Common Bile Duct Motility and Sphincter Mechanism:

I. Pressure Measurements with Multiple-Lumen Catheter in Dogs *

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Introduction

DURING the time of Hippocrates, the "Four Humors" and their relative balance or imbalance supposedly determined health and disease. Centuries later the control of one of the original Humors, yellow bile, was studied intensively by the Italian investigator Rugero Oddi.[16] He demonstrated the existence of a distinct muscular sphincter at the distal end of the common bile duct. Oddi believed that an imbalance in the sphincteric mechanism could interfere with normal bile flow and lead to jaundice, pain or both. During the intervening years much has been learned about the activity of the sphincter of Oddi and the flow of bile from the liver to the duodenum. However, there are certain aspects of biliary kinetics which remain unclear, particularly the role of the common bile duct in bile transport. Is the common bile duct merely an inert conduit or is the delivery of bile through the sphincter aided by coordinated muscular activity or peristalsis? The following studies were designed originally to gather information about this particular phase of biliary physiology. In addition, important information has been gained about the functional activity of the sphincteric mechanism itself.

History

In 1898, the first detailed anatomic study of the human extrahepatic biliary tree appeared in the literature.[7] Gross and microscopic investigations demonstrated the existence of transverse, longitudinal and diagonal muscle fibers in the gallbladder, cystic duct, hepatic duct and common bile duct of man. In a comparative study the canine common duct was found to contain no diagonal muscle layer. However, at the distal end of the canine common duct, the transverse and longitudinal muscle fibers were seen to form a relatively heavy layer. As the common duct is sectioned at intervals from the duodenum to the cystic duct, the muscle layers are seen to thin out gradually. The wall of the proximal common duct in both man and the dog is thus composed mainly of fibrous connective tissue with loosely associated muscle fibers.

From an anatomic standpoint intrinsic motor activity of the common bile duct was certainly to be suspected in several species. In 1923, Westphal[19] reported visible peristaltic activity of the common bile duct of the guinea pig, cat and rabbit. He

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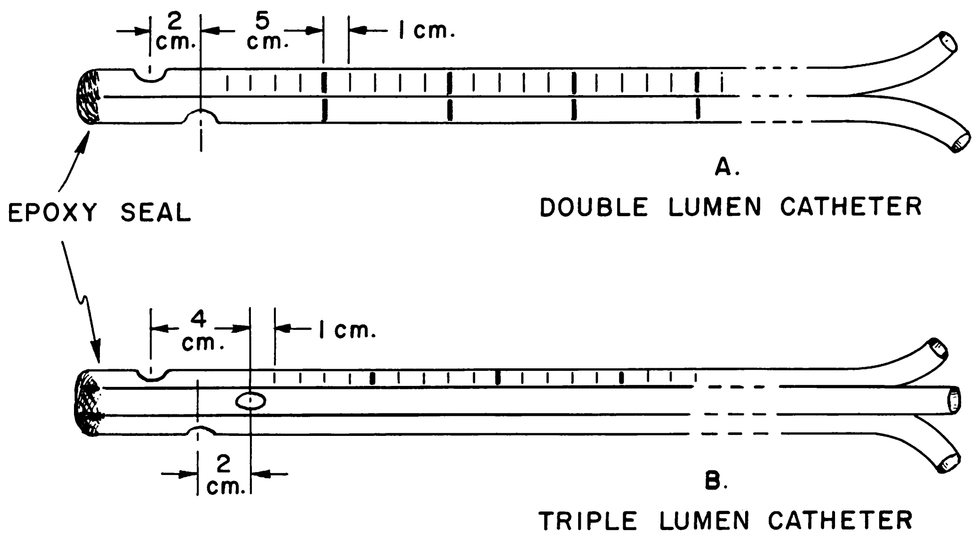

FIG. 1.

Description of Catheters	Internal Diameter	Wall	Total Length
A) Double lumen catheter	0.044 in.	0.010 in.	36 in.
B) Triple lumen catheter	0.028 in.	0.010 in.	36 in.

The catheters are made of polyvinyl tubing, fused together by light applications of cyclohexanone. The ends are sealed with *epoxy* glue.

believed that any disturbance in the normal motility of the extrahepatic biliary tree could lead to biliary stasis and gallbladder disease. Although direct vagal innervation of the biliary tree and sphincter was thought by Meltzer[11] to be critical in the egress of bile from the gallbladder, Whitaker[20,21] demonstrated that a denervated gallbladder and sphincter functioned normally. He postulated that the gallbladder and sphincter were responding to a humoral substance released in response to the ingestion of food, especially fats. This substance was later identified as cholecystokinin.

By 1932, paristalsis of the common bile duct was reported or postulated to occur in several species of laboratory animals. Although much was already known about gallbladder disease, there was very little information available on the function of the human extrahepatic biliary system. Mirizzi[13] in 1942 demonstrated what he thought to be peristalsis in the human common bile duct using radiographic technics. Burnett and Shields[1] in 1958 described peristaltic waves in the common duct using cinefluorography. They described waves occurring three to five times a minute with each wave lasting 1 to 3 seconds. Myers and coworkers[14] in 1962 attempted to confirm the work of Burnett and Shields and, in addition, did direct manometric studies of common bile duct pressure. In none of their investigations was any form of peristalsis or even local segmental spasm of the choledochus observed. In 1963 Scatliff, Mark and Simirak[17] also were unable to visualize any coordinated motor function in the human common bile duct. Thus the question of peristalsis of the common bile duct remained unsettled. The present study was initiated in the hope that a new method for study of common bile duct physiology might prove helpful.

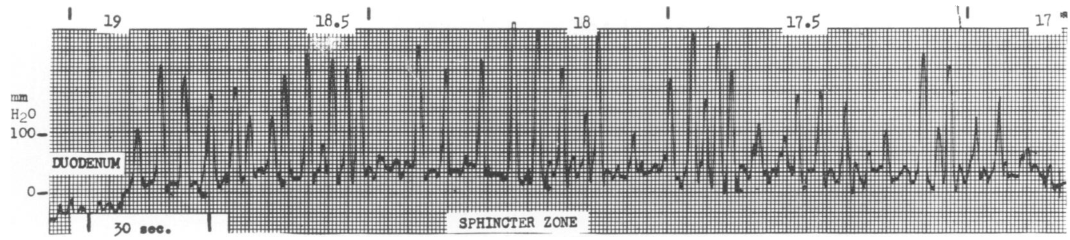

FIG. 2. Typical reproducible pressure profile of sphincter zone. Numbers on top indicate distance between skin edge and most proximal catheter opening. In this experiment sphincter zone was 2 cm. in length. Other findings include: 1) sudden pressure increase as catheter enters sphincter zone from duodenum, 2) rapid, (every 3–5 sec.) prominent waves which indicate sphincter contraction and 3) slower, (every 25–50 sec.) low pressure variation interpreted as representing ampullary emptying and filling.

Materials and Methods

Eighteen healthy mongrel dogs averaging 19 Kg. in weight were used for these experiments. The dogs were fasted at least 12 hours before laparotomy, performed under general anesthesia using intravenous sodium pentobarbital, 30 mg./Kg. The animals were allowed to breathe room air spontaneously. Using sterile technic, a midline abdominal incision was made. The gallbladder was elevated with a clamp so that the cystic duct and common duct could be visualized. The cystic duct was then isolated and ligated adjacent to the gallbladder, following which the cystic duct was incised at its most proximal point. A double or triple lumen catheter filled with saline was then gently guided through the cystic duct into the common duct and finally beyond the sphincter of Oddi into the duodenum. Openings in the catheters were at 2-cm. intervals (Fig. 1). The position of the catheter could be determined easily by gentle palpation through the duodenal wall. A ligature was also placed around the cystic duct below the site of catheter insertion. This ligature prevented slipping of the catheter but permitted its withdrawal by moderate traction. The abdominal wall was then closed in layers around the catheter to produce a closed system within the abdominal cavity. Normal saline was flushed through the catheters before they were attached to a Sanborn 964 multi-channel recorder. The transducers were positioned midway between the xiphoid and the posterior abdominal wall. This point was used as manometric 0. Respirations were recorded simultaneously by the use of a pressure pneumograph.

Initial pressure recordings were made with all catheter openings in the duodenum. The catheter was then withdrawn slowly, centimeter by centimeter, until the proximal catheter opening was in the sphincter or high pressure zone. Recordings were made at this level and gradual withdrawal of the catheter was again carried out with recordings being made every 0.5 to 1 cm.

TABLE 1. *Pressure Recordings of Duodenum, Sphincter Zone and Common Duct*

Resting Duodenal Pressure		Resting Sphincter Zone Pressure		Maximal Amplitude of Sphincter Contraction		Resting Common Duct Pressure	
Average mm. N.S.	Range mm. N.S.	Average mm. N.S.	Range mm. N.S.	Average mm. N.S.	Range mm. N.S.	Average mm. N.S.	Range mm. N.S.
−39	−60 to 4	93	44–210	203	70–281	60	31–149

Results

As the catheter was withdrawn from the low pressure region of the duodenum into the intramural portion of the common duct, a sudden increase in pressure was noted (Fig. 2). This high pressure or sphincter zone was approximately 2 cm. in length in the dog. As the catheter entered the common duct, the pressure was seen to fall slightly. The average pressure recordings in the duodenum, sphincter zone and common bile duct are shown in Table 1. These pressure recordings are in agreement with those of other investigators.[2,5] It should also be noted that the effect of barbiturate anesthesia on extrahepatic biliary tract pressure is negligible.[3,10,12]

The most prominent wave noted in the tracing while recording from the sphincter zone was a regular fluctuation occurring about every 3 to 5 seconds. In most cases this variation was seen every 3½ seconds. Rhythmic contraction and relaxation of the entire sphincter ampullae probably accounts for this wave. Other investigators have demonstrated a similar rate of sphincter activity.[8]

Another important rhythmic variation was seen to be superimposed on this basic sphincteric activity. Every 25 to 50 seconds a smaller variation in pressure was often noted. It is thought that this represents rhythmic emptying and filling of the ampulla, a kind of "ampullary suction." It was also noted that ampullary emptying and filling can occur without change in pressure being noted in the proximal common duct (Fig. 3, 4). For this reason there must be a third, more proximal, protective sphincter, the sphincter choledochus. Figures 5 and 6 represent further examples of the independent action of this proximal sphincter. These tracings were made after the animal had received morphine sulphate intravenously. Note that the pressure was first seen to rise simultaneously in the sphincter zone and in the common bile

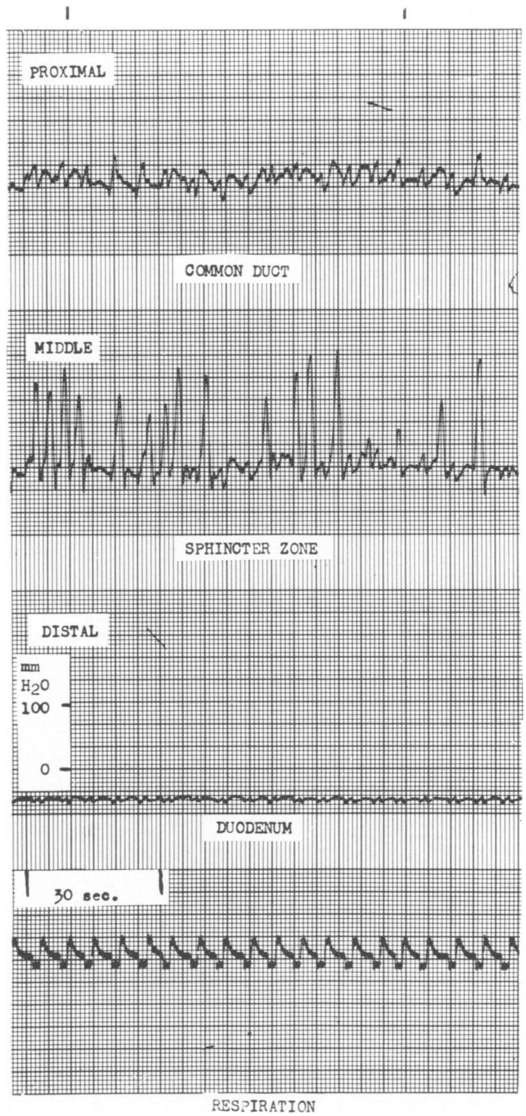

FIG. 3. Simultaneous pressure recordings are shown in duodenum, sphincter zone and common duct. Respirations are also recorded. Slower, low pressure variations, as well as the sphincteric contractions, are transmitted to common duct.

duct. Then a fall in pressure in the sphincter zone was recorded while the pressure in the common bile duct continued to rise. This is interpreted as representing contraction of the sphincter choledochus, associated with a relaxation of the sphincter papillae, allowing the ampulla to empty. Figure 4 also demonstrates that marked pressure variations in the sphincter zone

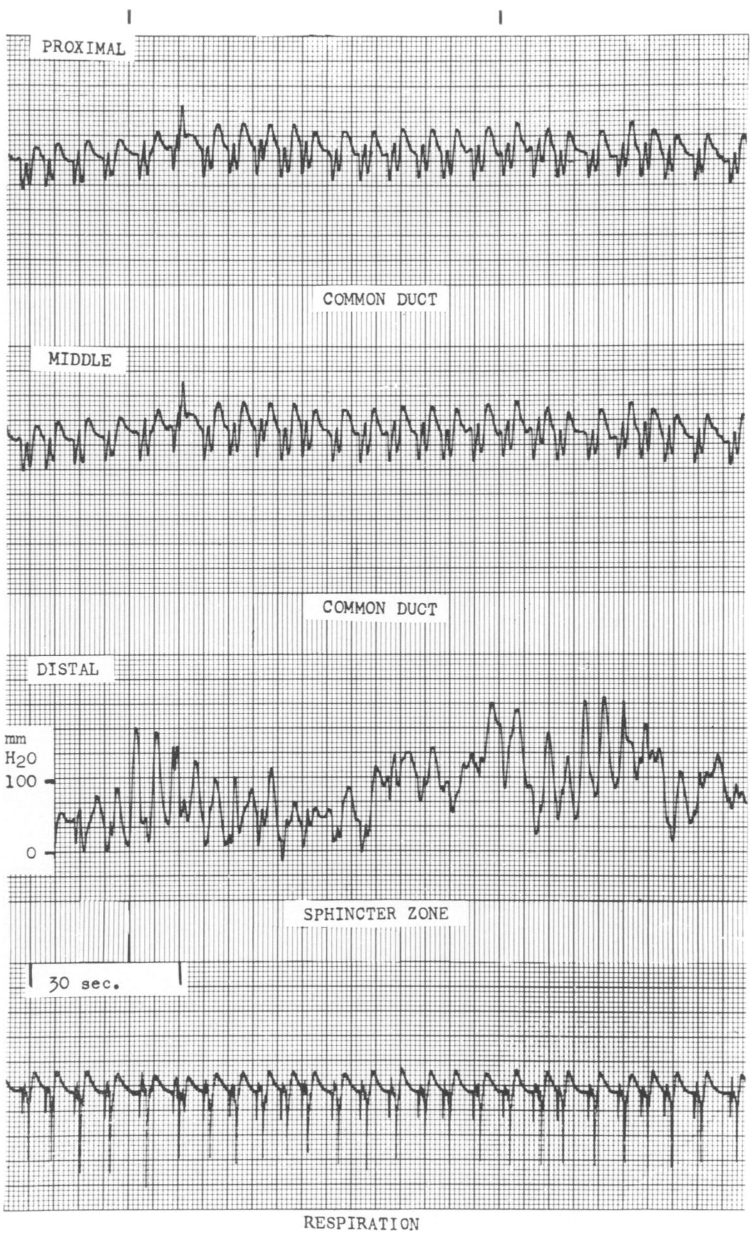

FIG. 4. In this tracing the very active sphincteric contractions and the slower waves of postulated ampullary activity are not transmitted to the common duct tracing.

may not be transmitted to the common bile duct.

As the catheter was withdrawn from the sphincter zone into the common bile duct, several changes in pressure were noted. First, there was usually a slight decrease in pressure. With this decrease there was seen to occur a regular, rapid fluctuation every 2 to 7 seconds which was associated with respiration. This change averaged 35 mm. of saline.

A second rapid fluctuation seen in many of the resting common duct tracings was due to the transmitted sphincter rhythm. The frequency of this variation was about every 3 to 5 seconds and was easily confused with respiratory variations. After morphine sulphate was given, the sphinc-

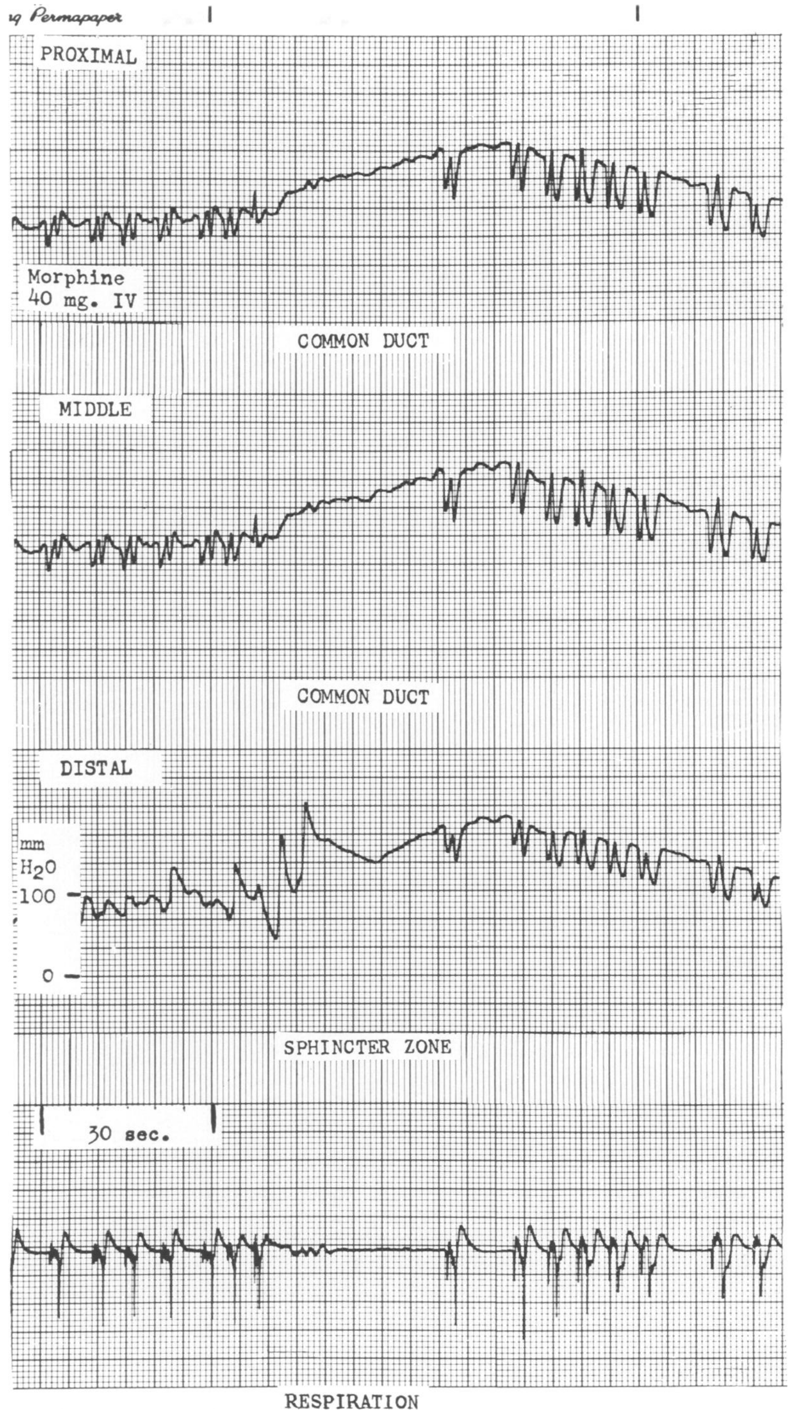

FIG. 5. The protective sphincter choledochus is here demonstrated. As pressure in the common duct rises, pressure in the sphincter zone falls.

ter rhythm was seen to be transmitted to the common duct tracings without respiratory interference (Fig. 6). It was also noted that the sphincteric waves were often transmitted with greater intensity to the more distal catheter openings in he common duct (Fig. 7). This is probably due to the decreasing amount of muscle in the

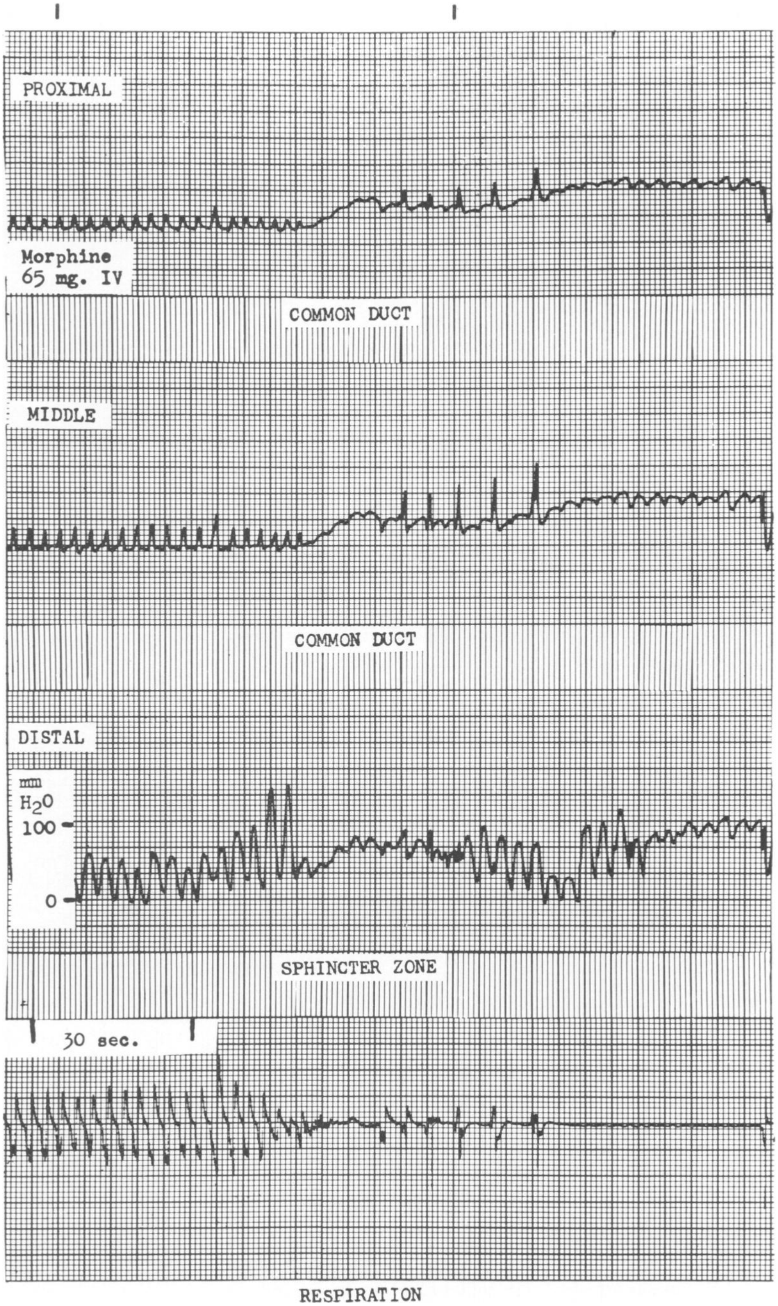

FIG. 6. This tracing presents another example of the protective, proximal sphincter fibers, the sphincter choledochus. Note, however, that even though the pressure is decreasing only in the sphincter zone, the intrinsic sphincteric rhythm is still transmitted to the common duct.

FIG. 7. Representation of pressure profile seen with all catheter openings in common duct. Simultaneous changes in pressure are noted with 1) respiration, 2) sphincteric activity and 3) ampullary activity, the 25–50 sec. minor variation in pressure. After morphine is given a pressure increase is noted in all catheters. Sphincteric activity is seen differentially transmitted along the duct. Sphincteric rhythm is exhibited during period of apnea caused by morphine.

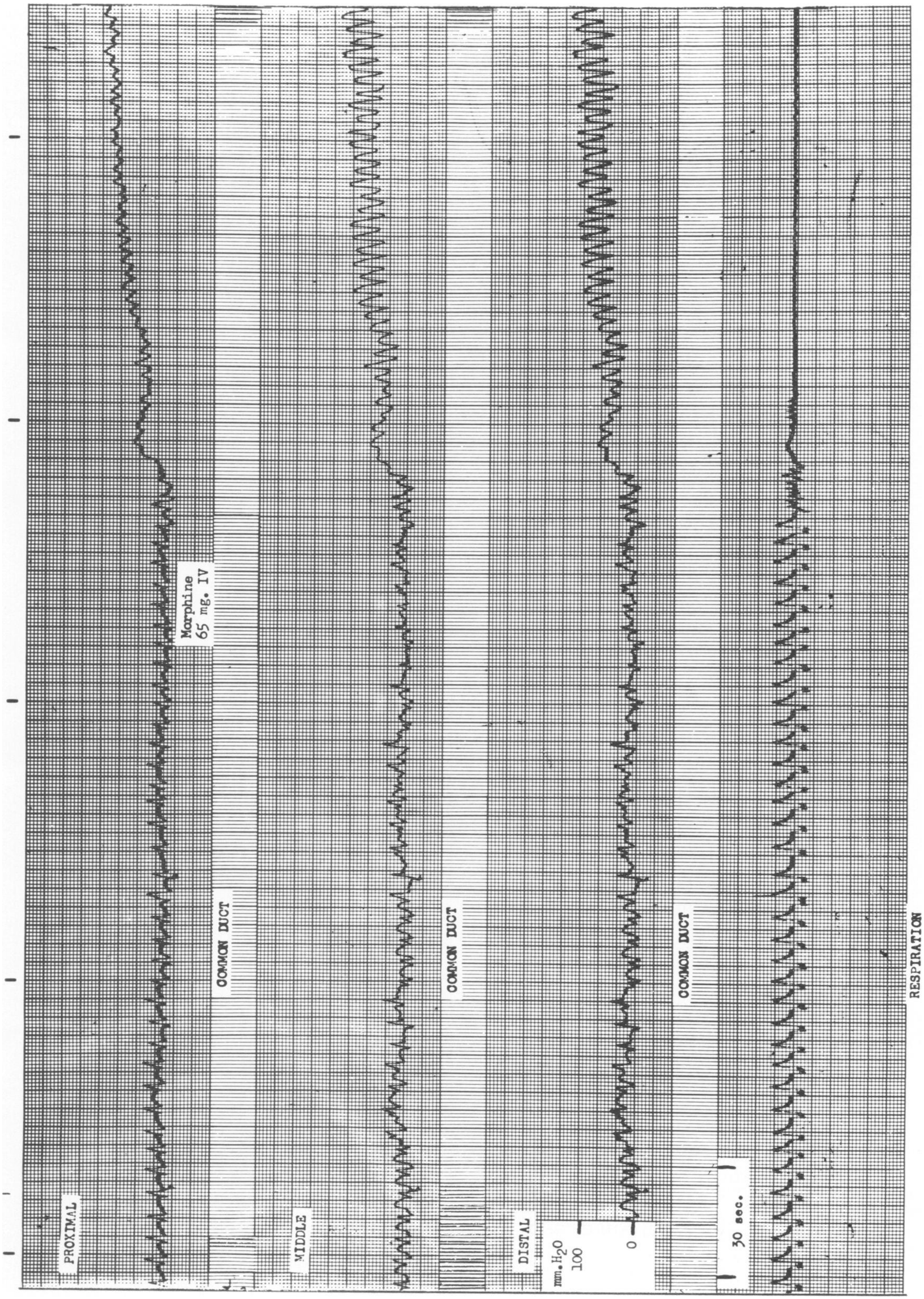
Morphine
65 mg. IV
PROXIMAL
COMMON DUCT
MIDDLE
COMMON DUCT
DISTAL
COMMON DUCT
mm. H2O
100
0
30 sec.
RESPIRATION

TABLE 2. *Drug Effects on Common Duct Pressure*

Change in Resting Common Duct After Morphine		Change in Resting Common Duct After Methacholine		Change in Resting Common Duct After Acetylcholine	
Average mm. N.S. Increase	Range mm. N.S. Increase	Average mm. N.S. Increase	Range mm. N.S. Increase	Average mm. N.S. Decrease	Range mm. N.S. Decrease
53	8–93	66	15–110	28	0–50

proximal common duct and greater distensability of this region.

A third rhythmic variation in pressure was frequently seen occurring every 25 to 90 seconds, averaging 16 mm. of saline. In Figure 7, an example of this minor rhythm is demonstrated occurring simultaneously in all catheter openings in the common bile duct. Therefore, this cannot be interpreted as common bile duct peristalsis. Menguy[12] has reported a similar slow, low pressure wave but offered no explanation for its occurrence. It would appear that this is due to ampullary emptying and filling.

Effect of Drugs on Common Duct Pressure

The spasmogenic effect of morphine on the sphincter of Oddi has been known for decades and was reconfirmed by the present study (Table 2). Although the tone of the sphincter mechanism was seen to be increased by the administration of morphine, the basic rhythm was unchanged. The contractions were seen to be of greater amplitude but still occurred on an average of every 3 to 5 seconds. Morphine also uniformly depressed the respiratory rate.

Methacholine chloride, 5 mg. given subcutaneously, was also noted to cause an increase in pressure in the common duct. No peristalsis was seen following the administration of this drug.

Acetylocholine injected directly through the proximal catheter opening into the common duct caused a decrease in common duct pressure. Atropine, as well as nalorphine, was found to lower the common duct pressure.

Discussion

The use of double or triple lumen catheters in the study of motor activity of the esophagus is now well accepted and widely employed.[15] Changes in esophageal function associated with certain disease states can easily be demonstrated. This study represents an attempt to use the simultaneous recording multiple lumen catheter in the investigation of extrahepatic biliary tract function.

In order to explain the pressure waves seen in the sphincter zone it becomes necessary to think of this mechanism as composed of three functional sphincters. Figure 8 is a diagrammatic representation of this postulated triple sphincter mechanism. The initial sudden rise in pressure noted when the catheter enters the sphincter zone is probably due to the tonus of the sphincter papillae.

Since Oddi's demonstration of a muscular sphincter at the distal end of the common bile duct, much has been learned and postulated about the role of this sphincter mechanism in health and disease. A malfunctioning sphincter mechanism has been singled out by clinicians as a factor in the etiology of cholangitis, jaundice, hepatitis, cholelithiasis, biliary colic, unexplained right upper quadrant pain, recurrent acute pancreatitis, dyspepsia and cholecystitis. As there is no reliable medical means of controlling a spastic sphincter, surgeons

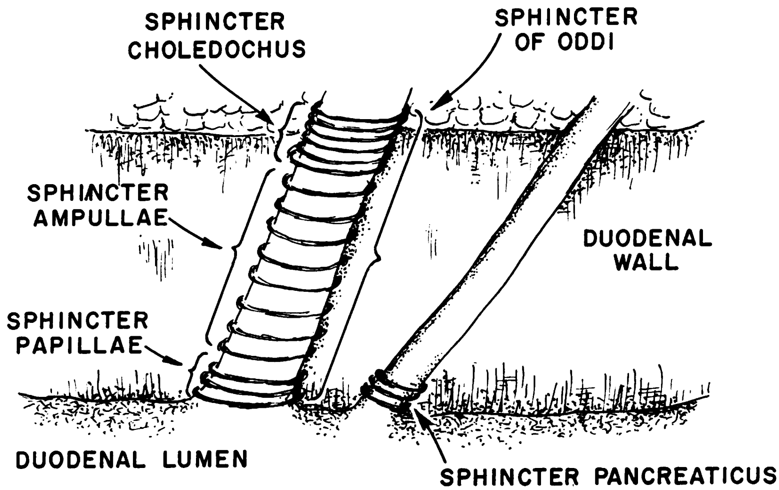

FIG. 8. The postulated triple sphincter mechanism is shown above. Functionally, the sphincter choledochus is perhaps the most important part of the mechanism.

have developed various technics of sphincterotomy. A reduction in ductal pressure without reflux or ascending infection is the goal. In 1936 Colp and Doubilet[4] reported that endocholedochal sphincterotomy could do just that. The procedure was soon performed on humans, especially for recurrent acute pancreatitis. A transduodenal sphincterotomy technic was also developed. The efficacy of this procedure has been a subject of much discussion and controversy.[6, 12] Lempke[9] in 1963 concluded that the effect of sphincterotomy is transient and that it usually does not alter biliary dynamics enough to be considered therapeutic.

In the present study the high pressure zone of the sphincter mechanism in the experimental animal was found to be about 2 cm. in length. Thus it would seem highly unlikely that a transduodenal sphincterotomy of about 1 cm. could afford a satisfactory means of reducing ductal pressure in the animal. Further studies in humans are being carried out to evaluate this aspect of the problem.

Despite prolonged measurements of resting common duct pressure following the administration of various drugs, no evidence of coordinated intrinsic motor activity of the common duct or peristalsis could be demonstrated.

Summary

Motility studies in the common bile duct using a double or triple lumen catheter were performed on 18 mongrel dogs with the following findings. 1) There is an intrinsic contractile rhythm of the sphincter of Oddi. Other variations in pressure in the sphincter zone are postulated to be due to ampullary filling and emptying as a result of a functionally triple sphincter mechanism. 2) Rhythmic pressure variations in the common duct tracings are believed to be due to respiration, transmitted sphincteric activity and transmitted ampullary emptying and filling. 3) No common duct peristalsis could be demonstrated. 4) On the basis of this experimental study further doubt is cast upon the efficacy of conventional transduodenal or endocholedochal sphincterotomy alone in ablating the muscular activity of the sphincter of Oddi.

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