914). In 1908 the first successful resection of a carcinoma of the cardia was reported, the lower oesophagus being freed, brought down and anastomosed to the stomach (Voelcker). Not until 1913, however, was the first successful resection of the thoracic oesophagus for carcinoma performed by Torek. Using the intercostal incision introduced by the thoracic surgeons, through the seventh left intercostal space, together with a tracheal insufflation anaesthetic as described by Meltzer and Auer (1909), he freed the oesophagus and divided it 1 in. above the diaphragm, invaginating the lower end twice with silk, "like an appendix stump" (Torek, 1913). After closing the chest incision, he then drew out the freed oesophagus through a second incision, in the neck, subsequently tunnelling down under the skin to bring the oesophagus out on the anterior chest wall over the second left interspace. The upper cut end of the oesophagus and a previously constructed gastrostomy were then permanently connected by a rubber tube. This case he showed twelve years later alive and well, swallowing without difficulty through the rubber tube.

Many surgeons followed in Torek's steps, but success was elusive. Pleural and mediastinal infections seemed almost inevitable. Of the few successes a number found the necessary tube intolerable. The construction of a prethoracic skin tube was a lengthy and often disappointing procedure. With such small chance of success, physicians could not recommend their patients to take such dire risks.

In the following years, radiotherapists began to claim encouraging results by the use of radium, X-ray, radon and later radium bomb therapy. In view of these claims surgeons handed over, it might almost be said, gratefully, the problem of carcinoma of the oesophagus to the radiotherapists, and, with one or two notable exceptions, left the problem entirely in their hands. Within the last decade, however, reports of the results of this type of treatment have been published which by no means realise its expectations (Watson, 1933, and others). Cures were as remote as ever, whilst the average expectation of life was increased, at most, by a few months. The realisation of this failure has provided a strong stimulus to the surgeon, and is responsible for the present widespread reawakening of interest in the field of oesophageal surgery. This has been further stimulated by the knowledge that the incidence of carcinoma of the oesophagus in the United States at least, is on the increase, and furthermore that out of more than 1,000 autopsies on such cases, 40·7 per cent showed no evidence of metastasis (Ochsner and De Bakey, 941).

At the present time, therefore, the surgeon approaches the problem with the following assets:—

(1) Improved methods of pre-operative preparation of the patient, including the use of a suitable diet, of vitamins, of amino acid therapy, of blood transfusions, and of complete oral hygiene.

(2) Controlled intratracheal anaesthesia with the use of new anaesthetic agents, including particularly cyclopropane.

(3) The experience gained in the tremendously progressive field of thoracic surgery, particularly in the matters of approach, and of post-operative treatment.

(4) The experience accumulated from a large amount of experimental work on animals, particularly in the matter of operative technique. This may be summarised briefly as having shown that end-to-end suture of the oesophagus is at best a precarious procedure, that safety lies in the use of interrupted, non-absorbable sutures, and that, above all, there must be no tension either at operation or subsequently when the erect position is assumed (Omi and Karasawa, 1913, Adams, 1941).

(5) The help of chemotherapy and more particularly of Penicillin in the control of post-operative infections.

The problems before the surgeon at present, therefore, consist of (*a*) procedure, (*b*) technique, and (*c*) control of post-operative complications, particularly of infection. As regards procedure, the modern trend is away from the difficulties and disappointments of prethoracic oesophagoplasty, toward the more physiological, one-stage intrathoracic anastomosis. Garlock (1944) describes a successful method of oesophago-gastric anastomosis within the chest showing clearly his method of fixing the stomach in the thorax in order to avoid tension in the erect position after operation. By far the most encouraging report in the history of oesophageal surgery comes from Churchill and Sweet (1942), who, out of eleven resections and oesophago-gastric anastomoses, report eight cases alive and well three months to two-and-a-half years after operation.

The future of the subject appears to depend upon the post-operative course of such patients. Whether the transposed stomach will take on the function of the oesophagus satisfactorily, or whether retention of food in the thorax will occur with consequent sensation of weight and distension after meals, remains to be seen. If retention occurs, the future of the subject may well lie in the intrathoracic transposition of jejunum or colon.

With these technical advances and with a wider knowledge of the problems to be faced, the surgery of the oesophagus has entered upon a new and encouraging phase which presents infinite possibilities for the meticulous but progressive surgeon.

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REFERENCES

ADAMS, W. E. (1941), *Surg. Gyn. and Obst.*, **72**, 312.
ALVAREZ, W. C. (1929), *The Mechanics of the Digestive Tract*, London, Heinemann, p. 82.
BILLROTH, T. (1871), *Arch. f. klin. Chir.*, **13**, 65.
BIONDIE, D. (1895), *Policlinico* (suppl.), p. 964.
BIRCHER, E. (1894), recorded by Bircher, Eugen, *Centralbl. f. Chir.*, 1907, **34**, 1479.
CHURCHILL, E. D. and SWEET, R. H. (1942), *Ann. Surg.*, **115**, 897.
CZERNY, A. (1877), quoted by von Hacker, *Arch. f. klin. Chir.*, 1908, **87**, 257.
DEPAGE, A. (1901), *J. de chir. et Ann. Soc. Belge de chir.*, **1**, 715.
GARLOCK, J. H. (1944), *Surg. Gyn. and Obst.*, **78**, 23.
HERZEN, P. (1908), *Centralbl. f. Chir.*, **35**, 219.
JIANU, A. (1912), *Deutsche Ztschr. f. Chir.*, **118**, 383.
KIRSCHNER, M. (1920), *Arch. f. klin. Chir.*, **114**, 606.
LOTHEISSEN, G. (1922), *Beitr. z. klin. Chir.*, **126**, 490.
MELTZER, S. J., and AUER, J. (1909), *Jour. Exper. Med.*, **11**, 622.
MIKULICZ, J. (1886), *Prag. Med. Wchnschr.*, **11**, 93.
MILTON, H. (1897), *Lancet*, **1**, 872.
MITCHELL, G. A. G. (1938), *Brit. Jour. Surg.*, **26**, 333.
OCHSNER, A., and DE BAKEY, M. (1941), *Jour. Thoracic Surg.*, **10**, 401.
OHSAWA, T. (1933), reproduced by Ochsner, A., and De Bakey, M., *Jour. Thoracic Surg.*, 1941, **10**, 401.
OMI, K., and KARASAWA, Z. (1913), *Ztschr. f. Chir.*, **124**, 574.
PLUMMER, H. S. (1910), *Surg. Gyn. and Obst.*, **10**, 519.
RICHARDSON, M. H. (1886), *Boston. Med. and Surg. Jour.*, **115**, 567.
ROUX, J. C. (1907), *Semaine Méd.*, **27**, 37.
SAINT, J. H. (1929), *Arch. Surg.*, **19**, 53.
TOREK, F. (1913), *Surg. Gyn. and Obst.*, **16**, 614.
TROTTER, W. (1914), *Burghard's System of Surgery*, **ii**, 248
VINSON, P. (1924), *Surg. Gyn. and Obst.*, **38**, 543.
VON HACKER, V. (1908), *Arch. k. klin. Chir.*, **87**, 257.
VOELCKER (1908), *Verhanl. d. deutsch. Gesellsch. f. Chir.*, **37**, 126.
VULLIET, H. (1911), *Semaine Méd.*, **31**, 529.
WATSON, W. L. (1933), *Surg Gye. and Obst*, **56**, 884.

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