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Radiological landmarks at the oesophago-gastric junction

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Anatomical studies have shown that three different appearances may be seen at the lower end of the oesophagus—namely, inferior oesophageal sphincter and vestibule relaxed, inferior oesophageal sphincter contracted and vestibule relaxed, and both the inferior oesophageal sphincter and the vestibule contracted. These studies have also demonstrated that the sling fibres of the stomach which hook around the notch between the lower end of the oesophagus and the fundus of the stomach mark the oesophago-gastric junction, and that a transverse mucosal fold forms at the same level as the sling fibres of the stomach when the vestibule is relaxed and distended. The behaviour of these structures in living persons was investigated radiologically, and in this paper an analysis of our findings is presented. As a result of these studies, a rational approach to the surgical repair of the hiatus in a patient with a hiatal hernia has been evolved.

The value of radiological studies of the lower end of the oesophagus is that they can demonstrate flow and movement. Flow in the lumen of the oesophagus can be observed during a barium meal examination. As the margins of the hiatus are not visible radiologically, movement of the hiatus cannot ordinarily be seen. In 15 patients who required a vagotomy, radio-opaque markers were placed on the anterior and lateral walls of the hiatus during the operation. The movement of the hiatus during normal and deep respiration and the effect such movements have on the lower oesophagus were subsequently studied radiologically. Movement of the wall of the oesophagus can be deduced, to some extent, by a radiological study of movement of the various rings and constrictions seen at the lower end of the oesophagus in adult patients during a barium swallow examination (Berridge, 1961). In 12 of the 15 patients mentioned above, radio-opaque markers were also attached to a number of points along the external wall of the oesophagus. Subsequently, the movement of the wall of the oesophagus during deglutition was investigated radiologically, and the effect of normal and deep respiration on the wall of the oesophagus was analysed.

The paper concludes with a discussion of the radiological appearances in the lower oesophagus studied in a large number of other patients and a description of the radiological landmarks in this region.

PATIENTS STUDIED AND TECHNIQUE

Various types of markers were placed on the hiatus of patients at operations for vagotomy: skin clips, tantalum wire as a skein, two pieces of tantalum wire hinged together at the top, and stainless steel rings. In nearly all cases the markers were so arranged that the movements of the two walls of the hiatus could be compared.

The oesophagus was marked with loops of tantalum wire or steel rings of a different size to those used on the hiatus. The types of marker used and the age and sex of the patients are set out in Table I.

During the operation for vagotomy a part of the lower limb of the phreno-oesophageal membrane was divided in all patients, and in patients 14 and 15 the defect in the membrane was repaired.

About three months after the operation radiological studies were carried out in all patients. A barium meal examination was performed and the effects of swallowing and of normal and deep respiration on the oesophagus were observed. The radiological technique included fluoroscopy using an image intensifier with television attachment, spot filming, and cine-fluorography.

RESULTS

MOVEMENT OF THE HIATUS WITH RESPIRATION

Downward movement On postero-anterior films (Fig. 1) and on lateral films (Fig. 2) the hiatus

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TABLE I

MARKERS ON HIATUS AND OESOPHAGUS

Patient	Age	Sex	Type of Marker on Hiatus	No. and Site of Markers on Lower Oesophagus	Remarks
1	45	F	Skin clips		
2	60	F	Tantalum wire (skein)		
3	60	F	Hinged tantalum wire		
4	40	M	Hinged tantalum wire	1 at O.G. junction	
5	50	M	Hinged tantalum wire	1 at O.G. junction and 2 above	Hiatal hernia
6	39	F	Hinged tantalum wire	1 at O.G. junction and 2 above	
7	41	F	Hinged tantalum wire	1 at O.G. junction and 2 above	
8	59	M	Hinged tantalum wire	1 at O.G. junction and 3 above	
9	61	F	Hinged tantalum wire	1 at O.G. junction and 3 above	
10	32	M	Hinged tantalum wire	1 at O.G. junction and 3 above	
11	75	M	Hinged tantalum wire	1 at O.G. junction and 3 above	Hiatal hernia
12	28	M	5 rings	1 at O.G. junction and 2 above	
13	54	M	4 rings	1 at O.G. junction and 2 above	
14	53	M	3 rings	1 at O.G. junction 1 at P.O. insertion 1 between the above	Phreno-oesophageal membrane repaired
15	39	M	3 rings	1 at O.G. junction 1 at P.O. insertion 1 between the above	Phreno-oesophageal membrane repaired

O.G. = oesophago-gastric; P.O. = phreno-oesophageal

moved downwards on inspiration. As the hiatus moved downwards on the wall of the oesophagus, a progressively shorter length of oesophagus remained in the abdominal cavity. On quiet respiration the mean descent was just under 1 cm. as measured on the films. On deep inspiration the descent was greater; the mean value was nearly 2 cm. on the P.A. films and just over 2 cm. on the lateral films.

When the movements of the markers on the right and left walls of the hiatus were compared on the P.A. films, the left wall was seen to move downwards more than the right, about 0·3 cm. more on quiet respiration and about 0·8 cm. more on deep inspiration. Thus the hiatus tends to rotate on inspiration as well as to descend.

Side-to-side movement On the postero-anterior films the hiatus moved slightly to one side or the other on inspiration, but this movement was too slight to have any appreciable effect on the radiological appearances of the oesophagus on respiration.

Forward movement The hiatus moved forwards on inspiration, about 1 cm. on quiet inspiration, and about 2·5 cm. on deep inspiration (Fig. 2). Again the markers on the left wall moved more than the right, but only very slightly so on quiet inspiration. The markers on the left wall moved about 0·5 cm. more than the right on deep inspiration.

Narrowing of the hiatus In order to be sure that narrowing takes place it must be demonstrated on postero-anterior and lateral films to exclude apparent narrowing due to rotation of the hiatus.

In this series the hiatus narrowed about 0·5 cm. on deep inspiration but only very slightly on quiet inspiration.

MOVEMENT OF THE OESOPHAGEAL MARKERS RELATIVE TO EACH OTHER AND THE HIATUS

With respiration In most instances the hiatus moved down on the oesophagus on deep inspiration (Fig. 1). As the oesophagus deviates to the left after it passes through the hiatus this downward movement tends to pull the oesophagus towards the mid-line and gives rise to a fictitious appearance of the hiatus moving to the right. The markers on the oesophagus also separated to a slight degree on inspiration, but this was not invariable.

The region of the notch on the left side between the lower end of the oesophagus and the fundus of the stomach did not stretch on inspiration.

On swallowing Semisolid substances taken by the subject in any position and liquids swallowed by the subject lying are moved down the oesophagus by stripping waves. It was found on cine-fluorography that the passage of a stripping wave down the oesophagus was attended by an oral movement of the markers on the lower thoracic oesophagus as the bolus passed through that area followed by a distal movement of the markers behind the bolus. When a thick substance was swallowed the markers on the gastro-oesophageal junction moved into the hiatus before the bolus reached it.

A matter of interest was the great oral movement of the oesophageal markers after pharyngeal

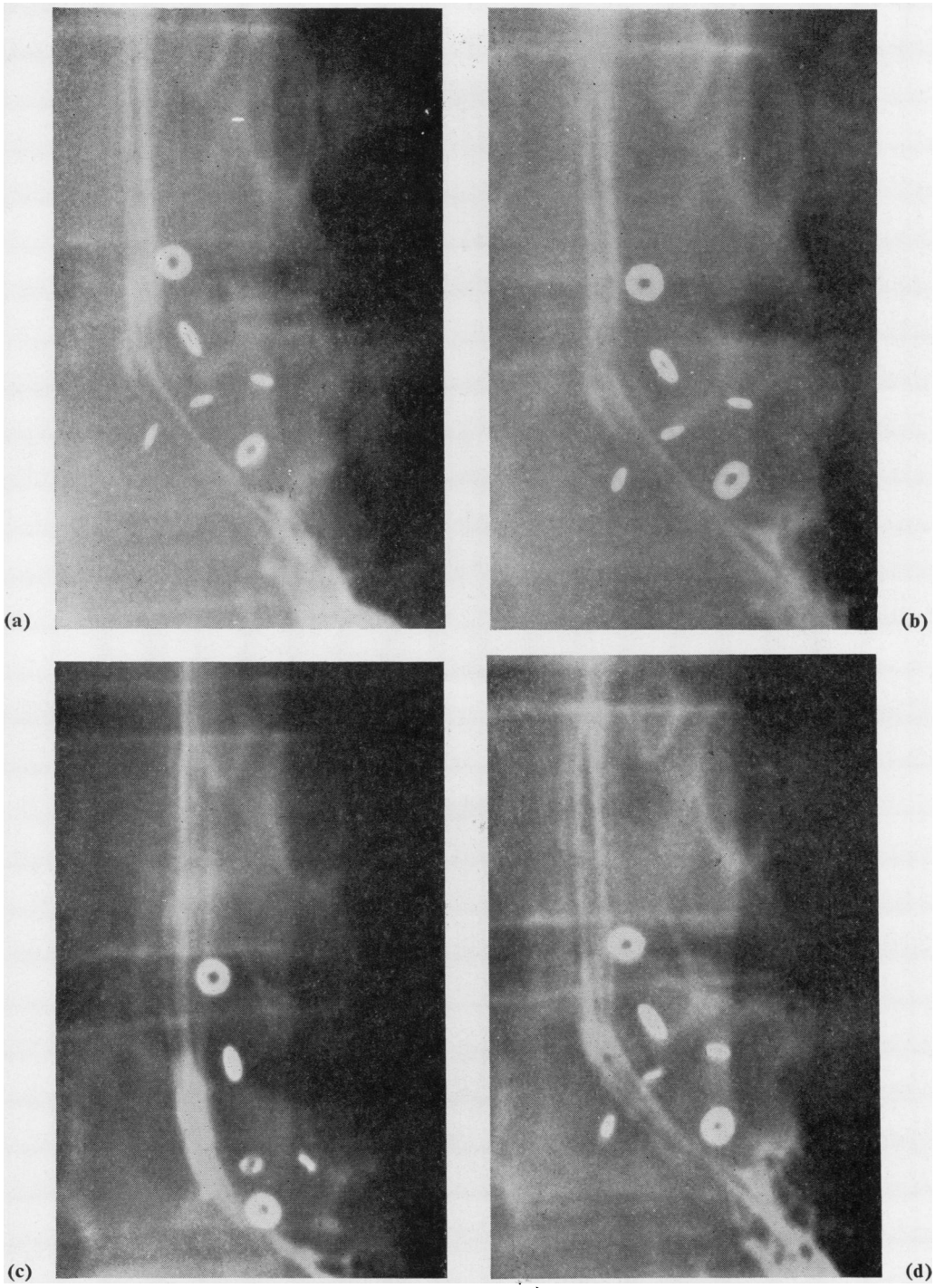
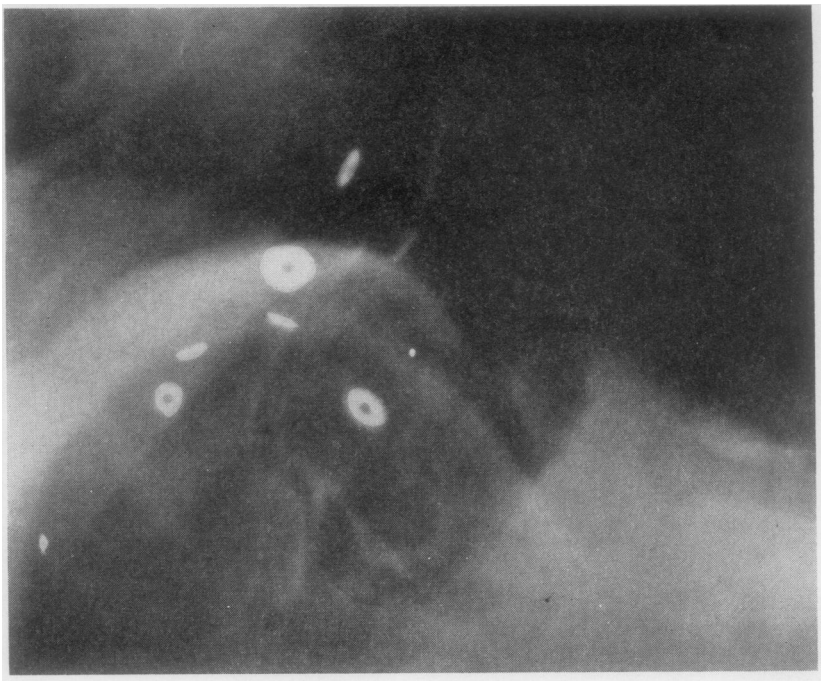
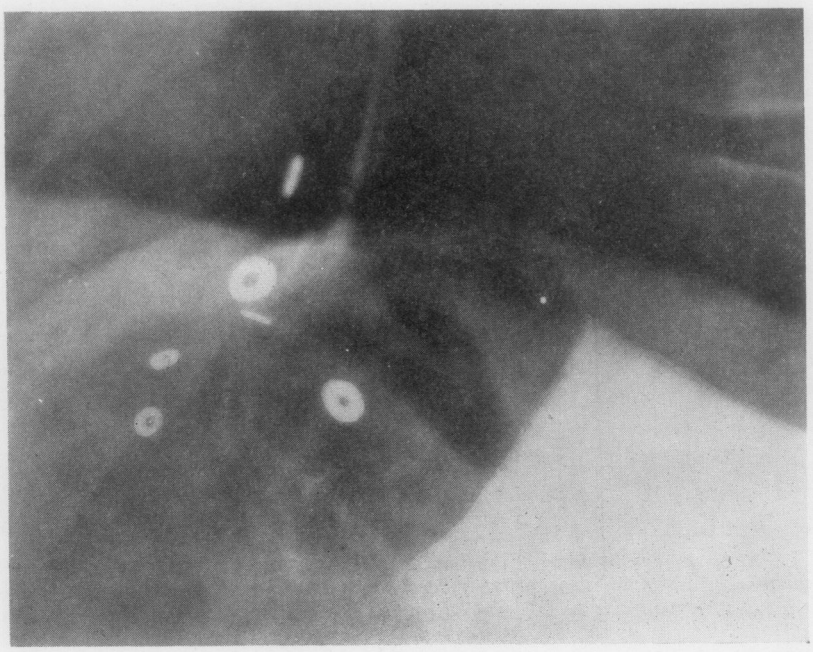


FIG. 1. *Effect of respiration on the hiatus and oesophagus, postero-anterior projection. Hiatus marked with three small rings placed on its anterior margin (middle ring) and half way down each wall; large rings placed on the gastro-oesophageal junction (lower ring), the insertion of the upper limb of the phreno-oesophageal membrane (upper ring), and between the other two; the middle ring coincides with the inferior oesophageal sphincter :* (a) *quiet inspiration;* (b) *quiet expiration;* (c) *deep inspiration, the hiatus narrows, the left wall of the hiatus moves more than the right, the hiatus slides downwards, and the vestibule is stretched;* (d) *deep expiration.*



(a)



(b)

FIG. 2

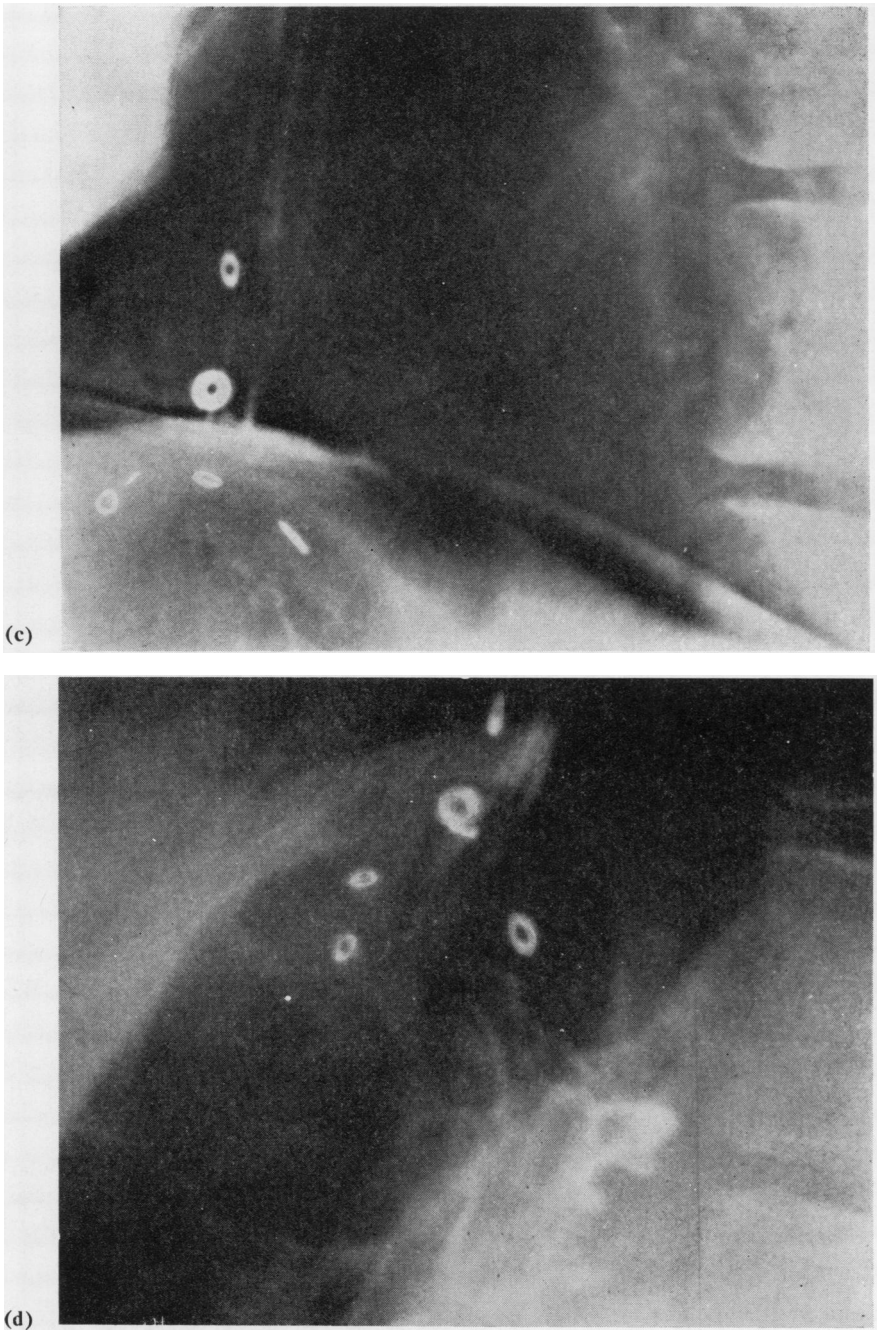


FIG. 2. *Effect of respiration on the hiatus and oesophagus, lateral projection. Three small rings on hiatus, and three large rings on oesophagus;* (a) *quiet inspiration, slight forward movement of hiatus;* (b) *quiet expiration;* (c) *deep inspiration, the hiatus moves downwards and forwards and the vestibule is stretched;* (d) *deep expiration.*

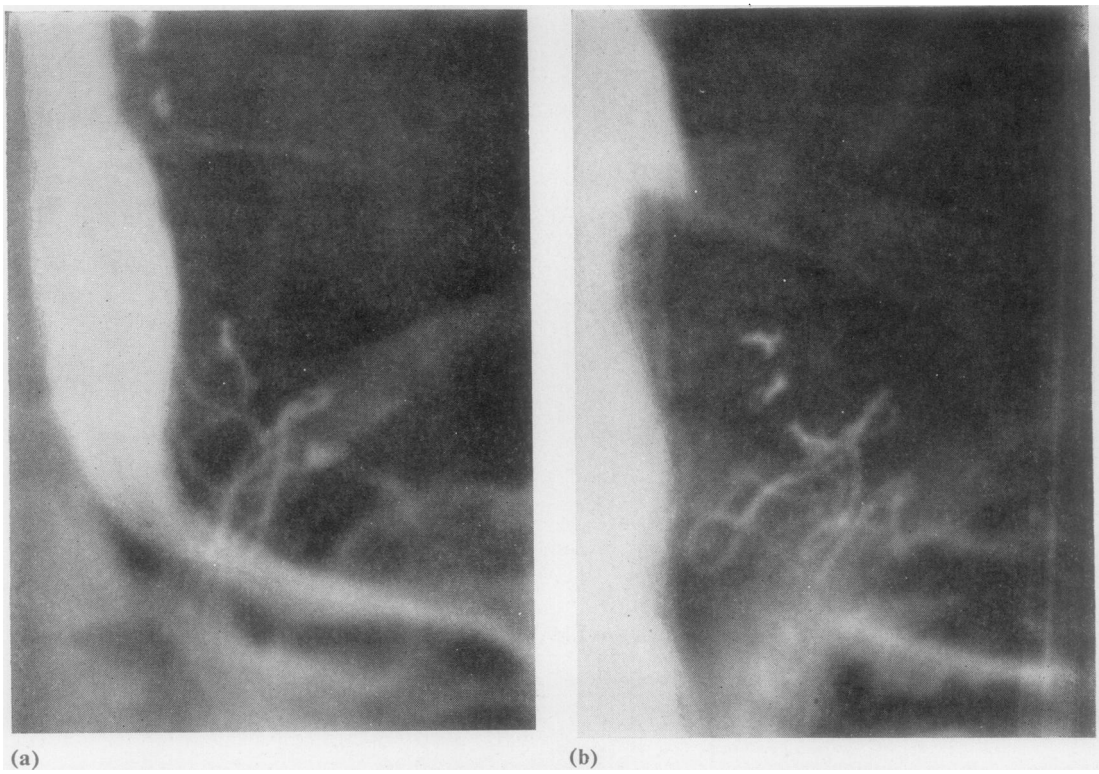


FIG. 3. *Effect of deglutition on the oesophagus. There are four markers on the lower oesophagus and a large, hinged tantalum wire on the hiatus:* (a) *bolus passing through lower oesophagus and vestibule;* (b) *after the bolus has passed and the vestibule has contracted. The upper markers on the oesophagus moved orally in* (a) *and downwards in* (b).

deglutition, although the marker placed at the notch between the lower end of the oesophagus on its left lateral aspect and the fundus of the stomach remained in the abdomen (Fig. 3).

RADIOLOGICAL APPEARANCES OF THE VESTIBULE The vestibule is a short length of oesophagus situated immediately above the stomach, partly above and partly below the hiatus.

The varying shape of the vestibule Shortly after deglutition, the inferior oesophageal sphincter and vestibule relax. This relaxation takes place before the stripping wave reaches the inferior oesophageal sphincter and vestibule. The stripping wave ends at the inferior oesophageal sphincter. Both the inferior oesophageal sphincter and the vestibule then contract. Hence, the inferior oesophageal sphincter and vestibule may be seen contracted, relaxed, or in the state of contracting or relaxing. The various radiological appearances seen in living persons bear a very close resemblance to the appearances seen in barium-filled necropsy specimens of oesophagus and stomach (Figs 4 and 5).

In the contracted state, the vestibule appears to be a narrowed part of the gullet containing larger mucosal folds than the gullet above. It may not retain a coating of barium and is then one type of 'empty segment'.

The relaxed vestibule may be tubular in shape or it may be fusiform. This fusiform chamber may be produced by distending the oesophagus well with contrast medium, or by partially obstructing the passage of the medium from the thorax to the abdomen. Thus, it may be seen on deep inspiration or when the intra-abdominal pressure is raised by other means.

The inferior oesophageal sphincter The upper limit of the relaxed vestibule is the inferior oesophageal sphincter, which is characteristically a ring sphincter when seen.

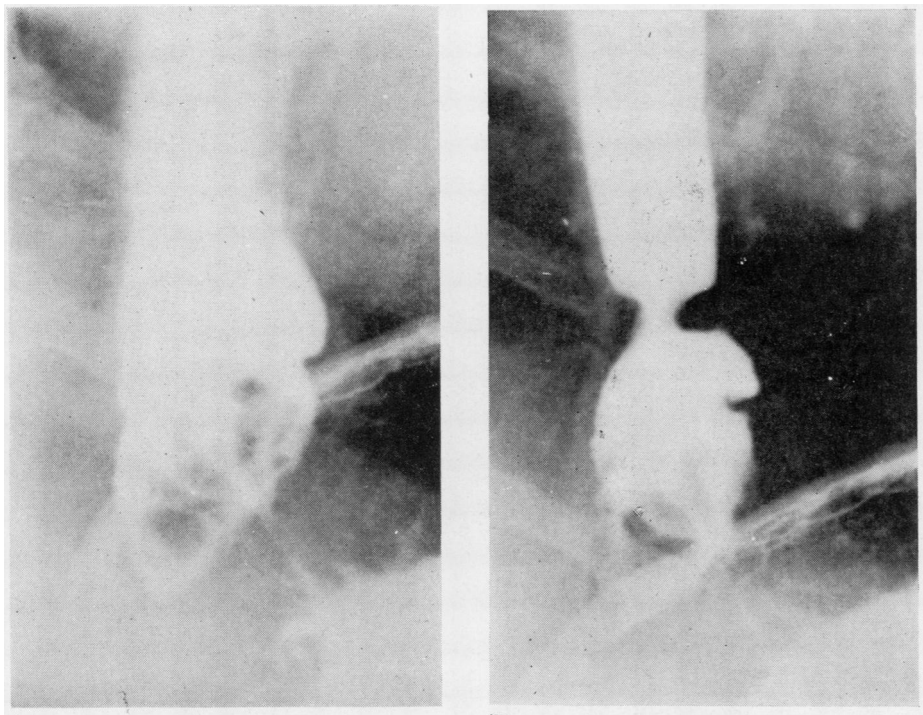


FIG. 4. *Small sliding hiatal hernia:* (a) *inferior oesophageal sphincter and vestibule relaxed, ring due to transverse mucosal fold;* (b) *inferior oesophageal sphincter contracted, vestibule relaxed, ring due to transverse mucosal fold.*

Usually, contraction of the inferior oesophageal sphincter precedes contraction of the whole vestibule by a very short interval, making it difficult to distinguish the inferior oesophageal sphincter from the vestibule. Under certain conditions, the inferior oesophageal sphincter can be made to contract independently of the oesophagus above and the vestibule below in all adults. The most reliable method of producing this independent contraction of the inferior oesophageal sphincter is to obstruct the lower oesophagus partially by placing the patient prone over a small bolster during the barium swallow examination. This may also be achieved by asking the patient to swallow a large bolus of thick barium. The inferior oesophageal sphincter is a physiological sphincter. When it relaxes completely there is no indication of its site or existence.

An interesting feature was observed in some of the subjects in whom a marker had been placed fortuitously in the region of the inferior oesophageal sphincter. The sphincter moved orally before the stripping wave reached it. The stripping wave ceased at the inferior oesophageal sphincter. The sphincter then moved downwards as the vestibule contracted. Without the markers such a movement would be indistinguishable from a wave passing right down and through the hiatus (Fig. 6).

The mucosa of the vestibule The junction of squamous and columnar epithelium takes place in the vestibule and is not usually recognizable radiologically; if it were it should be zigzag, but no zigzag structure is ever seen there. Due to its peculiar attachments the oesophageal mucosa never looks like gastric mucosa, but gastric mucosa can mimic oesophageal mucosa radiologically.

The oesophago-gastric junction Anatomical studies have shown that the sling fibres of the stomach always occupy the notch between the lower end of the vestibule on its left lateral aspect and the fundus of the stomach. These fibres are a reliable guide to the position of the oesophago-gastric junction. They form the notch seen radiologically on the left between the lower end of the vestibule and the fundus of the stomach. When necropsy

FIG. 5. *Small sliding hiatal hernia, serial films;* (a) *inferior oesophageal sphincter and vestibule relaxed, ring due to transverse mucosal fold;* (b) *stripping wave has stopped at inferior oesophageal sphincter, vestibule relaxed, transverse mucosal fold;* (c) *vestibule almost completely contracted, notch due to sling fibres of stomach.*

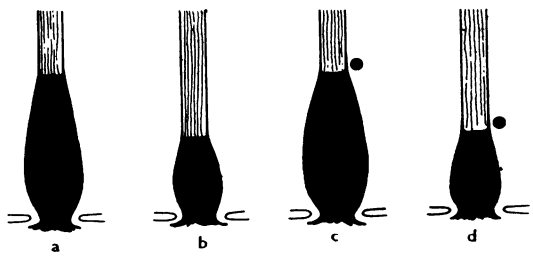


FIG. 6. *Similarity between a stripping wave passing down the oesophagus* (a and b) *and the formation of a vestibule* (c and d). *In* (a) *and* (b) *the wave is passing down the oesophageal wall. In* (c) *and* (d) *there is a marker at the inferior oesophageal sphincter. The stripping wave stops at the inferior oesophageal sphincter* (c) *and the vestibule then contracts* (d). *Without the markers it is not possible to distinguish* (a) *and* (b) *from* (c) *and* (d) *unless there is a delay before the vestibule contracts.*

specimens of oesophagus and stomach with a relaxed vestibule are distended, a transverse mucosal fold can be produced at the oesophago-gastric junction at the same level as the sling fibres of the stomach, no transverse fold having been seen or felt previously by inserting a finger into the upper stomach and lower oesophagus. The sling fibres of the stomach and the transverse mucosal fold are normally in the abdomen and their presence above the hiatus is certain evidence of hiatal herniation.

When a sleeve of stomach herniates through the hiatus, the sling fibres of the stomach may produce a notch of varying size on the left, marking the position of the oesophago-gastric junction. As the vestibule distends, this notch becomes progressively smaller, but it reappears when the vestibule contracts. Frequently, as the vestibule and herniated stomach are distended with contrast medium, a transverse ring forms at the same level as the notch caused by the sling fibres of the stomach. This ring usually appears first on the left and, unlike the notch, becomes more pronounced the more the vestibule and herniated stomach are distended. We have never observed this ring and the notch at different levels. Thus, it appears that this ring is caused by the transverse mucosal fold seen in necropsy specimens. Both in necropsy specimens and in living persons the transverse mucosal fold is produced by an unusual degree of distension of the oesophago-gastric junction, for it is not seen in living persons when the oesophago-gastric junction is normally located, and it may be made to appear in cases of sliding hiatal hernia by dilating the oesophago-gastric junction using special techniques, *e.g.*, placing the patient prone over a bolster.

Inferior oesophageal rings A number of different rings have been observed in the region of the vestibule. From the radiological point of view, these rings are best classified according to their anatomical site. They may be grouped into rings at the top of the vestibule and rings at the oesophago-gastric junction. These groups may be further subdivided into inconstant rings, *i.e.*, rings only seen intermittently or dependent on the degree of distension of the lumen, and constant rings, *i.e.*, rings which are seen irrespective of the degree of distension of the lumen.

Rings at the top of the vestibule (*a*) Inconstant rings: If flow from the vestibule into the stomach is partially obstructed by placing an adult patient prone over a bolster during a barium meal examination or if the patient swallows a large bolus of thick barium, the inferior oesophageal sphincter can be made to contract independently of the oesophagus above or the vestibule below in all cases. The constriction caused by the sphincter has rounded margins, becomes more pronounced as it narrows the lumen, and disappears completely when relaxed. Below a contracted inferior oesophageal sphincter the top of the relaxed vestibule is dome-shaped. The stripping wave ends at the sphincter.

(*b*) Constant rings: Sometimes, in patients with a sliding hiatal hernia, the inferior oesophageal sphincter is thickened and does not relax completely.

Rings at the oesophago-gastric junction (*a*) Inconstant rings: In patients with a sliding hiatal hernia lying prone over a bolster, a ring due to a transverse mucosal fold may form at the oesophago-gastric junction. The ring has sharper margins than the inferior oesophageal sphincter, becomes more obvious as the lumen widens, and disappears as the lumen closes. It may be seen to arise at the same level as the notch caused by the sling fibres of the stomach.

(*b*) Constant rings: Occasionally, in patients with a sliding hiatal hernia, the ring due to the transverse mucosal fold becomes thickened and is seen irrespective of the degree of distension of the lumen. This is the 'Schatzki ring' (Schatzki and Gary, 1953; MacMahon, Schatzki, and Gary, 1958; Schatzki, 1965). It seems likely that the change in the behaviour of the transverse mucosal fold is caused by peptic oesophagitis with submucous fibrosis. The situation of the mucosal junction is so variable that either ring at the oesophago-gastric junction could have squamous epithelium on its upper surface and columnar epithelium below.

Other rings may be seen higher up in the oesophagus, such as the ring associated with an oesophagus lined by columnar epithelium.

The various types of inferior oesophageal ring can only be distinguished by careful cinefluorography or viewing on a television screen.

'Empty segments' An 'empty segment' is a segment of oesophagus which does not retain its barium coating and is consequently not visible radiologically (Botha, 1958). In the patients with hiatal and oesophageal markers, several so-called 'empty segments' could be identified.

(*a*) During expiration, the hiatus can limit the expansion of the distended oesophagus slightly,

but more so on deep inspiration, and the large mucosal folds of the vestibule cause the oesophagus to appear empty as it passes through the hiatus.

(*b*) The contracted vestibule can give rise to an empty segment which will be partly above and partly below the hiatus.

(*c*) Stretching and compression of the vestibule below the hiatus may occur when a subject inspires as a bolus is passing through the vestibule. This gives rise to a short empty segment.

DISCUSSION

The radiological landmarks which may be seen in the distal oesophagus during a barium swallow examination are the inferior oesophageal sphincter, the vestibule, the oesophago-gastric junction, and the hiatus on deep inspiration.

THE HIATUS On inspiration, the hiatus slides downwards on the oesophagus, so that a progressively shorter segment of oesophagus remains in the abdomen.

The hiatus narrows only very slightly on quiet inspiration, but moderate narrowing may occur on deep inspiration. Thus, it can be assumed that the oesophagus is not squeezed by the hiatus on quiet inspiration but that it could be compressed on deep inspiration. The forward movement of the hiatus with inspiration and the greater movement of the left wall tend to hook the oesophagus forwards at this level. The oesophagus can be severely kinked in this way on deep inspiration. No support was given to the findings of Dinnick (1961) that the hiatus widens on deep inspiration, nor to those of Botha (1957) that it moves backwards on inspiration. If a finger is inserted into the hiatus at operation and the anaesthetic is lightened to allow spontaneous respiration, the finger is pressed back against the aorta with each inspiratory movement. It is misleading to draw conclusions about the function of the hiatus from an observation on an anaesthetized patient with an open abdomen. The cinefluorographic studies reported here show unequivocally that the oesophagus moves forwards with inspiration, not backwards. This finding is of importance in the planning of an operation for the repair of the hiatus in a patient with a hiatal hernia. It is better to suture the hiatal margins behind and not in front of the oesophagus, so that inspiratory movements tend to push the oesophagus away from, rather than towards, the suture line. Although it seems likely that narrowing of the hiatus and kinking of the oesophagus play a role in the closure of the vestibule on deep inspiration, ordinarily, during normal quiet respiration, the hiatus does not appear to have any sphincteric function.

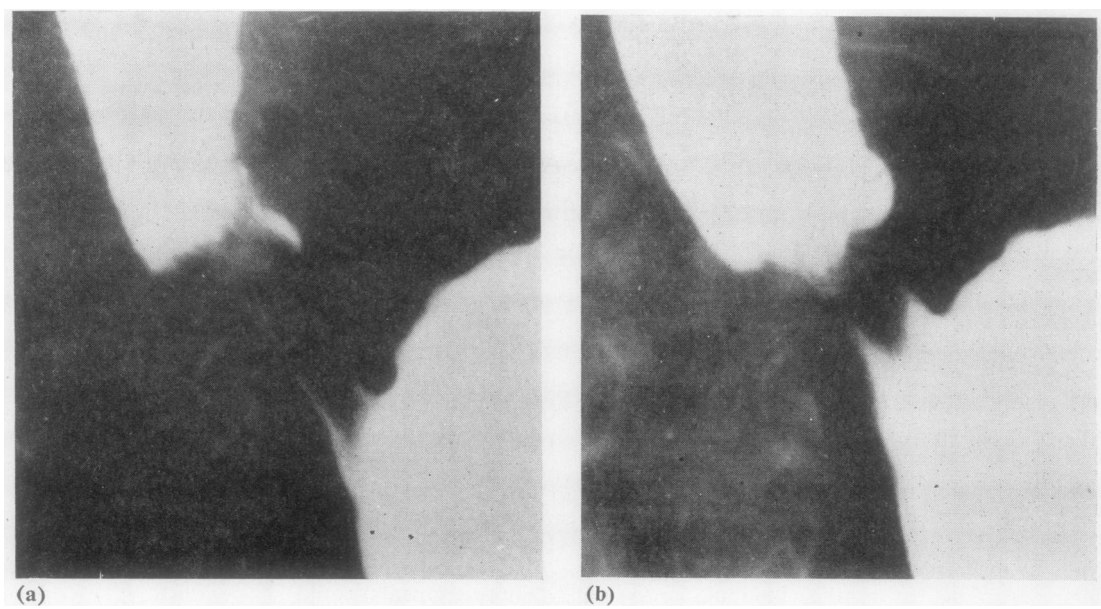


FIG. 7. *Effect of inspiration on contracted vestibule of a patient who had previously had no operation on the thorax or abdomen :* (a) *deep inspiration, vestibule stretched;* (b) *expiration, vestibule shorter than in* (a).

On inspiration, the vestibule is slightly stretched in most persons; presumably the oesophagus elongates higher up in some persons. It seems highly probable that the strength and elasticity of the phreno-oesophageal membrane determine the amount that the lower oesophagus (where the markers were placed) can stretch with respiration. Stretching of the vestibule also occurs in patients who have had no previous operation on the thorax or abdomen (Fig. 7), so it is unlikely to be due to the operative procedure. This stretching of the distal oesophagus probably enhances the sphincteric effect of the vestibule, especially on deep inspiration.

THE VESTIBULE In those patients in whom one of the markers had been fortuitously placed in the vicinity of the inferior oesophageal sphincter, a number of deductions could be made about the function of the vestibule. Shortly after deglutition and before the stripping wave reached the lower oesophagus, the marker on the inferior oesophageal sphincter moved orally, while the marker at the oesophago-gastric junction remained in the abdomen. A far greater amount of separation of the markers occurred after deglutition than on inspiration. This increase in length of the vestibule was likely to have been due to relaxation of its muscle layers initiated by deglutition. Presumably, shortening of the oesophagus above by the stripping wave also stretched the relaxed vestibule. Since the stripping wave ceased at the inferior oesophageal sphincter, the vestibule appeared to be functionally separate from the rest of the oesophagus. As the lumen of the vestibule closed, the marker on the inferior oesophageal sphincter moved distally, showing that the vestibule shortened as it narrowed, because its longitudinal and transverse muscle layers contracted simultaneously. The oral movement of the inferior oesophageal sphincter was not due to the operative procedure, for it may be observed in patients in whom no operation has been carried out in this region (Berridge, 1961). On deglutition, the marker at the oesophago-gastric junction moved upwards with shortening of the abdominal oesophagus. No reflux was observed in the 13 patients in whom the marker on the oesophago-gastric junction remained in the abdomen. The vestibule also formed a chamber, with a wider diameter than the oesophagus above, when the flow of contrast medium into the stomach was partially obstructed, *e.g.*, by deep inspiration or abdominal compression. These findings all support the concept of the vestibule as a functional entity.

Five different aspects of the function of the vestibule can be distinguished: (1) it permits free flow of the swallowed bolus into the stomach; (2) it temporarily stores a swallowed bolus whenever it is necessary to do so; (3) it can form a chamber with a sphincter immediately above it, which appears to act as a barrier between the negative intrathoracic pressure and the higher intragastric pressure, allowing food to be conveyed from the thorax to the abdomen against the pressure gradient without reflux; (4) it closes the oesophago-gastric junction after the oesophagus has been emptied of its contents by a stripping wave; (5) it prevents gastro-oesophageal reflux at rest.

When viewing the vestibule on a radiograph it should be remembered that it is not a static structure but can vary considerably in length, shape, and position relative to the hiatus.

As there are a number of different types of inferior oesophageal ring and empty segment in the lower oesophagus, these terms should always be qualified by a description of their type or cause. The difference between the various rings can only be resolved by careful cinematography or viewing on a television screen, so either of these techniques should be used whenever possible.

In patients with a sliding hiatal hernia, a notch on the left due to the sling fibres of the stomach, as well as a ring at the distal end of the vestibule caused by a transverse mucosal fold, mark the position of the oesophago-gastric junction. Since identification of these structures is facilitated by maximum distension of the oesophagus and partial obstruction to its out-flow, it appears to be advisable to use some method of achieving this in every case, such as placing the patient prone over a small bolster which does not support the thorax or pelvis, while the patient sucks barium continuously through a straw.

SUMMARY

The radiological landmarks in the distal oesophagus are the vestibule with the inferior oesophageal sphincter at its upper limit and the sling fibres of the stomach and transverse mucosal fold at its lower limit (the oesophago-gastric junction), and the hiatus on deep inspiration.

Radiological observations of the hiatus and lower oesophagus carrying opaque markers have shown that the hiatus moves forwards as well as downwards on inspiration and that its left wall moves more than its right one. The hiatus only narrows significantly on deep inspiration and its position may then be determined radiologically.

The lower oesophagus is stretched to a limited degree on inspiration.

Following deglutition, the vestibule elongates as it relaxes, and it shortens again when it contracts. The stripping wave ends at the inferior oesophageal sphincter, but, without special techniques to demonstrate this sphincter, a fictitious appearance may be produced of a stripping wave passing right down and through the hiatus.

Several different types of inferior oesophageal ring and empty segment are described. In patients with a sliding hiatal hernia, a notch on the left due to the sling fibres of the stomach, as well as a ring at the distal end of the vestibule caused by a transverse mucosal fold, mark the position of the oesophago-gastric junction.

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