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Fetal intraluminal portion of the sphincter of Oddi: a histological study using human fetuses

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SUMMARY

The sphincter of Oddi surrounds a common duct after joining of the bile and pancreatic ducts in the adult ampulla of Vater, but the fetal development of the submucosal portion of the sphincter is still obscure possibly because previous studies used horizontal or frontal sections. We examined serial sagittal histological sections of 12 human fetuses with 36-65 mm crown rump length or CRL (approximately 9-11 weeks) and semi-serial sections of the other 3 fetuses with 210-250 mm (25-30 weeks). Except for 1 fetus (36 mm CRL), fourteen fetuses carried the "intraluminal portion" protruding and floating in the duodenal lumen. Twelve of them had the sphincter extending to the anal side in the duodenal lumen, whereas two extended to the stomach side. The distal end of the sphincter seemed to detach from the duodenal mucosa at and around 9 weeks, and subsequently the common duct seemed to elongate freely without mucosal attachment in mid-term fetuses and, finally, become embedded again in the duodenal mucosa in the postnatal life. A possible discrepancy in growth rate between the sphincter muscle and duodenal mucosa was likely to allow the specific intermediate morphology, i.e., the intraluminal common duct. The fetal accessory papilla did not show such morphology. A minority of cases whose common duct extended to the stomach side might connect with abnormal union of the bile and pancreatic ducts.

Key words: Sphincter of Oddi – Ampulla of Vater – Submucosal portion – Intraluminal common duct – Human fetus

Common abbreviations: AD, right adrenal; APD, accessory pancreatic duct; CBD, common bile duct; CL, liver caudate lobe; D1, D2, first or second portion of the duodenum; GDA, gastroduodenal artery;IVC, inferior vena cava; MPD, major pancreatic duct; P, pancreatic head;TC, transverse colon.

INTRODUCTION

The common bile duct and the main pancreatic duct enter the duodenal submucosal tissue through the duodenal window and join together to provide a common duct in the ampulla of Vater. In contrast to the previous reports (Schwegler and Boyden, 1937a, b, c; Jit, 1957), at the window, our group described a great contribution of duodenal wall smooth muscles to the growing sphincter of Oddi in human fetuses (Yang et al., 2013). According to Yang et al. (2013), fetal development of a sphincter for the common duct (sphincter choledocus inferior by Boyden, 1957) finishes until a stage of 50 mm

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crown rump length or CRL and the common sphincter is consistently reinforced by the duodenal circular muscle layer from the left side.

It is well known that, in the greater duodenal papilla, a common duct after the joining of the bile and pancreatic ducts often takes a long downward course in the duodenal submucosal tissue (Avisse et al., 2000; Boyden, 1957; Dardinski, 1935; Papalmitiades and Rettori, 1957). Boyden (1957) called the submucosal portion of the sphincter "the sphincter ampullae". Ishibashi et al. (2000) described variations in the submucosal portion of the sphincter of Oddi: the maximum length of the downward course reached 17.9 mm in their horizontal type (83.3%, 95/114) of elderly Japanese duodenal papilla. According to Ishibashi et al. (2000), in the minor population (16.7%, 19/114), the short common duct protrudes vertically into the duodenal lumen to make a small papilla. However, previous studies seemed not to describe how and when the submucosal duct obtain the long downward course in fetuses, possibly because horizontal or frontal sections had been used for studies. Consequently, using sagittal sections, the aim of this study was to demonstrate fetal development of the submucosal portion of the sphincter of Oddi.

MATERIALS AND METHODS

The study was performed in accordance with the provisions of the Declaration of Helsinki 1995 (as revised in Edinburgh 2000). We examined the paraffin-embedded serial sagittal sections of 12 fetuses with 36-65 mm crown rump length or CRL (approximately 9-11 weeks), as well as semiserial sections of the other 3 fetuses with 210-250 mm (25, 28 and 30 weeks). All sections were stained with hematoxylin and eosin. The semiserial sections of the 3 large fetuses had been prepared by Jeong et al. (2009) with interval of 0.1 mm after decalcification using Plank-Rychlo solution (AlCl2/6H2O, 7.0 w/v%; HCl, 3.6; HCOOH, 4.6) for 3-5 days at room temperature. With the agreement of the families concerned, these specimens were donated to the Department of Anatomy of the Chonbuk National University in Korea, and the use of these samples for research was approved by the university ethics committee (CUH 2013-03-007). The fetuses were obtained by induced abortions. After abortion, each mother was personally informed by an obstetrician about the possibility of fetal donation for research: no attempt was made to encourage donation. The donated fetuses were fixed with 10% w/w formalin solution for more than 3 months. Because of randomization of the numbering, it was not possible to trace the family concerned.

RESULTS

Except for the smallest 1 fetus (36 mm CRL), fourteen of the present 15 specimens carried a distal part of the sphincter of Oddi extending freely into the duodenal lumen. Thus, a common duct after union between the bile and pancreatic ducts was likely to "float", to a greater or lesser extent, in the lumen without attachment to the duodenal mucosa at 9-30 weeks (Figs. 1-4). In the smallest specimen, the sphincter of Oddi was entirely embedded in the duodenal mucosa and submucosa. The short major papilla protruded vertically into the duodenal lumen (figures, not shown).

In 11 specimens with intraluminal portion of the sphincter at 9-11 weeks, nine specimens had the long intraluminal course of the common duct extending to the anal side (Fig. 1), whereas other 2 carried a short course extending to the stomach side (Figs. 2 and 3). In the majority (9 specimens), the main pancreatic duct and the common bile duct crossed obliquely the duodenal wall (Fig. 1B, C) and both ducts joined to provide a common duct in the duodenal submucosal tissue. Thus, a major part of the sphincter for the common duct existed in the ampulla of Vater (sphincter choledocus inferior et ampullae; Boyden, 1957). Notably, the common duct protruded inferiorly into the duodenal lumen and opened. The opening of the common duct extended to the anal side along 0.2-0.6 mm without attachment to the duodenal mucosa. Thus, the opening appeared to provide a "groove" extending along the left-right axis (Fig. 1D-G). A sphincter for the common duct existed in the ampulla lying in the submucosal tissue. We did not find any tissue debris along the sphincter as well as in the duct.

In the minority (2 specimens) at 9-11 weeks, the main pancreatic duct joined the common bile duct in or outside of the duodenal wall (Figs. 2B and 3B) and the common duct crossed vertically the duodenal wall (Figs. 2D and 3BC). Thus, the short ampulla vertically protruded into the duodenal lumen. The submucosal course of the common duct appeared to be shorter than the majority. A major part of the sphincter for the common duct was intramural rather than in the ampulla. In a specimen with 65 mm CRL (Fig. 2), the common duct opening accompanied a cecum-like duct and the latter extended to the stomach side along 0.3 mm-length without attachment to the duodenal mucosa. Likewise, in a specimen with 61 mm CRL (Fig. 3), the common duct protruded vertically into the duodenal lumen, but it provided a sac-like notch (0.1 mm diameter) toward the stomach side. Consequently, in midterm fetuses, the submucosal common duct was usually short in contrast to a relatively long "intraluminal portion" without attachment to the duodenal mucosa. The accessory pancreatic duct

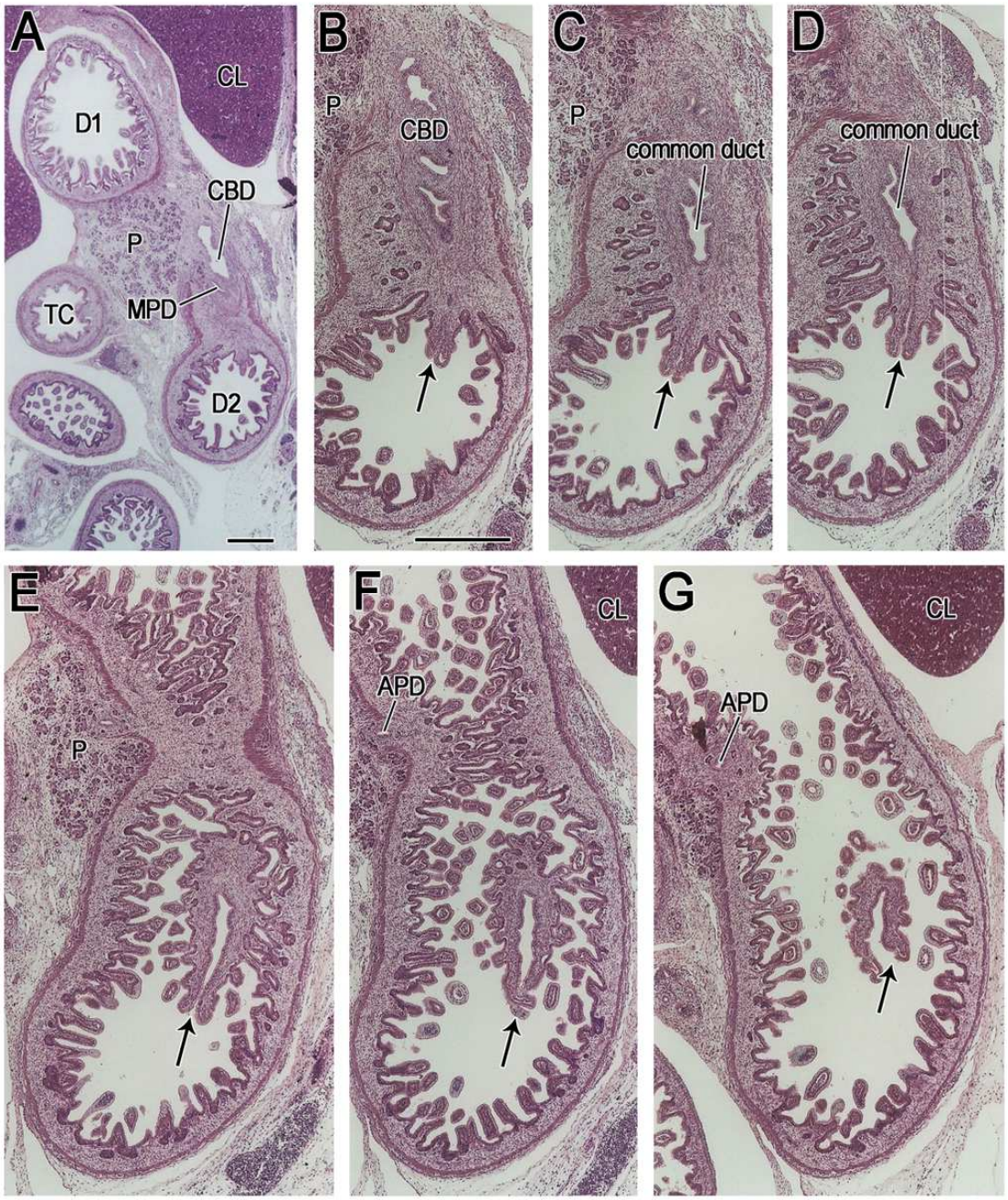

Fig. 1. A specimen with 54 mm CRL (approximately 10 weeks). Intervals between panels are 0.05 mm (A-B, B-C) and 0.1 mm (C-D, D-E, E-F, F-G). **(B-G)** Prepared at the same magnification (scale bar: 1 mm in panels A,B). **(A)** displays topographical relation around the sphincter of Oddi at the lower magnification. A common duct, after joining the bile and pancreatic ducts (CBD, MPD), protrudes inferiorly into the duodenal lumen and opens **(B,C)**. The opening extended to the anal side along 0.4 mm without attachment to the duodenal mucosa **(D-G)**. Thus, the opening provides a groove (arrows) extending along the left-right axis. The accessory papilla is embedded in the duodenal mucosa **(G).** Other abbreviations, see common abbreviations on first page of article.

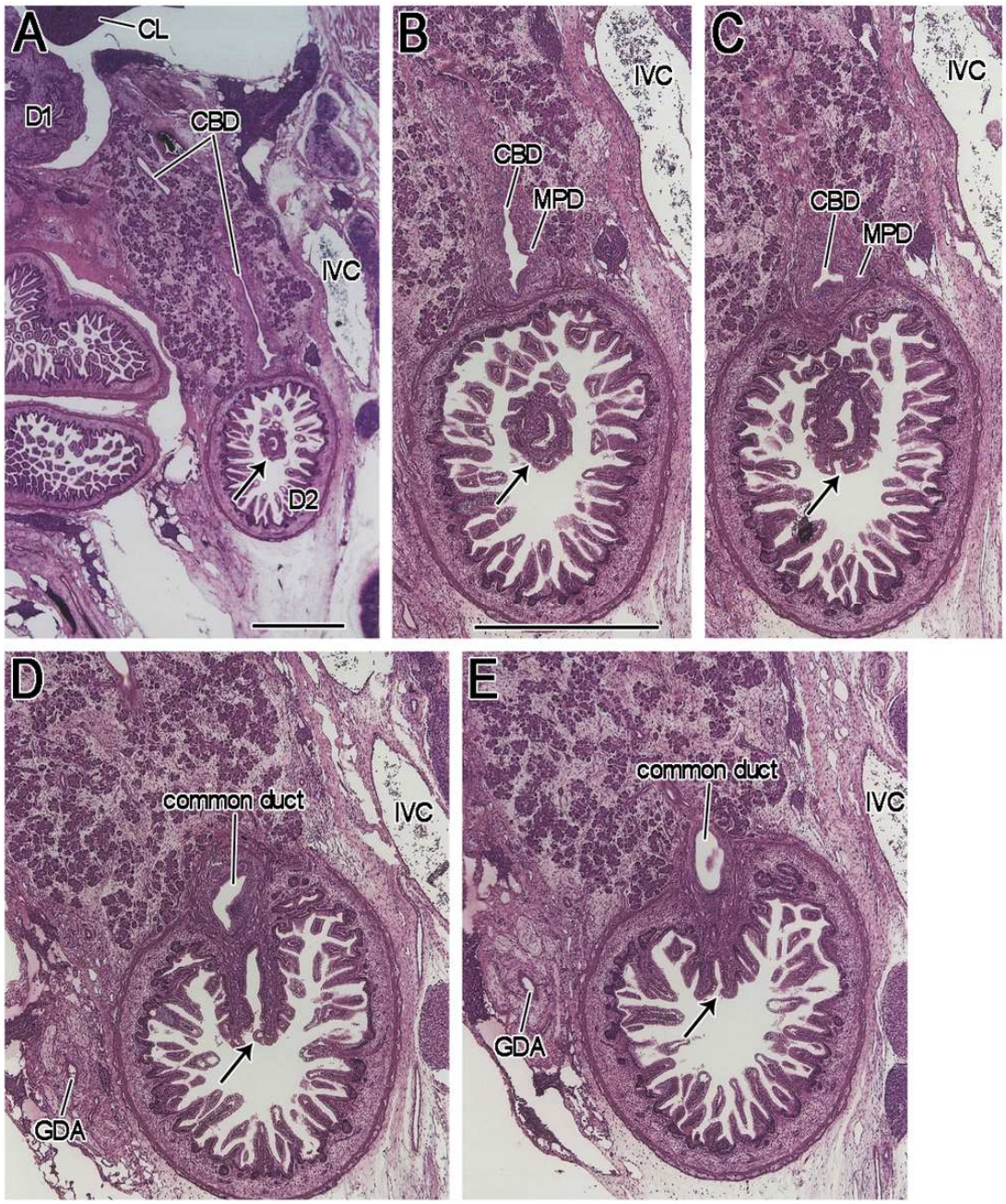

Fig. 2. A specimen with 65 mm CRL (approximately 11 weeks). Sagittal sections. Intervals between panels are 0.1 mm (A-B, B-C) and 0.05 mm (C-D, D-E). **(B-E)** were prepared at the same magnification (scale bar: 1 mm in A,B). **(A)** displays topographical relation around the sphincter of Oddi at the lower magnification. After passing through the duodenal wall, the common duct opens to the duodenal lumen (arrows in D,E), but a cecum-like duct (arrows in panels A-C) extends to the stomach side along 0.3 mm-length without attachment to the duodenal mucosa. For abbreviations, see the common abbreviations at the beginning of this article.

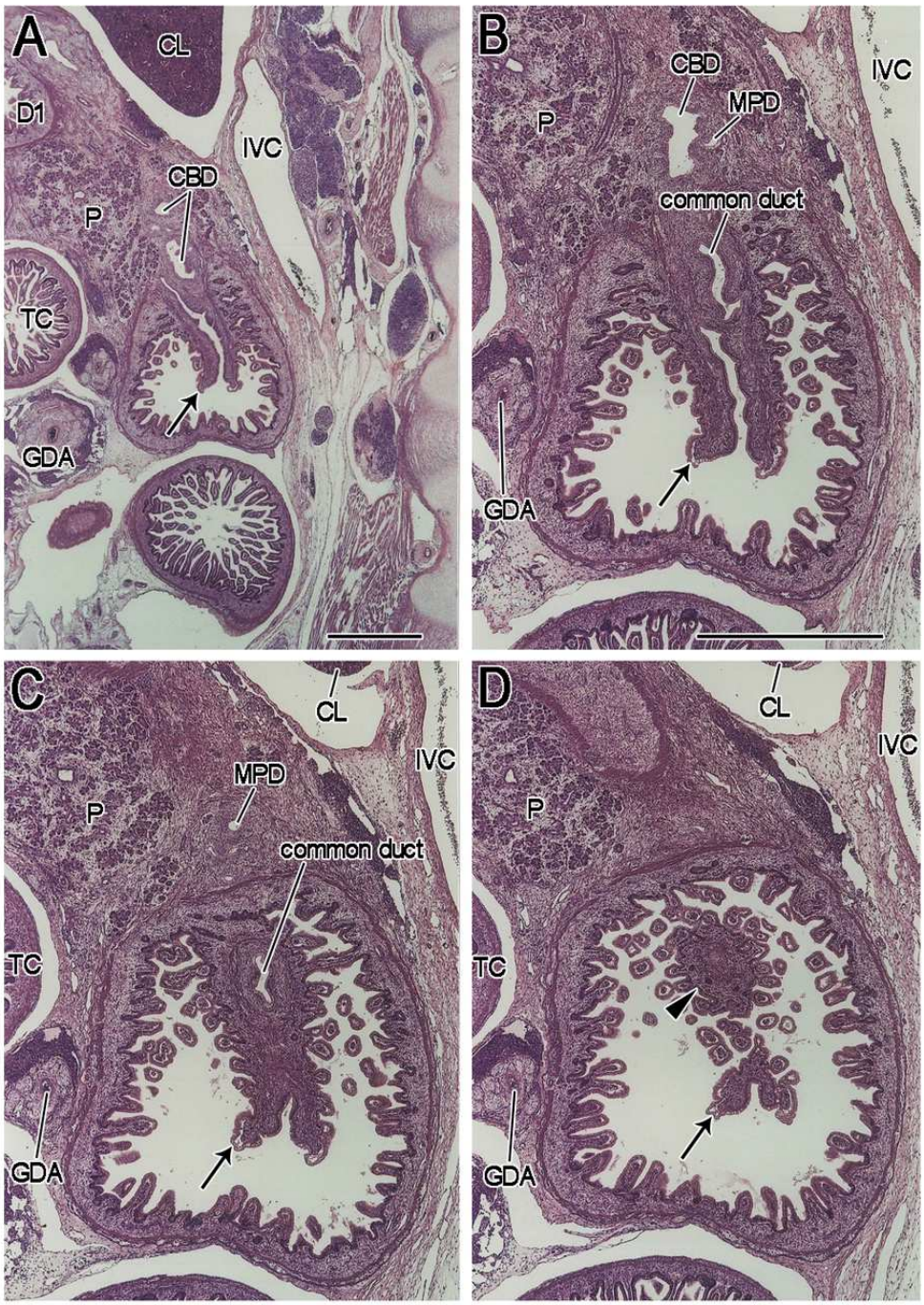

Fig. 3. A specimen with 61 mm CRL (approximately 11 weeks). Sagittal sections. Intervals between panels are 0.2 mm (A-B, B-C) and 0.1 mm (C-D). (B-D) were prepared at the same magnification (scale bar: 1 mm in A,B). **(A)** displays topographical relation around the sphincter of Oddi at the lower magnification. After passing through the duodenal wall, the common duct opens to the duodenal lumen (arrows in A,B), but a notch-like part (arrowhead in D) is present in the stomach side of the opening (arrows in C,D). For abbreviations, see common abbreviations at the beginning of this article.

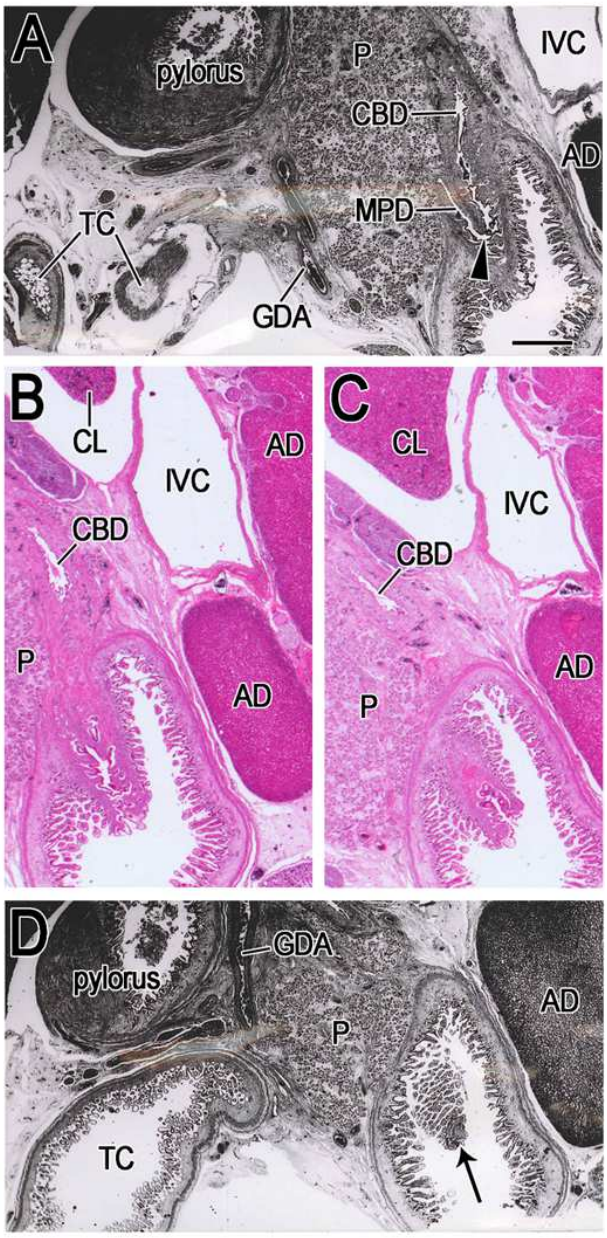

Fig. 4. A specimen with 210 mm CRL (approximately 25 weeks). Intervals between panels are 0.2 mm (A-B, B-C) and 0.4 mm (C-D). The common bile duct (CBD) joins the major pancreatic duct (MPD) in the submucosal tissue of the duodenum (arrowhead in A). The major duodenal papilla (arrow in D) extends leftward along 0.5-0.6 mm after opening in the right side (B,C). All panels are prepared at the same magnification (scale bar in A, 1 mm). Other abbreviations, see the common abbreviations at the beginning of this paper.

did not carry such an intraluminal portion but it was embedded in the submucosal tissue (Fig. 1G).

Three late-stage fetuses (25, 28 and 30 weeks) also carried the intraluminal portion of the sphincter (Fig. 4). In all of them, the common duct joined the major pancreatic duct in the submucosal tissue of the duodenum (Fig. 4A). The major duodenal papilla extended leftward, rather than inferiorly, along more than 0.5 mm after opening in the right side (Fig. 4B-D). Thus, the opening of the common duct still showed al groove-like appearance as in the mid-term fetuses. Although the size of the duodenum was more than 2 times greater than that in mid-term fetuses, the length of the intraluminal portion was not so changed.

DISCUSSION

According to the present study, 1) the distal end of the sphincter of Oddi seemed to detach from the duodenal mucosa at and around 9 weeks, and subsequently, 2) the common duct seemed to elongate freely without mucosal attachment in mid-term and late-stage fetuses. A possible discrepancy in growth rate between the sphincter muscle and duodenal mucosa was likely to allow for the specific intermediate morphology, i.e., the common duct floating in the lumen. Finally, we speculated that the intraluminal morphology seemed to regain the submucosal position in the postnatal growth of the duodenum after start of oral feeding.

It is well known that, in human embryology, temporal occlusion and subsequent recanalization occur in the duodenal lumen until 7 weeks (e.g., Hamilton and Mossman, 1978). Epithelial cell proliferation is considered to play a critical role for occlusion and the control mechanisms were postulated (Beaulieu and Calvert, 1987; Kylarová et al., 2004; Theodosiou and Tabin, 2003). However, according to Matsumoto et al. (2002), rather than proliferation, convergence of the epithelial cells occurs for active elongation of the duodenum in the occlusion phase. The floating stage seemed to correspond to a rapid growth phase of the bile duct diameter until 20 weeks according to a morphometrical study by Desdicioğlu et al. (2012). An intraluminal portion of the sphincter of Oddi or the currently observed “floating” duct was established in the duodenal lumen after complete recanalization. At the beginning of this study, we had an impression of the over-reactive canalization along the sphincter. However, along the duct, we did not find any tissue debris suggesting cell death.

Devereaux et al. (2002) and Yang et al. (2013) noted a function of a common sphincter surrounding both of the bile and pancreatic ducts just before the union of these ducts in the duodenal submucosal tissue. Such a submucosal sphincter, classically termed as the sphincter ampullae (e.g., Schwegler and Boyden, 1937c), seemed to grow inferiorly and elongate without any obstacle (i.e., the submucosal tissue) in the temporal intraluminal position in the majority. When the elongation is small, it may become the so-called vertical type of the major duodenal papilla (see the Introduction). Notably, the present 2 specimens whose common duct extended to the stomach side contained candidates of abnormal union of the bile and pancreatic ducts. Jona and Belin

(1976) reported anomalies of the ampulla, but all of their examples were combined with duodenal diverticulum. Yang et al. (2013) found, in 57 fetal specimens at mid-term, 4 specimens (CRL 31-35 mm) with the main pancreatic duct joining the common bile duct in the left or outside of the duodenal circular muscles. Although the present materials were too small in number, abnormal union of ducts might induce a sphincter or ampulla extending to the stomach side. For the further discussion, we need a correlation of morphologies between the submucosal portion of the sphincter and the abnormal union of the ducts.

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