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The Choledochoduodenal Junction in Sheep and Goat

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With 5 figures

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Abstract

The choledochoduodenal junction was studied in 15 sheep, 5 goats and 7 sheep fetuses by maceration technique, microdissection, and by microscopic examination. The bile duct extended from the junction of the hepatic and cystic ducts, entered the duodenum at the beginning of its descending part on the dorsomedial aspect, ran distally in the wall for about 1.5 cm and ended with an opening facing distally without raising a papilla. The average length of the bile duct was 8 cm; its structure along its course was also described.

The wall of the bile duct acquired muscle fibers only when it approached the duodenum. These originated from the longitudinal muscle of the duodenum. As the duct passed through the duodenal circular muscle, the latter split and formed a muscular ring so that the duct at that site was surrounded by two muscle layers. When the duct coursed distally in the submucosa, it was covered with longitudinal muscle bundles on its muscle (of duodenum) surface and thin oblique and circular muscle rings on its mucosal surface and its sides. Towards the distal end of the duct, the muscle fibers on the mucosal surface decreased and finally disappeared as the duct approached the lumen of the duodenum. The fetal material confirmed the findings in the adult.

The present results were discussed with the findings reported in other species. The authors believe that the structure of the choledochoduodenal junction in sheep and goat indicates the presence of a sphincter originating from and connecting with the duodenal musculature. The sphincter, therefore, should be influenced by the activity of the duodenal wall, causing flow of bile and pancreatic juices to be intermittent.

Introduction

As a definition of the sphincter of Oddi, Boyden (1937) quotes, "According to Francis Glisson (1654), who first observed this 'locking' mechanism, the spincter consists of ring-like fibers which occupy not only the opening of the bile duct itself but also the whole oblique tract through the intestinal wall." So also to Oddi (1887) it is "a more or less pronounced bed of circular fibers encircling the choledochal canal — which one is able to consider as almost completely independent, if one excepts some slender loops which lose themselves between the fibers proper of the intestine." Boyden ends his definition by saying, "It is an ejaculating as well as occluding mechanism. It is necessary, therefore, to

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define it as the entire musculus proprius of the terminal portion of the bile channel and of the associated pancreatic duct (of Wirsung) if the latter is present."

The choledochoduodenal junction has been studied in man (ODDI, 1886—7, 1887; HENDRICKSON, 1898; SCHWEGLER/BOYDEN, 1937; BOYDEN, 1957a; SINGH, 1962), chimpanzee (BOYDEN, 1955), dog (ODDI, 1886—7, 1887; HENDRICKSON, 1898; EICHHORN/BOYDEN, 1955), cat (BOYDEN, 1957b), horse (DIDIO/BOYDEN, 1962), sheep (ODDI, 1886—7, 1887), camel (RADMANESH, 1974), opossum (DUBOIS/HUNT, 1932), rabbit (HENDRICKSON, 1898), and guinea pig (HIGGINS, 1927; CAI/GABELLA, 1983). For a detailed annotated review of earlier literature, see BOYDEN, (1936, 1937).

According to the literature reviewed, no work has been done on the choledochoduodenal junction in sheep since that of ODDI (1886—7, 1887), almost a century ago. The present study is intended to close this hiatus and to report, for the first time, on the junction in the goat.

Material and Methods

The materials for this study were collected from 15 Dorset male sheep 5—12 months old, 5 male Alpine-cross goats 2 months old, and 5 male and 2 female sheep fetuses ranging from 63—200 mm CR length. The male sheep were slaughtered in the meat laboratory of the Animal Science Department, Cornell University, and the goats were sacrificed by the Department of Veterinary Anatomy for dissection. The sheep fetuses were kindly provided by Dr. H. E. EVANS, Chairman of the Department of Veterinary Anatomy.

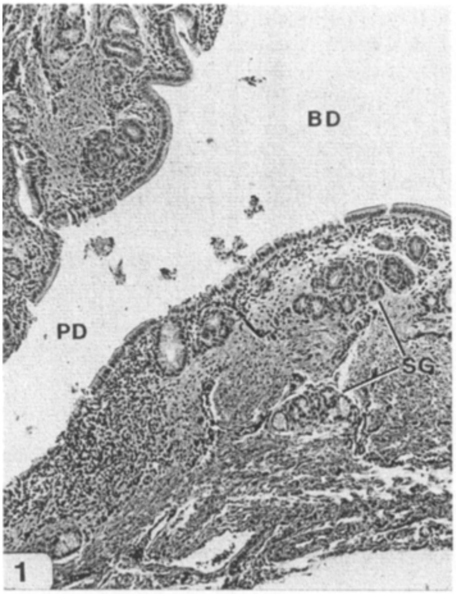
The course of the bile duct from the junction of hepatic and cystic ducts to the duodenum was examined *in situ* and measured. Then the specimens, including the appropriate parts of duodenum, bile duct and pancreas with its main duct, were excised. For maceration, fresh pieces of the choledochoduodenal junction from 5 sheep and 2 goats were immersed in 20 % nitric acid for 24 hours and then, after dissecting and removing the mucosa, were fixed in 10 % formalin according to KREILKAMP/BOYDEN (1936). The remaining specimens were fixed in 10 % formalin for histological study. The fixed materials of both fetal and adult specimens were embedded in paraffin and transverse serial sections of the duodenum and bile duct were cut at 10 μ. The sections were stained with H and E and by Masson's and/or Milligan's trichrome methods to differentiate muscle from collagenous fibers.

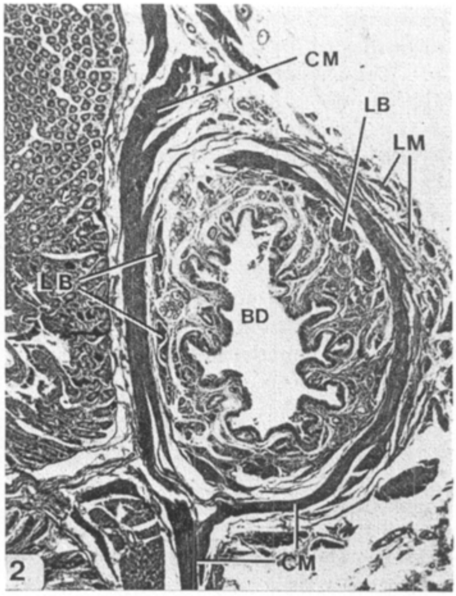
Results

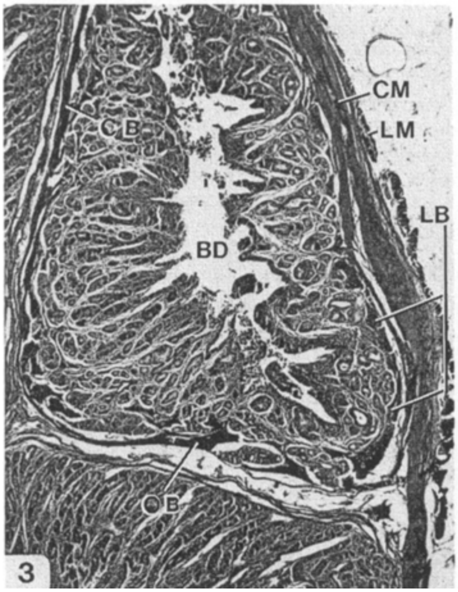
The bile duct in the sheep extended from the junction of the hepatic and cystic ducts to the beginning of the descending duodenum, entered the duodenal wall at the dorsomedial aspect, ran distally in the wall for about 1.5 cm, and ended with an opening that faced distally. The length of the bile duct measured on average 8 cm. The intramural course was nearly parallel to the long axis of the duodenum and raised the duodenal mucosa into a slight longitudinal fold. Although the opening of the bile duct was easily detected with the unaided eye, no papilla was present to mark it.

The main pancreatic duct (Wirsung) was found to be wholly embedded in the parenchyma of the gland. It joined the dorsal surface of the bile duct about 3 cm from the duodenum. The bile duct itself was partially embedded in the pancreas and therefore the junction of the two ducts could not be seen unless some of the pancreatic tissue was dissected away.

The microscopic structure of the extramural segment of the bile duct was the same throughout most of its length, both proximal and distal to its junction with the main pancreatic duct. The wall consisted of a folded mucosa lined by tall, simple columnar epithelium and a glandular lamina propria. The glands were simple tubular glands, predominantly serous. The lamina propria was rich in collagenous fibers, blood vessels and nerves, but no muscle was seen around the duct (Fig. 1). As the bile duct approached the duodenum, the mucosa became more and more folded and the glands more numerous. Though the diameter of the duct decreased during its intramural course, mucosal folds and glands increased (Fig. 3). The microscopic structure of the main pancreatic duct was the same as that of the bile duct. (The absence of muscle fibers indicates that the flow of







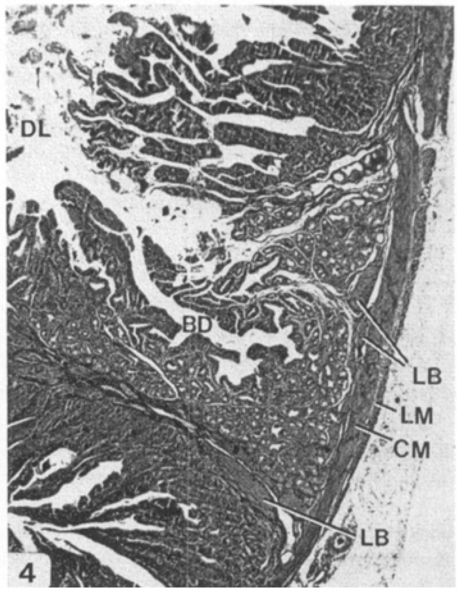


Fig. 1. Junction of bile duct (BD) with main pancreatic duct (PD). Note serous glands (SG) and absence of muscle. × 65

Fig. 2. Bile duct (BD) completely surrounded by duodenal circular muscle (CM). Note the longitudinal and oblique muscle bundles (LB) forming an inner muscle layer around the duct. × 23

Fig. 3. Bile duct (BD) in submucosa. It is covered with longitudinal muscle bundles (LB) on its muscular surface and with circular (CB) and oblique muscle bundles (OB) on its mucosal surface and sides. To the right of the duct are circular (CM) and longitudinal (LM) duodenal muscle coats. × 37

Fig. 4. Bile duct (BD) of goat opening into duodenal lumen (DL). Longitudinal muscle bundles (LB) are on the duct's muscular surface, followed by circular (CM) and longitudinal (LM) duodenal muscle coats. × 37

pancreatic juice at the confluence of the two ducts is unregulated.) The mucosa of the pancreatic duct merged smoothly with that of the bile duct, and no valvular mechanism was noted at the junction.

When the bile duct approached the duodenum, scattered longitudinal muscle bundles started to appear on the surface that faced the duodenum, and the longitudinal muscle layer of the duodenum was absent at that site. The closer the duct got to the duodenum the more longitudinal muscle bundles appeared such that the latter not only covered the surface of the bile duct facing the duodenum but also the remaining parts of its circumference until the whole duct became covered by longitudinal and some oblique bundles.

Macerated specimens showed that the bile duct pierced the longitudinal muscle coat of the duodenum whose fibers gave way so the duct could pass through (Fig. 5 B). Some of the longitudional muscle fibers appeared to attach to the sides of the duct and ran proximally on it and parallel to its longitudinal axis. On the surface of the duct facing the duodenum, some of the longitudinal fibers were reflected from the duodenum to the wall of the duct to which they became attached and on which they ran proximally (Fig. 5 A). Accordingly, the outer longitudinal muscle of the duodenum should be the origin of the bundles seen on the duct as it approached the duodenum.

The bile duct then penetrated the circular muscle layer which separated to form a transverse slit. The margins of the slit appeared to lie almost at the same level (Fig. 5 A). Transverse sections showed that the bile duct, for less than 1 mm of its passage through the

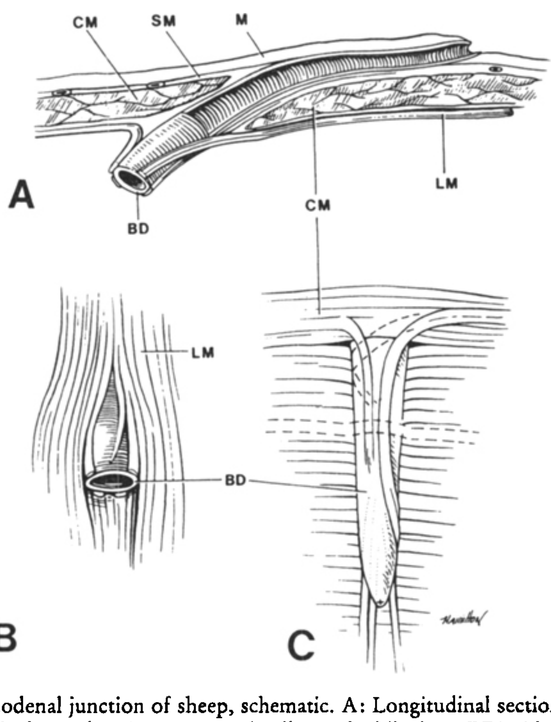


Fig. 5. Choledochoduodenal junction of sheep, schematic. A: Longitudinal section. Note bundles of the duodenal longitudinal muscle (LM) pass proximally on the bile duct (BD). Also note external and internal margins of duodenal circular muscle (CM) almost at same level. B: External aspect. Longitudinal muscle gives way to allow bile duct to pass through (macerated specimen). C: Internal aspect, mucosa removed by maceration. Bile duct (BD) emerges from slit in circular duodenal muscle (CM). Note fibers of the latter accompany duct; other fibers go beyond end of duct. Broken lines represent fibers seen in other specimens running obliquely and transversely over the duct

slit, was completely surrounded by the circular muscle of the duodenum. Thus at this site the duct was surrounded by two layers of muscle, (1) inner longitudinal and oblique bundles particularly thick at the ends of the slit which it acquired from the longitudinal coat of the duodenum and (2) an outer circular layer formed by the splitting of the duodenal circular muscle coat (Fig. 2). The surface of the bile duct facing away from the duodenum was covered in addition by the duodenal longitudinal muscle coat whose bundles had reunited distal to the penetration of the bile duct.

For the remainder of the intramural course, the surface of the bile duct facing the duodenal mucosa will be called mucosal surface, and the surface facing the duodenal muscle coat, will be the muscular surface.

After passing through the muscular ring into the duodenal submucosa, the duct appeared surrounded by (1) muscle fibers, predominantly longitudinal, on its muscular surface and (2) inner oblique and outer circular muscle fibers around the sides of the duct and the mucosal surface. It appeared that the splitting circular muscle coat of the duodenum thinned out on the mucosal surface of the duct and continued as the circular muscle of the duodenum on the muscular surface (Fig. 3).

In one of the macerated specimens, a few muscle fibers were seen to arise from the internal margin of the slit, turn distally to follow the duct and become attached to its mucosal surface; these fibers disappeared towards the distal end of the duct. The same specimen showed that the muscular surface of the duct was embedded in longitudinal muscle fibers which were attached to the circular muscle of the duodenum and continued beyond the distal end of the duct (Fig. 5 C). In the rest of the macerated specimens, a few fibers were seen departing from the internal margin of the muscular ring; these ran obliquely on the mucosal surface of the duct, passed around to its muscular surface and mixed with the circular muscle of the duodenum. They also showed that the duct was fixed by individual circular muscle fibers which surrounded it and came to attach to the duodenal circular muscle coat. These were variations noticed among the macerated specimens (Fig. 5 C). However, the intimate relationship between the duct and the duodenal circular muscle was always present.

Toward the distal end of the duct, the muscle fibers, particularly those on the mucosal surface, decreased and disappeared. The muscle fibers on the muscular surface of the duct persisted longer, but they also finally disappeared (Fig. 4).

The choledochoduodenal junction in the goat appeared to be the same as in the sheep. The intramural course of the bile duct was only 1 cm long, but considering that the goats were only 2 months old, it was comparable to the length in sheep. No longitudinal muscle fibers were seen running beyond the distal end of the bile duct or accompanying the bile duct on its mucosal surface as noted in the sheep.

Sections from sheep fetuses confirmed that the bile duct was joined by the main pancreatic duct before it reached the duodenum. As the bile duct approached the duodenum, some of the longitudinal duodenal muscle fibers opposite the duct were seen reflected toward the two sides of the duct. When the duct moved closer to the circular muscle of the duodenum, some fibers of the latter split and enveloped the bile duct. This process of envelopment indicated clearly that the bile duct was passing through a slit (yet to be formed) in the circular muscle of the duodenum. As the duct entered the submucosa, some longitudinal muscle fibers were seen on its mucosal surface, but the picture was not clear on the muscular surface where muscle fibers could not be differentiated from the surrounding mesenchyme. Also, some circular muscle fibers were seen on the mucosal surface of the bile duct forming an outer muscle layer of the duct; the latter fibers persisted for a short distance along the submucosal course of the duct. The presence of such circular muscle fibers on the mucosal surface of the duct, after passing into the submucosa, gave evidence that the circular muscle of the duodenum took part in the formation of the musculature of the bile duct. It confirmed, furthermore, the observation in the adult specimens that the mucosal surface of the bile duct was covered by an inner longitudinal muscle layer and an outer circular muscle layer.

Discussion

The structure of the bile duct, throughout most of its extramural course, consisted of a simple columnar epithelium and a glandular lamina propria, rich in collagenous fibers, vessels and nerves but no muscle fibers. This agrees with ODDI's (1887) findings although he did not report that the lamina propria was glandular. ODDI also reported, "As the point of entrance of the common bile duct into the intestinal wall is approached, the fusion of the circular fibers of the common bile duct with the intestinal wall becomes more intimate, so that the common bile duct cannot any longer be elevated." In the present study, it was found that it was fibers of the longitudinal and circular muscle coats of the duodenum reflected and attached to the wall of the bile duct that prevented the latter from being elevated or dislodged. Also in agreement with ODDI, the present study showed that the duct passes through a transverse slit in the circular muscle which he described as "button-hole-like".

Transverse sections at the level where the duct passes through the circular muscle of the duodenum revealed that the duct was covered by two layers of muscle: an inner layer which it acquired as it approached the duodenal wall and outer circular layer which was formed by the splitting of the circular muscle of the duodenum. Transverse sections distal to the slit in the circular muscle revealed a similar picture except that the outer circular muscle around the bile duct became thin on the mucosal surface of the duct and thick on the muscular surface and continuous with the duodenal circular layer. The same picture was observed in similar section of sheep fetuses, giving evidence that the circular muscle of the duodenum takes part in the formation of the musculature of the duct. These results are in agreement with the findings of ODDI (1887) except that he continues to ascertain, "the muscular ring of the duct seems, in the sections, to be entirely independent". He reports that the picture is typical of sheep and dog, while EICHHORN/BOYDEN (1955) give a different description of the choledochoduodenal junction in the dog. "It is characterised by a down growth of a septum of the tunica muscularis which differentiates the sphincter into an infundibular and a submucosal portion."

BOYDEN (1955), EICHHORN/BOYDEN (1955) and BOYDEN (1957b), studying the choledochoduodenal junction in different animals, were able to observe that the bile duct is passing through a funnel in the duodenal circular muscle and then runs distally in the submucosa; this funnel is longest in the dog, short in the cat, and very short in the chimpanzee. In man and horse the duct passes through a slit in the circular muscle and no funnel is formed (BOYDEN, 1937; DIDIO, 1962). Presently, in sheep the duct passes through a slit in the circular muscle which is in the form of a muscular ring too short to be called a funnel. Accordingly, the passage of the bile duct through the duodenal musculature in sheep is more like that of man than that of the chimpanzee. On the other hand, the origin of the musculature of the duct in sheep is found to be mainly from the duodenal muscle coat which is the case in the chimpanzee (BOYDEN, 1955) where the longitudinal muscle participates in the formation of the sphincter choledochus superior and the circular muscle envelops the duct more distally.

To some extent this junction in sheep is similar to that of the horse (DIDIO, 1962) in which the few encircling fibers that surround the bile duct in the proximal part originate as a splitting of the adjacent circular muscle of the gut.

A variation in the composition of the sphincter and the existence of a set of fibers that run between the bile duct and the duodenal musculature was noticed in the present study. Similar results were reported in other species (ODDI, 1887; HENDRICKSON, 1898; SCHWEGLER/BOYDEN, 1937; CAI/GABELLA, 1983). This set of fibers is called connecting and reinforcing fibers by HENDRICKSON who reports, "Out of eight specimens I found no two cases in which this irregular arrangement was alike".

ODDI (1887) concludes that the probable function of the sphincter in the species he studied, sheep included, is to render intermittent and regulate the flow of bile into the intestine. BOYDEN (1957b) believes that the sphincter of the bile duct in man differs from both dog and cat in that it enters the duodenum through a slit in the intestinal muscle and thus is not subject to the pressures of a muscular funnel as in dog and cat. DIDIO (1962) found in the horse, an animal without a gall bladder, that the choledochoduodenal junction has the least amount of encircling muscle of any species yet studied, and predicted accordingly that the flow of bile in the horse will be continuous and that spasmic contraction of the duodenum could interrupt the flow. However, the present study indicates the presence of a muscular sphincter in sheep and goat, originating and connecting with the duodenal musculature: the sphincter should therefore be influenced by the activity of the duodenal wall. Accordingly, the flow of bile in the sheep and goat is thought to be intermittent. The same holds true for the flow of pancreatic juice since the latter flows into the duodenum through the bile duct except for an unknown small amount entering the duodenum through an accessory pancreatic duct (ABDALLA/SACK, 1983).

Summary

The bile duct of sheep and goat was about 8 cm long, received the main pancreatic duct about 3 cm from the duodenum and had an intramural course of about 1.5 cm. Its wall and that of the pancreatic duct contained no muscle, indicating that pancreatic flow at the junction is unregulated. The longitudinal duodenal muscle coat supplied the bile duct with longitudinal bundles. Most of these followed the duct into the duodenal wall, some coursed proximally for about 1 cm. The bile duct passed through a split in the circular duodenal muscle. This was only about 1 mm long and thus could not be regarded an independent sphincter. Longitudinal and oblique bundles acquired earlier lay inside the ring of circular muscle. In the submucosa, the bile duct was accompanied by longitudinal muscle bundles from the longitudinal, and by longitudinal and oblique bundles from the circular duodenal muscle coats. Some of the longitudinal bundles passed beyond the distal end of the bile duct. The arrangement in the goat was similar except that bundles passing beyond the end of the duct were not observed.

It was concluded that bile flow into the duodenum is intermittent and, for lack of an independent sphincter, is subject to the contractions of the duodenum.

Zusammenfassung

Die Verbindung des Ductus choledochus mit dem Duodenum bei Schaf und Ziege

Der Gallengang von Schaf und Ziege war etwa 8 cm lang, nahm den Gang der Bauchspeicheldrüse 3 cm vom Zwölffingerdarm entfernt auf und verlief ungefähr 1,5 cm innerhalb der Wand des Darmes. Seine Wand und die des Pankreasganges enthielten keinen Muskel, was darauf hinweist, daß der Fluß des Pankreassaftes nicht reguliert wird.

Der Längsmuskel des Duodenums sendet längsverlaufende Fasern an den Gallengang. Diese folgen dem Gang in die Darmwand, ziehen aber auch proximal für etwa 1 cm auf den Ductus choledochus. Der Gallengang tritt dann durch einen Spalt in der Ringmuskelschicht des Duodenums. Dieser Spalt begleitete den Gang nur 1 mm, so daß von einem unabhängigen Schließmuskel keine Rede sein kann. Längs- und Schrägbündel, die schon vorher von der Längsschicht des Duodenums kamen, lagen innerhalb des Muskelspaltes. Im submukösen Gewebe des Duodenums wurde der Gallengang von Längsbündeln aus dem Längsmuskel des Duodenums und von Längs- und Schrägbündeln aus der Kreisschicht des Duodenums begleitet. Einige der Längsbündel überliefen das Ende des Gallenganges. Bei der Ziege waren der Aufbau der Wand des Gallenganges und die Muskelbündel, die ihn begleiteten, dieselben; nur konnten die Fasern, die über das Ende des Ganges hinausgingen, nicht beobachtet werden.

Diese Befunde deuten auf einen unterbrochenen Gallenfluß hin. Da kein unabhängiger Schließmuskel gesehen wurde, sollten diese Unterbrechungen auf den Kontraktionen des Duodenums beruhen.

Résumé

La jonction du Conduit cholédoque avec le Duodénum chez le Mouton et la Chèvre

Le conduit cholédoque du Mouton et de la Chèvre mesurait 8 cm de long, recevait le conduit pancréatique principal à 3 cm environ du duodénum et présentait un trajet intramural de 1,5 cm environ. Se paroi, ni celle du conduit pancréatique, ne contenait de muscle ce qui indique le l'écoulement pancréatique n'est pas régulé au niveau de la jonction. La couche musculaire longitudinale du duodénum envoyait des faisceaux longitudinaux le long du conduit cholédoque. La plupart de ceux-ci suivaient le conduit à travers la paroi duodénale, alors que quelques uns le remontaient proximalement sur 1 cm environ. Le conduit cholédoque passait, par une fente, dans la couche musculaire circulaire du duodenum. Cette fente n'accompagnait le conduit que sur 1 mm seulement, si bien qu'on ne peut parler de sphincter indépendant. Les faisceaux longitudinaux et obliques, issus du duodénum, s'étalaient bientôt à l'intérieur de l'anneau de la couche musculaire circulaire. Dans la sous-muqueuse, le conduit cholédoque était accompagné de faisceaux musculaires longitudinaux, issus de la couche musculaire longitudinale du duodénum, ainsi que par des faisceaux longitudinaux et obliques, en provenance de la couche circulaire. Quelques-uns des faisceaux longitudinaux dépassaient l'extrémité distale du conduit biliaire. Chez la Chèvre, la disposition était semblable à l'exception du fait que les faisceaux allant au-delà de la terminaison du conduit n'ont pas été observés.

On en a conclu que le flot biliaire passant dans le duodénum est intermittent et, qu'en l'absence d'un sphincter indépendant, il se trouve soumis aux contractions duodénales.

Resumen

La unión entre el conducto colédoco y el duodeno en la oveja y la cabra

El conducto colédoco de la oveja y de la cabra tenía aproximadamente una longtud de 8 cm, recibiendo el conducto pancreático principal aproximadamente a 3 cm del duodeno y mostrando un trayecto intramural cerca de 1,5 cm. Su pared y la del conducto pancreático no presentó ninguna musculatura, lo cual indica que el flujo pancreático no tiene regulación en el sitio de unión. La musculatura longitudinal del duodeno suministró fibras longitudinales para el conducto colédoco. La mayoría de estas fibreas siguieron el conducto hacia la pared duodenal, aunque algunas lo acompañaron en sentido proximal por 1 cm, aproximadamente. El conducto colédoco pasó por una hendidura en la musculatura circular del duodeno. Esta hendidura, de una extensión de aproximadamente 1 mm, no pudo considerarse como un esfinter independiente. Los fascículos longitudinales y oblicuos, incorporados con anterioridad, se ubicaron dentro del anillo de musculos circulares. En su submucosa, el conducto colédoco fue acompañado por fascículos musculares longitudinales provenientes de la capa longitudinal de la muscularis del duodeno, y por fascículos longitudinales y oblicuos que se originaron de la capa circular del mismo. Algunos de los fascículos longitudinales sobrepasaron el final del conducto colédoco. La disposición de estas fibras fue parecida también en la cabra, con la diferencia de que no se observaron fascículos sobrepasando el final del colédoco.

Se puede concluir que el flujo de la bilis hacia el duodeno se efectua en forma intermitente, dependiendo de las contracciones del duodeno debido a la falta de un esfinter independiente.

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