THE SPHINCTER MECHANISM OF THE LOWER END OF THE BILE DUCT*

BY

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That some sphincteric arrangement exists in this region is of course incontrovertible. The obliquity of the bile duct in its passage through the wall of the duodenum, which attracted the attention of Fallopius in the sixteenth century, would seem to indicate an important part played by the muscular coats of the gut in the control of biliary outflow; this obliquity of channel and the marked prolongation of the "portio intestinalis" of the choledochus in certain animals—e.g., sheep, certain whales, seal, walrus, dolphin, leathery turtle, etc.—are very significant. Samson Wright (1940), however, adumbrates a dual mechanism and suggests the existence of additional fibres round the termination of the duct just before it finally reaches the lumen of the duodenum. It is concerning the existence of this special sphincter, its nature, and origin that there appears to be uncertainty.

The precise relation of function to structure may necessitate investigation by several methods of approach; there is no contentious rivalry between the methods of science, and one may prove of value in supplementing the lessons learned from another mode of inquiry, and may help to illumine the dark and more obscure parts of the problem. Various methods of investigation have been utilized by many different workers on the present problem: (1) the lessons from the results of operative surgery in man; (2) the experimental method, including the pharmacological approach; (3) the study of anatomy, including histological and embryological methods; and (4) the comparative-anatomy approach.

Surgical Evidence in Favour of a Special Intrinsic Sphincter

The hepatic infections which appear prone to constitute a frequent aftermath of promising operations for reconstruction of the injured or strictured main biliary channel, when the choledochus or more often the hepatic duct is united by surgical effort to the stomach or duodenum, and the recurrent attacks of cholangitis which are apt to punctuate the after-story of those for whom choledocho-duodenostomy has been performed for other pathological conditions of the main duct, are suggestive of a special sphincter mechanism at the lower end of the bile canal. The presence of such an intrinsic mechanism appears the more probable, since the bilio-digestive anastomoses referred to involve a portion of the alimentary tube apart from the biliary caruncle, and in those cases in which an end-to-end repair of the structured duct is possible and the integrity of the ostium is maintained, ascending cholangitis is less likely to appear. There seems to be something peculiar in the neuromuscular mechanism in this area which is absent in the muscular tissues of the neighbouring stomach or duodenum.

The presence of air in the upper portion of the biliary tree may denote a patent anastomosis, but also indicates the absence of a sphincter controlling reflux into the duct. The readiness with which the contents of a barium meal may penetrate up to the hepatic ramifications of the biliary tree after hepatico-duodenostomy was demonstrated radiologically by Lardennois; no mechanism comparable to that which obtains at the

"biliary ostium" is reproduced by any surgical attachment of hepatic duct or choledochus to duodenum.

Mallet-Guy, Auger, and Croizat demonstrated experimentally the constancy and severity of ascending biliary infection which follows any surgical intervention that sections or destroys the sphincter mechanism; Bengolea and Velasco-Suarez (1939) also specially emphasized the frequency of cholangitis as a sequel to choledocho-duodenostomy, and entered a strong plea against its routine performance.

The remarkable immunity (Walton, 1939b) to ascending infection shown by cases of congenital dilatation of the bile duct for which an anastomosis has been performed between such a bile pond and the duodenum may be due to the escape of a certain quantity of the bile through the normal ostium and the preservation of the normality of the sphincter mechanism.

The Experimental Method of Inquiry

Perhaps the greater bulk of the literature relating to the problem has emanated from the experimental laboratory. The intermittent flow of bile from the intact papilla in man and gall-bladder-bearing animals, which contrasts with the continuous dribble in mammals which lack a gall-bladder, is thought to suggest the action of a special sphincter mechanism in the former group. The differing reaction to mechanical irritation of the biliary caruncle in the two mammalian groups which either boast or lack a gall-bladder has been reckoned as betokening divergent sphincter mechanisms; and the dilatation of the extrahepatic ducts after experimental or surgical cholecystectomy has also been regarded by some observers as indicative of some special functioning sphincter in the gall-bladder group and its absence in the other.

Mann and Higgins (1927) pointed out that if the intramural bile duct in animals was dissected away from the duodenal wall, care being taken to remove all the intestinal muscle grossly visible, there remained enough muscle around the lower end of the duct to prevent the escape of bile, even at a pressure greater than the secretory pressure of the liver or that induced by contraction of the gall-bladder: the area of the duct in this experiment which responded to stimulation was limited and restricted. Lueth (1931) expressed his certainty that the intramural portion of the common bile duct possesses a special sphincter mechanism, and even estimated that this sphincter exerts one-third to one-sixth of the total resistance offered to the flow of fluid through the "portio intestinalis."

Considerations of space preclude any complete catalogue and review of the experimental work devoted to the problem, and it would be churlish and impertinent for a surgeon dealing mainly with human anatomy to pass judgment on the labours of those whose approach to the problem bristles with formidable technical difficulties, yet it is not easy to find the truth amidst the fog of conflicting experimental results. Despite the use of methods of inquiry cleverly devised, elaborately staged, and graphically recorded, the experimental investigation of this limited anatomical district is necessarily a somewhat rude insult to the integrity of the extrahepatic ducts, and engenders a certain scepticism and a lack of confidence in the deductions derived therefrom. For example, some disturbance of the sphincter mechanism in man results from a mere choledochotomy, as is evidenced by the presence of pancreatic ferments in the human bile which drains from the bile duct; the escape of granules of

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carmine, etc., as shown by Bond, also suggests the derangement of sphincter action effected by a minor mundane manoeuvre. The accuracy of results in experimental work which involves incision and intubation of the bile duct must therefore be always open to criticism.

The Pharmacological Method of Approach

Major Hilary Long (1942) has ingeniously endeavoured, by means of carefully conducted pharmacological perfusion experiments upon the biliary ducts, to differentiate purely sphincter effects from those produced by the activity of the duodenal musculature, and claims by her research to have demonstrated an intrinsic choledochal sphincter acting "independently" of duodenal tone and peristalsis in the dog. The pitfalls and difficulties of the experimental method have already been sympathetically referred to; yet very suggestive and illuminating is her contention that the concentration of bile salts and the alkalinity of the bile produce relaxation of this special sphincter; thus the sphincter may be closed to the efflux of bile which is not of the appropriate reaction and concentration, and a train of untoward circumstances be inaugurated.

The Anatomical Approach

The arrangement of the muscle fibres round the intramural portion of the duct has been investigated by different workers employing histological methods or the dissection-microscope on material preserved and prepared in diverse fashions. There has been little unanimity of opinion since the time of Oddi, who claimed in 1887 to have demonstrated a more or less distinct band of circular fibres encircling the "portio intestinalis" of the duct, which, apart from some slender loops that lose themselves between the fibres proper of the gut, are almost independent. Hendrickson (1898) as a result of dissection both described and depicted an intrinsic circular sphincter in man, dog, and rabbit; Boyden and his co-workers in text and illustration have described an intricate web of muscle fibres surrounding the duct which are separable into definite collections and for which a very special nomenclature has been coined; nevertheless, these workers neither discuss nor depict any circular fibres near the papillary orifice, such as have been mentioned and figured by Hendrickson, Newman (1931, 1933), and others. Broman (1921) mentioned a well-formed intrinsic sphincter in the foetus of the Antarctic whale, and Helly (1899) also emphasized its existence in human anatomy. On the other hand, Auster and Crohn were unable to demonstrate any distinct intrinsic sphincter.

My colleague Prof. John Kirk kindly interested himself in the subject on my behalf, and investigated *adult and foetal human material* both histologically and by dissection, and has afforded me ready and willing access to his preparations. We have assured ourselves that in no specimen examined histologically was any circular arrangement of muscle fibres found at or near the opening of the common bile duct on the duodenal papilla. Muscle can be seen in considerable amount on the more basal portion of the intramural duct; but this is oblique and longitudinal in its arrangement, and can be definitely and indubitably traced in continuity with the circular muscle coat of the duodenal wall; in other words, when the duct pierces the outer wall of the duodenum it carries in some of the circular muscle fibres of the duodenum, which are now arranged in an oblique and longitudinal fashion in the wall of the duct itself. The muscle of the duct is abundant in its basal intramural portion, and bundles of the longitudinal muscle fibres can be traced into the connective-tissue core of many of the villous processes.

It was subsequently realized that our findings are very closely comparable to those of Dardinski (1934-5), who reported: (1) the greatest constriction of the common duct is produced by the intestinal muscle; (2) the independent muscle fibres described by Oddi as responsible for sphincteric action, are longitudinal or oblique, and not circular. He also (3) drew attention to the muscle fibres in the villi and suggested that they may play an active part, and (4) noted the mucous gland which we had observed as a most conspicuous feature in histological examination of the terminal bile and pancreatic passages. Furthermore, microscope-dissection of the lower extraduodenal part of the common bile duct shows the presence of well-defined longitudinal muscle fibres which pass deep to

the longitudinal muscle of the bowel and become directly continuous with the circular coat of the duodenum. The longitudinal and oblique arrangement of the muscle fibres in the duct wall would seem to indicate that the papillary muscle acts as a retractor of the papilla; and this action, in point of fact, can be readily seen in operations in man which involve opening of the duodenum. This initial retraction of the papilla is followed by the biliary efflux from the ostium and inspection of its postero-internal wall.

The muscle bundles in the villi by their contraction may stiffen these structures and secure their closer apposition, in a manner comparable to the disposition of the human fingers assuming what is termed the "accoucheur's hand"; on the other hand, the temporary intermittent shortening of the villous processes by the action of the contained muscle fibres may aggregate them into a clump or cluster which prevents regurgitation of the duodenal contents, and, acting in co-ordination with the circular tunic of the duodenum, temporarily holds up the issue of bile. Kirk and I have also satisfied ourselves that no circular arrangement of fibres exists in the hepatic duct in either adult or foetal material; there is no evidence of an anatomical sphincter here, despite cholangiographic suggestions of a "physiological sphincter" (Mirizzi, 1940).

An *embryological approach* towards solving the question of a separate intrinsic sphincter has been employed by Boyden and Schwegler (1936, 1937) with exemplary thoroughness. They claim that the *musculus proprius* of the duct differentiates *in situ* from the mesenchyme and is *not an emanation from the duodenal musculature*. It is admitted that where the duct penetrates the gut wall the margins of the "fenestra" contribute a few scattered fibres to the outer longitudinal coat of the sheath, but that the inner circular coat round the lumen of the duct is exclusively intrinsic in origin. These authors, as a result of their studies of the foetal and adult stages, mention "fasciculi longitudinales," but, unlike Kirk and myself, pay far more attention to an annular sheath of intrinsic muscle round the duct, and also describe a "sphincter ampullae" (!).

The Comparative Approach

Like any other discipline the "comparative" method is not without its dangers and pitfalls: generalizations drawn from the dissection or examination of a single specimen are apt to be misleading: the law of variation obtains in the subhuman as well as in the human type. The concepts of human anatomy are based upon numberless dissections of myriads of material; it is essential that museums of comparative anatomy should assemble ample store material, to be held at the disposal of research workers. The so-called "Physiological Series" of the old Museum of the Royal College of Surgeons of England contained much that constituted an illuminating basis and background of the anatomy of man.

My "comparative" interest in this region concerned itself initially with the involution of the so-called "ampulla," which in point of fact is an infrequent abnormality in man. The beautifully arranged physiological series in the lamented Museum in Lincoln's Inn Fields afforded strong evidence that the "ampulla" is an involutionary anatomical structure, and it may be possible some time to produce and publish morphological evidence in support of this view. But a study of the collection referred to also furnished here and there naked-eye evidence that the muscle surrounding the terminal part of the bile duct originates from the intestinal musculature: elementary embryology would indeed suggest such a derivation.

No comprehensive comparative histological study has been possible during the war, but careful examination of such selected material as time has permitted indubitably confirms the genesis of the muscular sheath of the "ampulla" from the muscular coats of the duodenum in at least certain types; for example, the origin of the bile-duct musculature in the circular coat of the duodenum is apparent in the lion and tiger cub, and Prof. John Kirk has made extensive researches in the cat. In this animal, where the duct pierces the duodenal wall the circular muscular coat becomes greatly thickened and is indeed several times thicker than the circular coat of the bowel at a short distance proximally and distally. In this region where the circular coat is so markedly thickened Auerbach's plexus is distinctly enlarged, and clumps of ganglion cells may be seen

collected in that area in much greater numbers than in the duodenal wall elsewhere. The muscular thickening and the concentration of ganglion cells must indicate increased muscular action where the common bile duct penetrates the circular coat of the bowel from without. No sign of any intrinsic circular muscle ring round an ampulla has been discernible. It is hoped that in the future further comparative histological investigation

FIG. 3.—Civet (*Viverra civetta*): R.C.S. Museum (store specimen). Wall of ampulla formed by muscle of duodenum, which ceases abruptly at apex of ampulla. No muscle in walls of pancreatic and biliary ducts. (I.e., ampulla=intestinal pouch, not a mere dilatation of lower end of ducts.) (Cross-hatching indicates cut surfaces)

FIG. 4.—Seal (*Phoca vitulina*): R.C.S. Museum (store specimen). Ampulla wall formed of intestinal muscle, which is confined to the pouch and does not extend into the bile duct. (Cross-hatching indicates cut surfaces.)

may be carried out. But there is also macroscopic evidence of such a muscular relationship: thus in certain of the Carnivora—e.g., *Viverra civetta*—and in some Pinnipedia—e.g., *Phoca vitulina*—it is abundantly clear even to the naked eye that the muscular coat of the ampullated duct takes origin from the intestinal muscle tunics (Figs. 3 and 4).

Summary

This paper comprises two sections of a recent Hunterian Lecture.

It emphasizes the low grade of malignancy of many tumours of the lower end of the common bile duct and adjacent head of the pancreas, and appeals for more radical measures in this type of case. Several personal cases of resection are quoted, and reference is made to those of other surgeons.

The diverse methods of scientific investigation lend support to the view that a special intrinsic sphincter exists at the terminal portion of the common bile duct or the conjoined bilio-pancreatic duct.

The muscle sheath of the duct is derived from the circular muscle tunic of the duodenum.

Although circular muscle derived from the bowel tunics is to be found round the basal portion of the intramural duct, only longitudinal and oblique fibres are present in the distal portion of the papilla.

Some of these fibres are prolonged as a core into the villous processes with which the wall of the terminal segment of the duct abounds.

The direction and arrangement of these fibres shows that their action is partly to retract the papilla and partly to erect or to aggregate the villous processes centripetally, thereby preventing reflux from the duodenum and controlling the exit of bile.

There is no circular arrangement of fibres close to the ostium—a reputed disposition credited with mythical properties.

There are few muscular fibres in any of the extrahepatic biliary ducts, and certainly no circular disposition of muscle fibres forming a sphincter in the hepatic duct.

The kindly co-operation of Prof. John Kirk and of Prof. A. J. E. Cave has been invaluable in the preparation of this lecture; my warmest thanks are due to both these friends for all their help so spontaneously and enthusiastically given. Mr. S. R. Scarfe of the Anatomical Department, Middlesex Hospital, has prepared the innumerable histological sections which have formed the basis of part of this inquiry, and to him I am indeed most grateful. My friend Col. A. E. Hamerton has generously afforded me material from the Gardens of the Zoological Society. Surgeon Commander W. A. Hopkins, R.N., and members of the staff of the pathological department of a naval hospital have readily and eagerly granted me facilities for work in their laboratory. Surgeon Vice-Admiral Sir Sheldon Dudley has always a stimulating effect on any worker, and at all times encouraged me, so that the occasional minutes and hours of surgical inactivity inevitable in war have not been idly spent, and an endeavour has been made to carry on, though feebly, the spirit and tradition of the Founder of our Museum, who seized the fleeting hour for Science, even amidst the distractions and disorders of war.

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ENTERITIS IN A NURSERY HOME ASSOCIATED WITH GIARDIA LAMBLIA*

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The following account of a prolonged outbreak of enteritis associated with *Giardia lamblia* (*G. intestinalis*), affecting both children and adults in a nursery home for evacuees, is reported partly because little attention seems to have been paid in Great Britain during recent years to infections with this protozoon and partly because there is reason to suspect that the condition is commoner than is generally supposed.

History

The outbreak occurred in a spacious country-house, referred to as the Grange, used both as a family residence and as a wartime nursery. The domestic arrangements of the two communities were separate, but there was naturally a good deal of communication between the two sides of the house. Consequently, the entire population, numbering 51 in Jan., 1941,

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