The anatomical extent of the pyloric sphincteric cylinder, the pyloric mucosal zone and the pyloric antrum

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Summary

The anatomy of the pyloric sphincteric cylinder is discussed. The pyloric ring is not a separate anatomical structure, but is an inherent part of the cylinder. Contraction of the cylinder narrows the diameter of the pyloric ring, and thus of the pyloric aperture. The extent of the sphincteric cylinder is determined on radiographs. It is seen to be 3-5 cm in length when fully contracted. Anatomical features of the pyloric mucosal zone are reviewed. On the aboral side both the cylinder and the mucosal zone end at the ring. The entire cylinder is lined by pyloric mucosa, but the mucosal zone extends orally beyond the confines of the cylinder. In gastric ulcer it may extend much further up the stomach. In contrast to the cylinder, the greatest length of the mucosal zone is on the lesser curvature.

The sphincteric cylinder and the pyloric mucosal zone are clearly defined anatomically. The term 'pyloric antrum', in contrast, has been used in many different senses.

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It is not always appreciated that peristaltic or peristalsis-like contractions in the distal stomach differ from those in the corpus. Normally, peristaltic waves commence in the upper part of the body of the stomach, some distance below the gastro-oesophageal junction. These narrow, annular, constricting waves travel in an aboral direction, but do not proceed as far as the pyloric aperture. Several centimetres orally to the aperture each wave becomes stationary, at the same time initiating a concentric, tube-like or segmental contraction of the remainder of the stomach. These features are seen regularly during conventional barium meal examination. (During the double-contrast barium meal examination gastric contractions are abolished by the administration of anticholinergics.)

The characteristic pyloric contractions can only be due to some specialization in the structure or function of the gastric musculature. Anatomists have clearly demonstrated the existence of a pyloric sphincteric cylinder in the distal stomach. Contractions of this structure will account for the tube-like or segmental pyloric contractions. In the present investigation the anatomical boundaries of the cylinder in relation to the boundaries of the pyloric mucosal zone and the pyloric antrum are examined.

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The pyloric sphincteric cylinder

Cunningham[1] stated that, as far as the muscular structure went, no part of the stomach was more definite or more distinct than the pyloric sphincteric cylinder. The cylinder referred to a tube-like thickening of the muscularis externa, approximately 3-4 cm in length, in the distal stomach. The pyloric sphincteric ring (pyloric ring), 3-4 mm in width, was shown to be the aboral thickening of the cylinder. While the circular muscle fibres of the ring were sharply demarcated from those of the duodenum by a fibrous septum, there was no such division on the gastric side, where the circular fibres of the ring merged imperceptibly with those of the cylinder. The ring did not form a separate anatomical structure, but constituted an inherent part of the cylinder. Anatomically the cylinder could best be demonstrated in the fetus and the child and in adult specimens hardened in formalin. Forssell[2] and Torgersen[3] came to similar conclusions. The specialized muscular compartment, called the sphincteric cylinder by Cunningham, was designated the 'canalis egestorius' by these authorities. Contraction of the circular fibres of the canalis narrowed the lumen, while contraction of the longitudinal fibres approximated its circular loops. According to Forssell and Torgersen the canalis functioned as a unit. None of its constituents, e.g. the right loop (the pyloric ring), was able to act or contract independently. Again the canalis was shown to be several centimetres in length.

The radiologically visible contractions of the canalis egestorius or sphincteric cylinder have been documented.[4] Subsequently it was shown that during contraction of the cylinder the diameter of the pyloric aperture varied proportionally to the diameter of the cylinder.[5] Closing and opening of the aperture (surrounded by the ring) were found to be functions of contraction and relaxation respectively of the cylinder,[5,6] thus confirming the view that the ring does not function independently. Contraction of the cylinder caused a marked rise in intraluminal pressure.[7] The extent of the cylinder was re-evaluated in morbid anatomical, living anatomical and radiographic studies,[6] and again it was found to be approximately 3-4 cm in length in adults in its contracted state.

Materials and methods

The contractions of the pyloric sphincteric cylinder were studied radiologically in 20 normal adult subjects referred for barium meal investigation because of vague upper abdominal symptoms. Subjects were considered to be normal if no organic lesion could be demonstrated radiologically in the oesophagus, stomach and duodenum. Double-contrast barium meal studies were done but the administration of anticholinergics was omitted in order to exclude pharmacological modification of gastric contractions. Films of the full stomach were taken in the erect, right anterior oblique position: (*a*) at the commencement of contraction of the pyloric sphincteric cylinder (Fig. 1), and (*b*) during full contraction of the cylinder (Figs 2 and 3). The following measurements were taken on the films, during full contraction of the cylinder: the length of the pyloric sphincteric cylinder on the lesser curvature, and the total length of the lesser

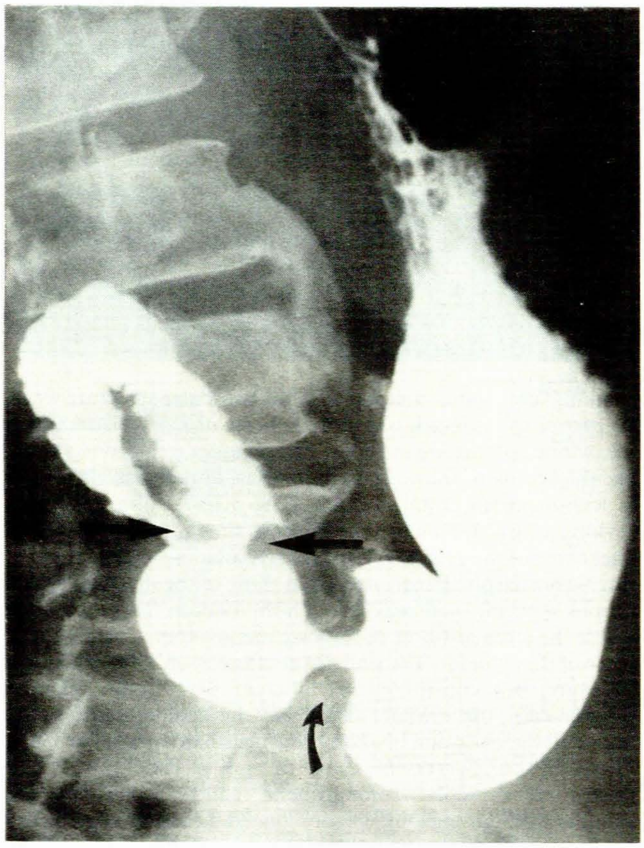

Fig. 1. Radiograph showing point at which peristaltic wave stops (curved arrow). **The sphincteric cylinder is located between this point and the pyloric ring** (arrowed).

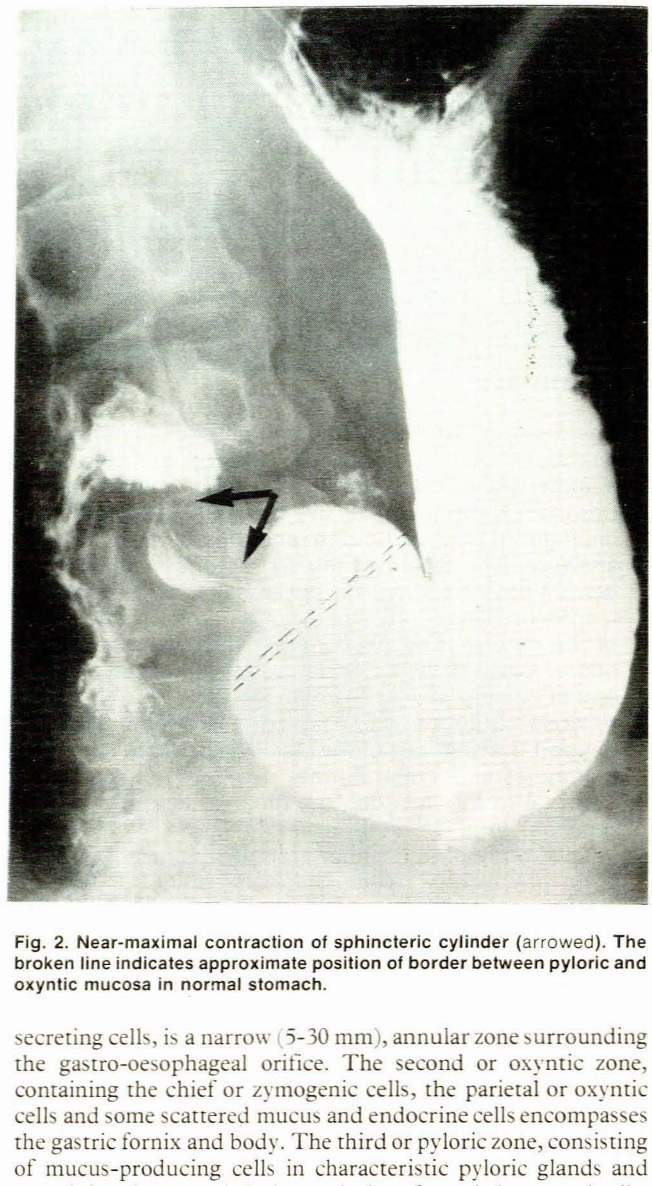

Fig. 2. Near-maximal contraction of sphincteric cylinder (arrowed). **The broken line indicates approximate position of border between pyloric and oxyntic mucosa in normal stomach.**

curvature. The percentage of the lesser curvature involved was calculated. Similar measurements were taken on the greater curvature. In all instances the measurements were taken by placing a string on the gastric outlines and measuring the length of the string. The curvatures were measured from the pyloric ring to the level of the gastro-oesophageal junction. The measurements in 5 typical cases are given (Table I). It is seen that when fully contracted the pyloric sphincteric cylinder is approximately 3 cm in length on the lesser, and 5 cm in length on the greater curvature. It was always shorter on the lesser than on the greater curvature. Successive contractions gave the same figures. (In contrast the lengths of the curvatures were found to vary, and consequently the percentage figures are less reliable.)

The pyloric mucosal zone

It is well known that, on the basis of the cell population of the glands, three mucosal zones are differentiated in the stomach. The cardiac zone, consisting overwhelmingly of mucus-secreting cells, is a narrow (5-30 mm), annular zone surrounding the gastro-oesophageal orifice. The second or oxyntic zone, containing the chief or zymogenic cells, the parietal or oxyntic cells and some scattered mucus and endocrine cells encompasses the gastric fornix and body. The third or pyloric zone, consisting of mucus-producing cells in characteristic pyloric glands and containing the overwhelming majority of gastric hormonal cells, lines the pyloric part of the stomach.

Border on aboral side

Using macroscopic techniques in 53 fresh, non-diseased postmortem specimens, Landboe-Christensen[8] found that the border between pyloric and duodenal mucosa might lie either on the perpendicular, duodenal side of the pyloric ring, at the top of the ring, or on the sloping gastric side of the ring. With ageing there was a tendency for the border to shift from the duodenal to the gastric side of the ring.

TABLE I. MEASUREMENTS SHOWING LENGTH OF PYLORIC SPHINCTERIC CYLINDER (PSC) IN RELATION TO LENGTH OF GREATER AND LESSER CURVATURES

	Case 1	Case 2	Case 3	Case 4	Case 5
Length of PSC on lesser curve (cm)	3,2	3,5	2,5	3,2	2,8
Length of lesser curve (cm)	23,2	22,5	20,0	23,0	21,2
% of lesser curve involved	13,0	15,0	12,5	14,0	13,2
Length of PSC on greater curve (cm)	5,0	5,0	3,5	5,4	4,0
Length of greater curve (cm)	26,0	35,0	30,0	33,0	34,0
% of greater curve involved	19,0	14,0	12,0	16,0	12,0

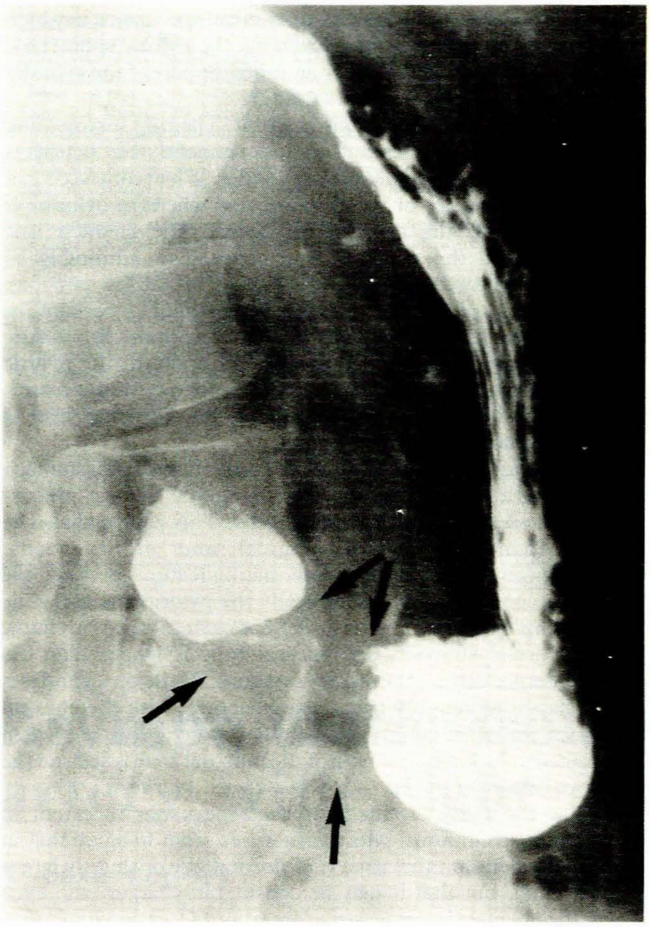

Fig. 3. Maximal contraction of sphincteric cylinder causing triangular 'gap'.

Using microscopic methods in 110 cases of partial gastrectomy for duodenal ulcer, Oi and Sakurai[9] came to essentially similar conclusions. In all specimens the border was within 5 mm of the summit of the pyloric 'sphincter muscle' (i.e. the pyloric ring), either on the duodenal or on the gastric side. The pyloric mucosa was in direct contact with the duodenal mucosa, i.e. the border could be identified as a line, in contrast to the border between pyloric and oxyntic mucosa, which consisted of a transitional zone of varying width.

Border on oral side

Landboe-Christensen[10] studied the extent of the pyloric mucosal zone on the oral side by macroscopic techniques in 47 non-diseased, fresh postmortem specimens. In all instances this zone was longer on the lesser than on the greater curvature, covering on average 7,2 cm of the lesser, and 5,2 cm of the greater curvature. The average percentage of the lesser curvature covered was 44%, and the average percentage of the greater curvature covered was 12%. The border between pyloric and oxyntic mucosa was irregular, often dentate or tortuous, and as a rule a number of islets of oxyntic mucosa were encountered in the pyloric zone. There was a transitional area of varying width between the two zones. In practice, a line drawn from the junction of the upper three-fifths and lower two-fifths of the lesser curvature, running downwards and to the right, indicates the approximate boundary of pyloric mucosa (Fig. 2).

Dean and Mason[11] studied 117 fresh gastric resection specimens microscopically (resection for either duodenal or gastric ulcer). In 18 cases of duodenal ulcer the average length of pyloric mucosa along the lesser curvature was 9,0 cm, and along the greater curvature 7,4 cm. On an average the pyloric mucosa extended for 1,5 cm further up the lesser than the greater curvature. In the majority of all duodenal ulcer specimens the transitional zone between pyloric and oxyntic mucosa varied from 0,5 to 5 cm in width, the average width being 1 cm.

The upper limit of the pyloric mucosa showed wide individual variations. Patients with gastric ulcers tended to have a greater extent of pyloric mucosa than those with duodenal ulcers, and women with gastric ulcers had more pyloric mucosa than men with gastric ulcers.

Schrager *et al.*[12] studied 13 fresh, postmortem, non-diseased stomachs. The average length of pyloric mucosa between the 'sphincter' (i.e. the pyloric ring) and the boundary zone on the lesser curvature was 8,9 cm, with an average 'sphincter'-to-cardia distance of 22,5 cm. Thus the pyloric zone encompassed 40% of the lesser curvature. On the greater curvature the average figures were 4,8 cm, 39 cm and 12% respectively. Comparative studies showed that in the majority of duodenal ulcer patients the pyloric zone was larger than in normal controls, and in the majority of gastric ulcer cases it was almost twice the normal size.

In surgical pH monitoring tests, Capper *et al.*[13,14] found a wide variation in size between the small pyloric zone of duodenal ulcer and the larger zone of gastric ulcer cases. With duodenal ulceration the zone was usually of normal size or smaller, extending to a line 3-4 cm from the pylorus. (In their only normal subject, the pyloric zone was 4-5 cm in length.) In gastric ulcer cases the pyloric zone was very much larger, at times encompassing the whole of the lesser curvature. Capper *et al.* concluded that the junction between the distal alkaline, pyloric zone and the proximal oxyntic zone was not static, but that it might migrate up and down the stomach. The alkaline zone could have been a normal 'antrum', but it could also have represented oxyntic mucosa which had been altered by gastritis.

Royston *et al.*[15] found, in patients with duodenal ulcer, that the mean area of the antrum, as defined histologically, was double the mean antral area defined as the alkaline zone in the pH studies of Capper *et al.*[13,14]

The test of Moe *et al.*[16,17] was based on the differential excretion of dyestuffs from the gastric corpus and the 'antrum' in dogs. The mean area of the 'antrum' was found to occupy 20% of the total gastric area, with a range of 10-30%. A modification of the test was used by Hedenstedt *et al.*[18] in humans, the results being controlled histologically. On the whole, the pyloric zone was found to be larger than that determined by Moe's test. In all cases the extent of pyloric mucosa was greater on the lesser than on the greater curvature. Amdrup *et al.*[19] used the Congo red test for a precise determination of the 'antrum' prior to antrectomy for gastric ulcers. In their experience the 'antrum' in gastric ulcer cases was often larger than in duodenal ulcer cases, sometimes extending high up on the lesser curvature and occasionally as far as the cardia.

Hormonal cells

A huge literature has accumulated on the hormonal cells of the gut. For the sake of brevity only a few salient features will be mentioned in connection with their distribution in the stomach.

As regards **gastrin**-producing (G) cells, a study by Royston *et al.*[15] showed results similar to those of Stave and Brandtzaeg.[20] The highest density of G cells was found in the 'antral' mucosal glands near the pylorus, the number gradually decreasing to the junctional zone between the antrum and body, where there was a marked decrease in numbers. No G cells were found in the fundi of patients with duodenal ulcer. The G-cell population ranged from 8 to 15 (mean 10) million in control subjects, and from 3 to 43 (mean 18) million in those with duodenal ulcer. According to Mortensen[21] G cells are not usually present in the fundus.

The concentration of **somatostatin** in the rat stomach was determined by Arimura *et al.*[22] The hormone was found in the mucosal zones of the pylorus and body, but not in the cardia. According to Bloom and Polak[23] the highest concentration of somatostatin-producing cells in the stomach occurred in the pyloric mucosal zone, with a lower incidence in the remainder of the stomach.

The relative numerical frequency of **vaso-active intestinal peptide** (VIP) cells in the various gastric mucosal zones has not been determined in detail.[23] According to Alumets *et al.*[24] structures with a sphincteric function received a particularly rich supply of VIP nerves, more so than the smooth muscle of adjacent portions. Among these were the oesphagogastric junction and the pyloric sphincter. This was such a consistent finding that an evaluation of the density of VIP innervation, in their opinion, should assist in anatomically defining a sphincter.

While the **enkephalins** are widely distributed, their highest concentration in the gastro-intestinal tract occurs in the gastric 'antrum' and proximal duodenum, according to Polak *et al.*[25,26] Enkephalin cells are not usually found in the gastric fundus.

The pyloric antrum

As long ago as 1906 Cunningham[1] pointed out that we owed the doubtful advantage of the introduction of the term 'antrum pylori' to the anatomist Willis. He stated that the term had been employed in many different senses and that it was largely responsible for much of the obscurity associated with the pyloric part of the stomach. According to Cunningham it was rarely possible to obtain a clear anatomical conception of what was meant when this term was used. Forssell[2] and Torgersen[3] expressed similar views. Grossman[27] pointed out that many writers had commented upon the lack of uniformity of terms used to describe parts of the stomach, and the ambiguity of some of them. Usually the pyloric portion was divided into the pyloric vestibule or antrum adjacent to the gastric corpus, and a pyloric canal adjacent to the sphincter. An example of this is seen in a fairly recent edition of *Gray's Anatomy*,[28] where the pyloric antrum is shown to be a segment situated between the incisura angularis and the sulcus intermedius. As such, it is on the oral side of the sulcus and does not extend as far as the pyloric aperture. A different edition, *Anatomy of the Human Body*,[29] published in the same year, however, states that the antrum is the portion between the sulcus intermedius and the pyloric aperture, i.e. it is on the aboral side of the sulcus. With so much uncertainty, it seems that surgeons will have to be very careful in the interpretation of certain anatomical definitions of the 'antrum' before it is excised at antrectomy.

Du Plessis[30] stated that anatomists and clinicians usually used 'antrum' to describe that portion of the stomach distal to the incisura, but that surgeons are concerned with the part of the stomach lined by pyloric mucous membrane, which is larger than the anatomical antrum, as it may extend upwards for about 44% of the length of the lesser curvature. According to Capper *et al.*[13] the problem of antrectomy involved recognition and accurate definition of the antrum. It could best be defined as the distal part of the stomach which contains and releases gastrin. The mucosa of this part is of the pyloric type and the pH is in the neutral or alkaline range. For antrectomy to be adequate, it has to be shown that the excised tissue contains all the gastrin-secreting mucosa of the stomach. Surgeons generally indicate the pyloric mucosal zone when using the term 'antrum'.

Conclusions

Two anatomico-functional divisions of the pyloric part of the stomach are clearly identifiable. The first, the muscular pyloric sphincteric cylinder, is a tube of thickened muscularis externa, approximately 3-5 cm in length when fully contracted (in adults). It is definable in morbid anatomical specimens, in which it is seen to end in an aboral thickening, the pyloric sphincteric ring or pyloric ring. The ring is an inherent part of the cylinder and not a separate anatomical structure.

The entire cylinder functions as a unit. The ring surrounding the pyloric aperture does not act independently but contracts together with the remainder of the cylinder. When contracting, it narrows the diameter of the aperture, and when the cylinder is fully contracted, the aperture is closed. The characteristic contractions of the cylinder lend themselves admirably to radiological study during life.

A practical application of this concept should perhaps be considered in the 'pylorus-preserving' operation for gastric ulcer, where an incision is made 1,5 cm orally to the pyloric ring.[31,32] While this preserves the ring, it follows that it bisects the sphincteric cylinder. It is surmised that this may lead to abnormal functioning of the ring.

The second anatomico-functional entity in the distal stomach is the pyloric mucosal zone, containing the pyloric mucus-secreting and the gastric hormonal cells. This zone can also be clearly identified by histological and other means. (Radiologically there are no differentiating features between the various mucosal zones.) Anatomically the pyloric mucosal zone differs from the sphincteric cylinder in extent as well as in shape. In the normal stomach the mucosal zone is longer than the cylinder, especially on the lesser curvature. While the cylinder is a fan-shaped or roughly triangular structure, with the apex on the lesser curvature and the base on the greater curvature (when contracted), the greatest length of the mucosal zone is seen on the lesser curvature (Fig. 2).

Unlike the cylinder, the mucosal zone varies in extent in pathological conditions. Most authorities seem to agree that in duodenal ulceration this zone is of normal size or slightly larger than normal, but that it may be considerably larger, and even twice the normal size, in gastric ulceration. Occasionally it may extend as far as the cardia on the lesser curvature. Consequently the oral border of the pyloric mucosal zone has the ability to migrate up and down the stomach, depending on the condition of the patient.

Aborally both the mucosal zone and the sphincteric cylinder end at the pyloric ring.

In contrast to the above, the pyloric antrum can not be defined precisely in anatomical terms. Today, 75 years later, one can still corroborate Cunningham's original statement, namely that the term 'pyloric antrum' is being employed in many different senses, and that it is largely responsible for much of the obscurity associated with the pyloric part of the stomach.

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Asymptomatic isolated left subclavian artery with right aortic arch

A case report

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Summary

An isolated left subclavian artery with a right-sided aorta was discovered during autopsy of a 34-year-old Black woman who had died of pulmonary tuberculosis. The left subclavian artery arose from the end of a 5 cm long, fibrous cord attached to the pulmonary trunk, and received blood by retrograde flow in the left vertebral and supreme intercostal arteries. Isolated left subclavian artery with right-sided aorta may be accounted for by abnormal development and degeneration of the embryonic aortic arches.

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Isolated left subclavian artery with dextraposition of the aortic arch is rare, usually occurring in patients with congenital heart disease (tetralogy of Fallot),[1-5] congenital subclavian steal syndrome[6-8] and, in the case of a young infant, persistently patent bilateral ductus arteriosus.[9]

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Rather than arising from a right-sided aortic arch, the left subclavian artery is connected to the pulmonary trunk by a ductus arteriosus which may or may not be patent. An open ductus is usually associated with a congenital heart defect.[3-4] When the ductus is closed, the left subclavian artery usually receives blood by retrograde flow down the left vertebral artery and from arteries anastomosing with branches of the thyrocervical trunk.[7] In one case, in which the left subclavian artery had an atresic proximal portion, a good anastomotic flow was described between a posterior intercostal branch of the aorta and the costocervical trunk.[10]

We report a case of isolated left subclavian artery and dextra-aorta which was apparently asymptomatic, discovered during routine autopsy of a female patient who had died from an unrelated cause.

Case report

The patient was a 34-year-old Black woman admitted to hospital in a confused state. There was no history of symptoms of subclavian steal syndrome, such as fainting or weakness of the left arm, and no cyanosis, jaundice, or clubbing of the fingers was noted on examination. There was a trace of oedema, and the jugular venous pressure was mildly raised. Three blood pressure recordings taken on the day of admission were reported as 120/80 mmHg,110/70 mmHg and 90/70 mmHg; there was no mention of the side on which the recordings were taken.

A clinical diagnosis of bronchopneumonia was made. A chest radiograph showed patchy consolidation of both lung fields and bilateral pleural thickening. The aorta was reported to be left-