Best Practice & Research Clinical Gastroenterology
Vol. 22, No. 4, pp. 553–567, 2008
doi:10.1016/j.bpg.2008.02.003
available online at http://www.sciencedirect.com

1A

The normal anatomy around the oesophagogastric junction: An endoscopic view

H. Worth Boyce* MD, MS, MACG

Professor of Medicine and Radiology
Director of Joy McCann Culverhouse Center for Esophageal and Swallowing Disorders
University of South Florida College of Medicine, Departments of Internal Medicine and Radiology, 12901 Bruce B. Downs Boulevard, Box 72, Tampa, FL 33612, USA

Where the oesophagus ends and the stomach begins has been a bone of contention for decades between the histologist, physiologist, gastroenterologist, radiologist and surgeon. The oesophagogastric junction (OGJ) is an important anatomical region because of its essential functions in relation to swallowing and as a site of structural defects, inflammation, metaplasia and neoplasia. The location of the diaphragmatic hiatus in relation to the distal oesophagus, the level of the squamocolumnar mucosal junction (SCJ), the location of the distal margin of the mucosal palisade veins and the proximal margin of the gastric mucosal folds are features that permit an accurate endoscopic diagnosis of hiatal hernia and reflux sequelae, including even a minimal extent for Barrett's oesophagus. The physiological OGJ region can be considered to be between the rosette of the lower oesophageal sphincter (LOS) and the angle of His. The most reliable benchmarks for the precise mural OGJ that can be identified during endoscopy are the levels of the cephalad margins of the linear gastric mucosal folds, viewed with the lumen deflated as much as possible, that are juxtaposed to the level of the caudad extent of the oesophageal mucosal palisade veins.

Key words: oesophagogastric junction; squamocolumnar mucosal junction; gastric folds; lower oesophageal sphincter; palisade veins; diaphragmatic hiatus.

> ***'Anatomy is the only solid foundation of medicine; it is to the physician and surgeon what geometry is to the astronomer'*** *William Hunter, circa 1750*

The oesophagogastric junction (OGJ) is an important anatomical region because of its essential functions in relation to swallowing and as a site of structural defects,

* University of South Florida College of Medicine, Department of Internal Medicine, 12901 Bruce B. Downs Boulevard, Box 72, Tampa, FL 33612, USA. Tel.: +1 813 974 2034; Fax: +1 813 974 7031.
E-mail address: wboyce@health.usf.edu

inflammation, metaplasia and neoplasia. Manometric study is required for the evaluation of functional derangements, while endoscopy with biopsy is essential for the diagnosis of structural and histological abnormalities. Where the oesophagus ends and the stomach begins has been a bone of contention between the histologist, physiologist, gastroenterologist, radiologist and surgeon for many years.

The oesophagus in the average adult is about 25 cm long. It passes through the diaphragmatic hiatus at approximately 38 cm from the incisor teeth and joins the stomach at about the 40 cm level. The normal level of the OGJ and squamocolumnar mucosal junction (SCJ) measured during endoscopy may vary by 1–2 cm depending on the body habitus, type of endoscope used and the care with which such measurements are made. More accurate distance measurements are made on endoscope withdrawal than during insertion because the instrument is in a more straightened position.

It is important to observe carefully during oesophagoscopy and record the characteristics of the distal oesophagus and proximal stomach in all patients. The location of the diaphragmatic hiatus in relation to the distal oesophagus, the level of the SCJ, the location of the distal margin of the mucosal palisade veins and the proximal margin of the gastric mucosal folds are features that permit an accurate endoscopic diagnosis of hiatal hernia and reflux sequelae, including even a minimal extent for Barrett's oesophagus. The levels of these features as measured from the central incisor teeth or alveolar crest should be recorded in every oesophagoscopy report.

There are four anatomical–endoscopic benchmarks to be included in a complete examination of the OGJ region: the proximal margin of the lower oesophageal sphincter (LOS), if it is demonstrable; the squamocolumnar mucosal junction; the level of disappearance of the linear mucosal palisade veins; and the proximal margins of the gastric mucosal folds. The rosette (proximal margin) of the intrinsic segment of the LOS is difficult to localise in normal subjects without special care, because the inflation pressure usually produced during endoscopy exceeds LOS pressure and obliterates the focal lumen narrowing at the level of the rosette. The location of the SCJ is the least reliable of the four benchmarks because of its known potential for cephalad migration when a patient develops a Barrett oesophagus. The most reliable endoscopic benchmark for the OGJ was reported two decades ago to be the cephalad margin of the linear gastric folds with the lumen deflated as much as possible.[1] The level of the distal margin of the oesophageal palisade veins also provides a close approximation of the OGJ.[2] A histological criterion, i.e. the most distal location of the submucosal oesophageal glands, is reported to be a more precise indicator of the location of the OGJ, but obviously is of no help for either endoscopic localisation of the OGJ or for decisions on biopsy sites during endoscopy.[3,4] The anatomical features of the OGJ region will be discussed in the sequence they would be encountered during an endoscopic examination. It is important to understand that there are variations within the range of normality that will be easily recognised and interpreted as such by the experienced endoscopist.

LOWER OESOPHAGEAL SPHINCTER

In response to a swallow, the LOS functions by receptive relaxation to allow the timely passage of swallowed material presented to its proximal margin in response to the antegrade pressure generated by an orderly primary or secondary peristaltic wave through the oesophageal body. After passage of the bolus, the sphincter closes and maintains a resting pressure which is sufficient to prevent pathological degrees of gastro-oesophageal reflux under normal conditions.

The LOS consists of two components, the intrinsic and crural segments. The intrinsic segment is represented by a 1–2-cm zone of contraction of oesophageal muscle. There is no evidence for a focal anatomical intrinsic sphincter muscle and this segment is considered to be a physiological sphincter without an anatomical correlate. The closure of the more distal or crural segment of the OGJ results primarily from extrinsic pressure produced by compression from the diaphragmatic crus at the hiatus, as well as from surrounding structures.[5,6] Endoscopic identification of the LOS region can be most accurately assessed in patients with achalasia or a hypertonic intrinsic segment and such observations will be discussed and illustrated here. The often-elevated pressure in the LOS with achalasia provides the ideal opportunity to study the precise location, anatomical relationships and dimensions of the intrinsic and crural segments. The combination of achalasia with a hiatal hernia allows precise evaluation of the crural segment of the LOS.

The proximal margin or rosette of the intrinsic segment of the LOS is only seen in some subjects with a normal oesophagus when inflation is kept to a minimum. At the point of closure of the proximal end of the sphincter there may be several (usually 4–6) mucosal folds that disappear into the centre of the closed lumen (Figure 1). This closure produces the rosette appearance with the lumen being precisely centred at the point where these longitudinal folds converge. Since the LOS can dilate to allow the passage of a 2–3-cm diameter bolus and shut completely, it is not surprising that the excessive mucosa necessary for lumen expansion during relaxation becomes folded in a linear orientation on contraction or closure and forms this mucosal rosette. These mucosal folds probably serve as a potentiating factor in preventing reflux when the LOS has exerted its force and, together with the muscularis mucosa, it can be considered a relatively watertight plug. The rosette does not always appear with closure of the LOS.

As the closed normal LOS is approached with the endoscope it will relax with gentle scope pressure and with passage through the stomach there is no detectable resistance.

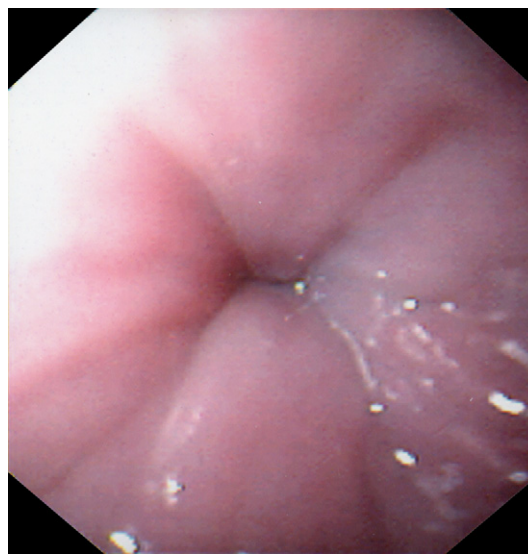

Figure 1. Endoscopic view of the mucosal rosette at the proximal margin of the lower oesophageal sphincter (LOS).

This intrinsic segment of the LOS is often not detectable in patients with gastro-oesophageal reflux disease because of its usually hypotensive state. As the intrinsic sphincter zone relaxes, one can identify the squamocolumnar mucosal junction about 2 cm beyond (Figure 2). This proximal or intrinsic segment of the LOS is most easily demonstrated in patients with achalasia because the point of closure is more obvious from the contrast in lumen diameter between the dilatation of the body of the oesophagus and the typical tight closure of the usually hypertonic sphincter. The length of the intrinsic sphincter segment measured during endoscopy is between 10 and 15 mm. This level of intrinsic sphincter segment closure corresponds with the so-called oesophageal A-ring or muscular contraction ring, both in location and in contour, which may be seen during radiography as well as antegrade endoscopy. The distance between the caudad margin of the intrinsic sphincter segment and the SCJ, i.e. the length of the crural sphincter segment, can be measured during a retrograde view from the proximal stomach by comparison with the endoscope diameter to lie approximately 10–15 mm cephalad to the normally located SCJ (Figure 3). This anatomical relationship is most readily documented in the presence of a small hiatal hernia in a patient with elevated LOS pressure but can be apparent to the careful observer in subjects with normal LOS pressure when over-inflation of the stomach is produced (Figure 3).

The total LOS length is measured during endoscopy at about 3 cm. The OGJ is located in the distal third of the crural segment of the LOS. The intrinsic segment of the LOS is lined by squamous oesophageal epithelium and the crural segment is lined by the same squamous epithelium to a level at, or several millimetres cephalad to, the margin of the angle of His. In the normal state, a retroview reveals several millimetres, of columnar epithelium extending from the margin of the SCJ to the angle of His (Figure 4).

After the endoscope is passed into the proximal stomach, a retroversion manoeuvre should be performed to view the fundus from below. In the normal setting, the insertion tube of the endoscope can be seen exiting a snugly fitting intra-abdominal crural segment of the LOS (Figure 4). The snug fit in this region is sustained throughout respiration and during moderate insufflation of the stomach, except that transient

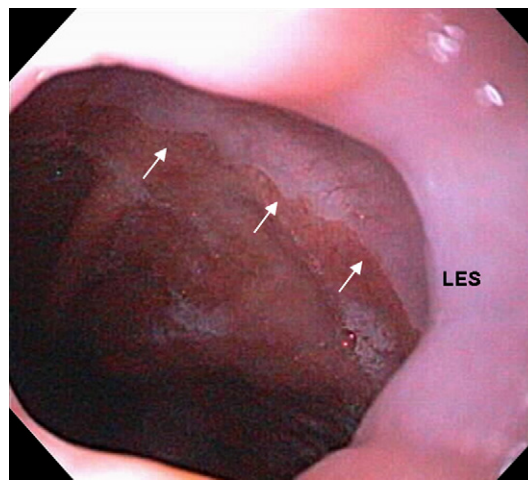

Figure 2. View through the partially opened lower oesophageal sphincter (LOS) revealing the squamocolumnar junction below (arrows).

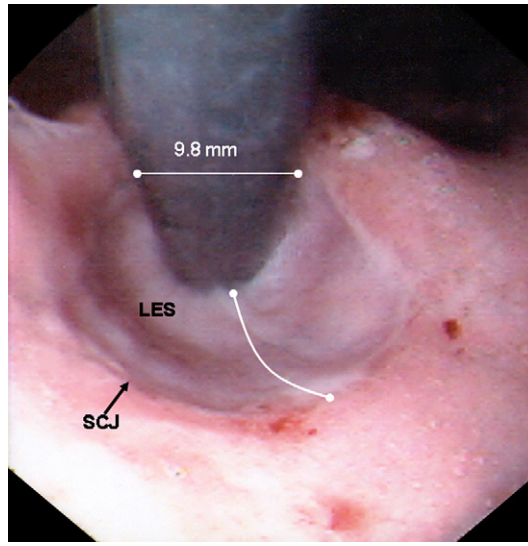

Figure 3. Retrograde view of the crural segment of the lower oesophageal sphincter (LOS) opened between the squamocolumnar junction (SCJ) and the LOS by gastric inflation pressure. The endoscope diameter is used to estimate the distance of the SCJ below the closed intrinsic segment of the LOS, i.e. about 9.8 mm. The angle of His is draped over the endoscope between the 10 o'clock and 3 o'clock positions.

relaxation in response to primary and secondary peristalsis or gastric over-distention, as shown in Figure 3, exposes the mucosa in the crural sphincter segment. The angle of His is located on the greater curvature aspect of the proximal stomach and demarcates the most distal margin of the crural sphincter region.

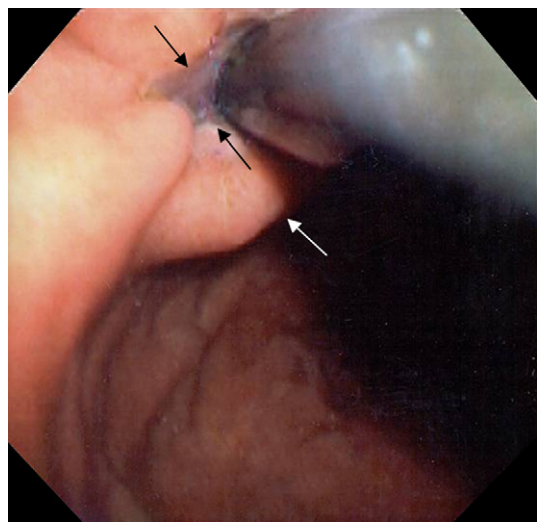

Figure 4. Retrograde view of the position of the squamocolumnar junction (SCJ) (black arrows) at the distal margin of the closed crural segment in relation to the angle of His (white arrow).

An elevated, rounded, linear elevation of the proximal gastric wall that protrudes towards the lesser curvature to variable degrees can be identified in some persons with normal anatomy during a retroversion examination and corresponds to the so-called intra-abdominal 'submerged segment' located just below the diaphragmatic hiatus (Figure 5). The crural segment of the LOS lies within this 'submerged segment' and can be opened as gastric inflation pressure is increased (Figure 4). This segment is typically patulous and displaced cephalad when a hiatal hernia is present.

SQUAMOCOLUMNAR MUCOSAL JUNCTION

The SCJ comes promptly into view during antegrade endoscopy about 2 cm beyond the intrinsic segment of the LOS (Figure 2) and located at a level just below the diaphragmatic hiatus, as seen with inflation during endoscopy (Figure 6). The squamous mucosa of the oesophagus is a pinkish-grey colour and contrasts sharply with the reddish-orange (salmon) colour of the gastric columnar epithelium.

The junction of the squamous and columnar epithelium appears after minimum inflation as a slightly irregular or undulating line, the so-called ora serrata or 'Z' (zig-zag) line (Figure 7A, B).[7,8] This irregularity is due to small, peninsula-like projections of the gastric columnar epithelium that extend up to 5 mm cephalad along the margin of the squamous mucosa. As the lumen is inflated, the serrations straighten and in some will present as a straight circumferential line (Figure 7C) when a small hiatal hernia is present.[9] The cephalad displacement of the OGJ into the thorax with a hiatal hernia allows adequate distention for this to occur. At the stage of maximal lumen distention, especially if accentuated by a sniff or sudden inspiration to increase intrathoracic negative pressure, a dynamic circumferential ring-like elevation (the so-called dynamic 'B' ring) may form, but again, only when a hiatal hernia is present (Figure 7D).[9] This dynamic structure is of no clinical significance but its development does indicate that the normally located SCJ is inherently unable to expand to the same degree as the tissues immediately above and below its margin.

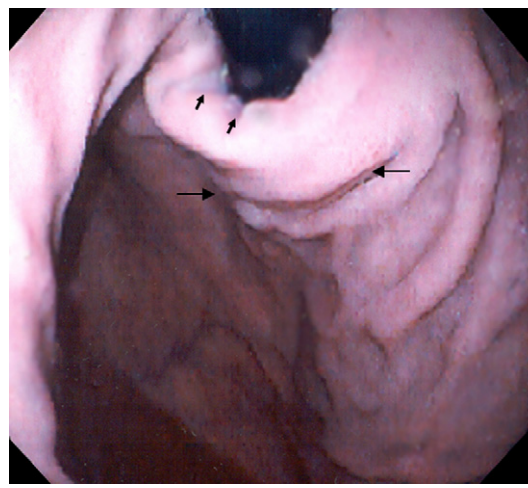

Figure 5. The so-called submerged or intra-abdominal segment of the distal oesophagus that contains the crural segment of the lower oesophageal sphincter (LOS) is shown between the two lower arrows. The margin of the squamocolumnar junction (SCJ) is shown by the upper arrows.

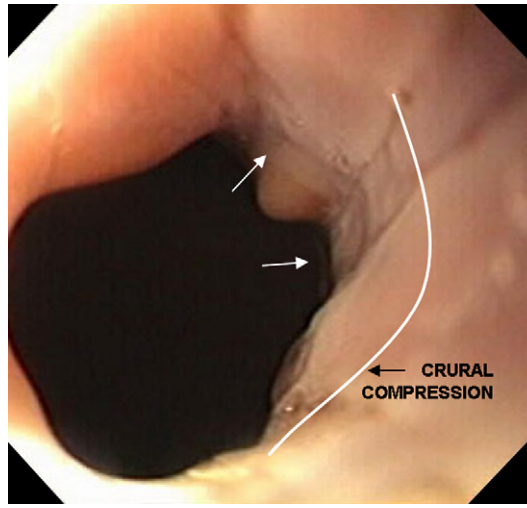

Figure 6. With inflation of the oesophagus and stomach, the distal oesophagus opens below the hiatus revealing the squamocolumnar junction (SCJ) in its normal location (arrow). The luminal compression at the level of the diaphragmatic hiatus is represented by the curved white line.

The occurrence of this dynamic ring-like elevation confirms the presence of a hiatal hernia. Interestingly, this dynamic 'B' ring is only seen when the SCJ is in its normal location with a hiatal hernia and is never demonstrable as a complete circumferential ring if the SCJ is in or below the diaphragmatic hiatus and when either severe oesophagitis or a Barrett oesophagus are present. The dynamic 'B' ring occurs at the same anatomical location as the Schatzki ring, but the latter is a static ring that maintains a persistent, reduced lumen diameter with oesophageal lumen distention by either air or barium.

The normal SCJ is located in the distal portion of the oesophageal crural sphincter segment below the hiatus and just proximal to the angle of His (Figures 3 and 4). Histological studies and micro-voltage potential difference measurements performed in conjunction with oesophageal manometry have demonstrated that the mucosal junction is at the lower end of the LOS. During endoscopy, lumen insufflation usually causes the SCJ to elevate to the level of the hiatus or just above (less than 2 cm) into the thorax (Figure 7A, B). This line of demarcation between the two types of mucosa is readily identifiable in the absence of pathological changes. If there is uncertainty about the location of the SCJ it can be dramatically demonstrated by the application of several millilitres of Lugol's iodine solution through an endoscopic catheter. The iodine will stain the glycogen in the oesophageal squamous epithelium to a brown-black colour in a few seconds (Figure 8). In addition to surface characteristics and colour, the normal distal extent of the oesophageal squamous epithelium is located at the cephalad margin of the gastric folds and 2–3 mm cephalad of the level of abrupt disappearance of multiple, linear, frequently branching, small mucosal palisade veins that extend to and onto the proximal margin of the gastric folds.

In some normal subjects, one or more very small islands of columnar epithelium may be present just proximal to the SCJ (Figure 9). Biopsy typically reveals gastric-type columnar epithelium without intestinal metaplasia. However, squamous islands along the SCJ are not considered normal and suggest the presence of a short segment of intestinal metaplasia (Barrett oesophagus). For this reason, the finding of squamous

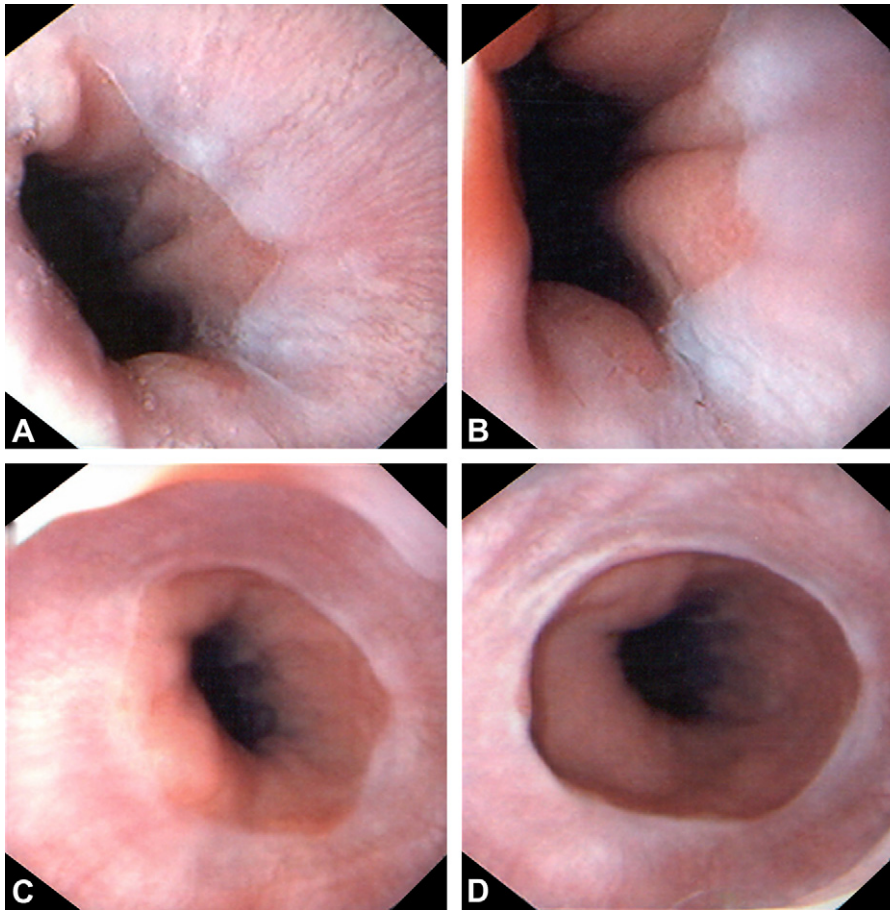

Figure 7. As the distal oesophagus is inflated, the lumen opens to reveal the squamocolumnar junction (SCJ) just below the hiatus (A). With additional inflation, the SCJ migrates above the hiatus (B). With increasing inflation the SCJ loses its serrated contours and the gastric folds are flattened (C). Additional inflation distends the gastric lumen sufficiently to demonstrate a small hiatal hernia and the oesophageal lumen proximal to the SCJ. The SCJ now protrudes as a smooth dynamic ring (D). The compression of the gastric wall by the diaphragmatic crura is seen in the centre.

islands indicates the need for biopsy. Mucosal biopsies adjacent to these islands are likely to reveal intestinal metaplasia.[10]

PALISADE MUCOSAL VEINS

In the distal 3–4 cm of the oesophagus is a longitudinal plexus of small veins that course through the lamina propria and disappear into the submucosa at the OGJ.[11–13] This region of linear veins is referred to as the palisade zone (Figure 10). The etymological meaning, from the French *palissade*, and ultimately from the Latin *palus* or stake, is

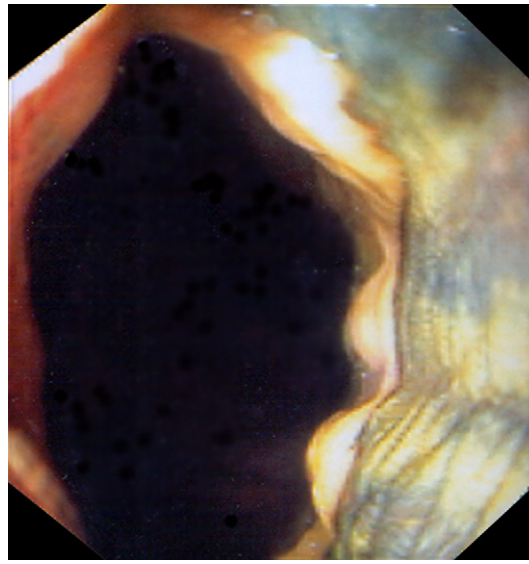

Figure 8. Although not often necessary, the squamocolumnar junction (SCJ) is easily stained by iodine, which provides a clear delineation between squamous and unstained columnar epithelium.

defined as: a fence of stakes especially for defence. The dense concentration of these fine, linearly orientated veins has also been referred to as 'sudare-like veins' by the Japanese because their appearance resembles a traditional sun-shade made of bamboo ('*sudare*' in Japanese).[13]

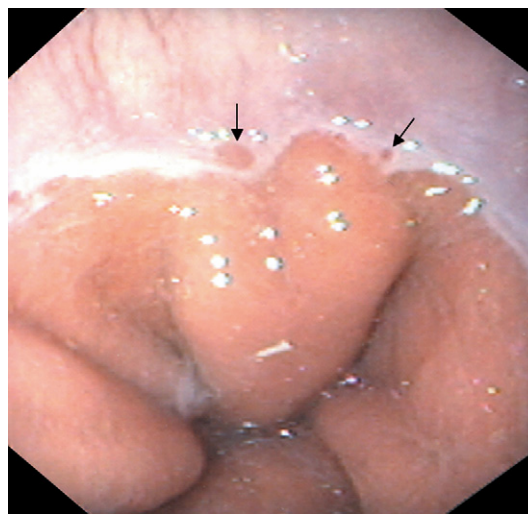

Figure 9. Two small islands of normal columnar epithelium are shown just proximal to the squamocolumnar junction (SCJ) (arrows).

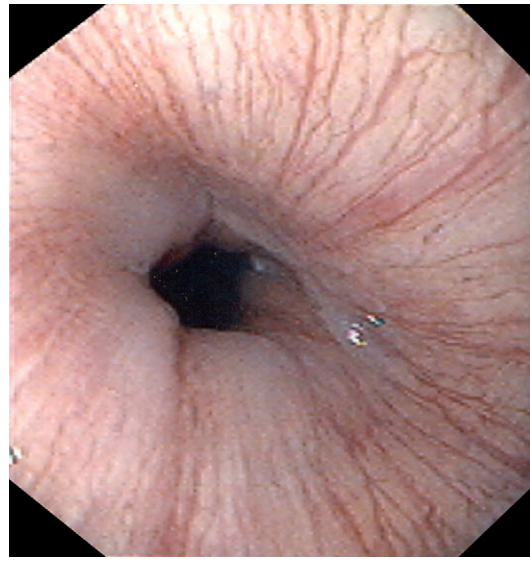

Figure 10. The linear palisade vessels in the lamina propria of the mucosa are shown extending towards the squamocolumnar junction (SCJ).

The distal oesophageal squamous mucosa with its pinkish-grey colour and translucency allows clear visualisation with good colour contrast of the linear, palisade veins in the lamina propria layer of mucosa. Visualisation of the palisade veins above the SCJ is improved by distending the oesophageal lumen with inflation and by narrow band imaging (NBI) (Figure 11). This vascular pattern is less discrete caudad to the SCJ in

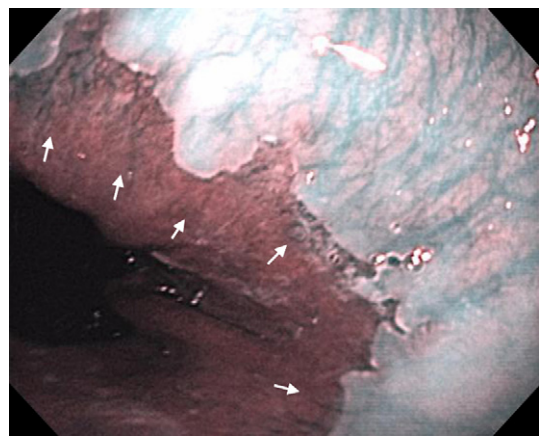

Figure 11. In this view of an irregular squamocolumnar junction (SCJ) (without intestinal metaplasia) the palisade vessels' appearance is enhanced with the use of narrow band imaging (NBI). The distal extent of the vessels is indicated by arrows.

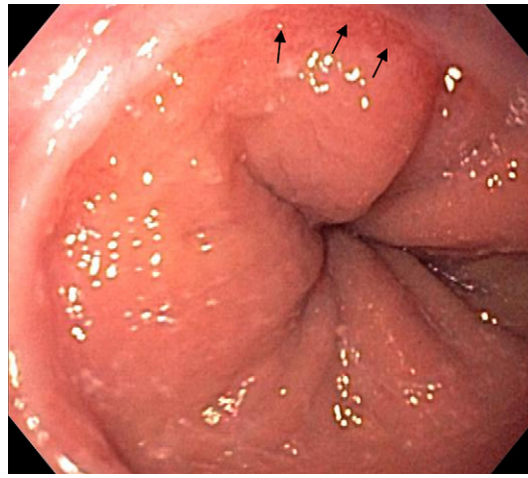

Figure 12. View of another presentation of very small vessels extending below the squamocolumnar junction (SCJ) that are difficult to visualise with standard light (arrows).

some patients and appears as a band of irregular hyperaemia along the gastric side of the SCJ (Figure 12). NBI improves the definition of this unique vascular pattern (Figure 13). This vascular anatomy can be easily studied during endoscopy by both antegrade and retrograde endoscopic inspection. When inflammation of the squamous mucosa is present this vascular pattern may be partially or totally obscured.

The palisade mucosal veins can be traced to a level 2–3 mm distal to the normally located SCJ where they disappear (Figures 11–13 and Figure 14C, D). This level of palisade vein disappearance into the submucosa is a reliably close, although not an absolutely precise, indicator of the level of the muscular or true anatomical OGJ.[11–13]

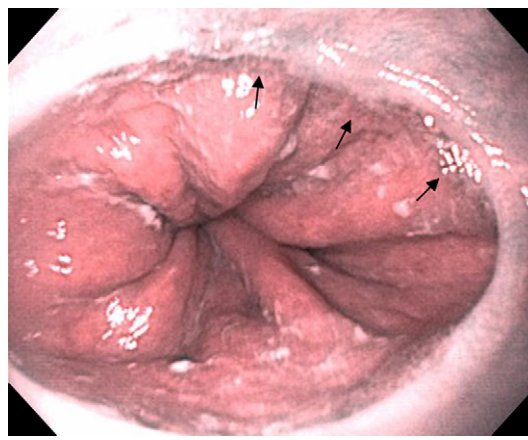

Figure 13. Narrow band imaging (NBI) in the same patient as in Figure 12, produces accentuation of the vessels in a dark blue colour and their level of disappearance into the submucosa.

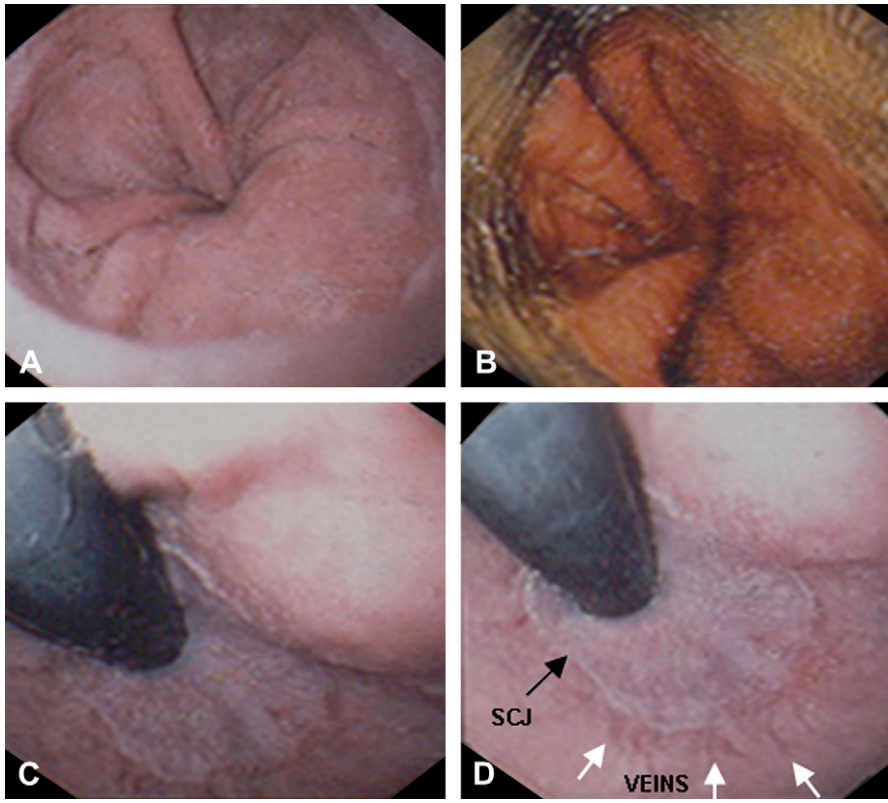

Figure 14. Antegrade views of the unstained (A) and the iodine stained squamous mucosa document the relationship of the juxtaposition of the squamocolumnar junction (SCJ) to the proximal margin of the gastric folds. Retrograde views (C and D) demonstrate the absence of folds obliterated after gastric inflation. The SCJ and distal extent of the palisade vessels are shown (arrows).

DIAPHRAGMATIC HIATUS

The compression of the so-called crural or intra-hiatal segment representing the caudad half of the LOS is identified during antegrade endoscopy by noting an accentuation of the lumen compression as the diaphragmatic crura slowly descend during inspiration or abruptly descend if the patient is able to perform a sniff manoeuvre. The wall of the distal oesophagus is slightly indented or smoothly compressed as the hiatal margin moves inferiorly with a sniff or deep breath. Crural compression of the lumen of the gastric wall of a hiatal hernia (Figure 7C, D and Figures 12,13) is more easily identified when these respiratory manoeuvres are performed. It is possible in most instances to determine the crural level with relative precision.[9,14] Breathing manoeuvres can accentuate this location. As the lumen is gently inflated the patient, if sufficiently conscious, may be asked to sniff or inhale rapidly, at which time the diaphragmatic hiatus moves inferiorly either quickly, or gradually, depending upon the breathing manoeuvre used to demonstrate its location.

PROXIMAL MARGINS OF GASTRIC FOLDS

The cephalad margins of several linear gastric folds are normally located circumferentially and immediately contiguous to the normal SCJ (Figure 7B, Figures 8,9,12,13 and Figure 14A, B). Accurate determination of the level of the proximal margins of the gastric folds requires that minimal lumen inflation be used. Over-inflation flattens or obliterates the folds producing the impression that the fold margins are farther away from the SCJ (Figure 7C, D). This results in an endoscopic impression that a Barrett oesophagus is present and provokes the endoscopist to incorrectly biopsy proximal stomach rather than oesophagus.[10] The proximal margins of the gastric folds provide the most easily visible and best endoscopic benchmark for the muscular junction between the oesophagus and the stomach as well as a benchmark for the expected normal location of the SCJ.[1] These relationships to the OGJ can also be demonstrated on surgical and autopsy specimens.

For practical clinical and endoscopic purposes, the proximal margins of the gastric folds, with the lumen deflated as much as possible to ensure their normal positions, remain the benchmark that most clearly correlates with the true OGJ. Although a variation of several millimetres occurs, such minimal variation is of no practical significance to the clinician endoscopist. When biopsies are done, especially for Barrett oesophagus, they should begin at the level of the proximal margin of the gastric folds with the lumen deflated as much as possible to ensure tissue sampling of the most distal margin of the oesophagus.

The proximity of the cephalad margin of the gastric folds to their normal location at the SCJ may not be apparent on the gastric retroview due to their obliteration/flattening by the intragastric inflation pressure (Figure 14C, D). By reducing the degree of

Figure 15. Retrograde view reveals linear gastric folds (arrows) along the lesser curvature (*magenstrasse*) and the angle of His on the greater curvature aspect of the proximal stomach.

inflation during retroversion endoscopy, the gastric folds may or may not be observed to return to their normal location contiguous to the SCJ.

Other important benchmarks for the study of the OGJ region are the angle of His and the relative positions of the greater and lesser curvature aspects of the proximal stomach. When the stomach is not over-inflated and no hiatal hernia is present, the endoscopist can readily identify the greater curvature side by locating the angle of His (Figures 3–5,15). The lesser curvature of the proximal stomach is identified in many patients by the location of the *magenstrasse* (stomach street) as described by the father of endoscopy, Rudolf Schindler (Figure 13). This peculiar linear orientation of gastric folds can serve as a benchmark for localising lesions that occur on the lesser curvature side of the distal oesophagus or proximal stomach.

SUMMARY

The junction between the oesophagus and the stomach has been defined in several ways, usually depending on the speciality interest of the person providing the definition, whether it be physiologist, histologist, radiologist, surgeon or endoscopist. After many years of argument, measurement and confusion, there appears to be a consensus emerging based on the work of both long-established scientific disciplines and modern manometric and endoscopic technology. The endoscopist depends on reliable anatomical benchmarks that can be utilised in all patients to document the location of the OGJ. The criteria for locating this junction must be reliable for making a reasonably practical decision during the endoscopy that will serve to enhance proper diagnosis both by direct inspection and biopsy sampling.

The most significant clinical need for identifying the OGJ is related to the diagnosis of Barrett oesophagus and hiatal hernia. For this purpose, there must be a benchmark that can be easily identified, with a fixed anatomical position that remains identifiable for most of the pathological conditions that affect the region. Endoscopists need as reliable and practical a benchmark as possible since they are not able to utilise pathologist's histological criterion, i.e. the most caudad location of the oesophageal submucosal glands, for identification of the OGJ during endoscopy.

The physiological OGJ region can be considered to be between the rosette of the LOS and the angle of His. The most reliable benchmarks for the precise mural OGJ that can be identified during endoscopy are the levels of the cephalad margins of the linear gastric mucosal folds, viewed with the lumen deflated as much as possible, that are juxtaposed to the level of the caudad extent of the oesophageal mucosal palisade veins.

Practice points

- The oesophagogastric mural or muscular junction is best identified during endoscopy by locating the cephalad margins of the gastric folds with the lumen deflated as much as possible.
- The caudad margins of the oesophageal mucosal palisade veins are also a reliable, supplemental endoscopic benchmark for the oesophagogastric junction.

REFERENCES

*1. McClave SA, Boyce HW & Gottfried MR. Early diagnosis of columnar-lined esophagus: a new endoscopic diagnostic criterion. *Gastrointest Endosc* 1987; **33:** 413–416.
*2. Boyce HW. Endoscopic definition of esophagogastric junction regional anatomy. *Gastrointest Endosc* 2000; **51**(5)**:** 586–592.
3. Shi L, Der R, Ma Y et al. Gland ducts and multilayered epithelium in mucosal biopsies from gastroesophageal junction region are useful in characterizing esophageal location. *Dis Esophagus* 2005; **18:** 87–92.
*4. Chandrasoma P. Controversies of the cardiac mucosa and Barrett's esophagus. *Histopathology* 2005; **46**(4)**:** 361–373.
*5. Mittal RK & Balaban DH. Mechanisms of disease: the esophagogastric junction. *N Engl J Med* 1997; **336**(13)**:** 924–932.
6. Heine KJ, Dent J & Mittal RK. Anatomical relationship between the crural diaphragm and the lower esophageal sphincter: an electrophysiologic study. *J Gastrointest Motil* 1993; **5:** 89–95.
*7. Savary M & Miller G. *The Esophagus: Handbook and Atlas of Endoscopy*. Solothurn, Switzerland: Gassmann, 1978.
*8. Wallner B, Sylvan A & Janunger K-G. Endoscopic assessment of the 'z-line' (squamocolumnar junction) appearance: reproducibility to the zap classification among endoscopists. *Gastrointest Endosc* 2002; **55**(1)**:** 65–69.
9. Boyce HW. Hiatus hernia and peptic diseases of the esophagus. In Sivak MV (ed.). *Gastronenterologic endoscopy*. 2nd ed. Philadelphia: WB Saunders, 2000, pp. 580–597.
*10. Boyce HW. Barrett esophagus. Endoscopic findings and what to biopsy. *J Clin Gastroenterol* 2003; **36**(Suppl. 1)**:** S6–S18.
*11. De Carvalho CAF. Sur l'angio-architecture veineuse de la zone de transition oesophagogastric et son interpretation fonctionnelle. *Acta Anat* 1966; **64:** 125–162.
12. Noda T. Angioarchitectural study of esophageal varices. With special reference to variceal rupture. *Virchows Arch A Pathol Anat Histopathol* 1984; **404:** 381–392.
*13. Vianna A, Hayes PC, Moscoso G et al. Normal venous circulation of the gastroesophageal junction. A route to understanding varices. *Gastroenterology* 1987; **93:** 876–879.
*14. Trujillo NP & Boyce HW. Gastroscopic evaluation of the esophagogastric junctional area. *Gastrointest Endosc* 1967; **14:** 120–123.