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A Human Embryo of Carnegie Stage 13

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=Abstract= **A human embryo obtained from a salpinx resected for the treatment of an ectopic gestation was serially sectioned and observed. Four chambers of the heart were well delineated, though not completely separated. The dorsal pancreas was observed while the ventral pancreas was not yet formed. It was hard to clearly demarcate the cecal area because of no obvious dilatation. The septum transversum was nearly completely occupied by the hepatic parenchyme. The gall bladder-cyctic duct primordium was also observed. The intestine distal to the duodenum was attached to the posterior body wall by a prominent dorsal mesentery. The respiratory tree showed primary bronchi, and no mesenchymal differentiation around the tree was achieved yet. The mesonephric system showed variable developmental features depending on their location in the body. The mesonephric duct was already connected to the cloaca, and some localized dilatation of the duct surrounded by mesenchymal condensation, which would become the metanephric blastema, foretold the formation of the ureteric bud. The otocyst had been completely separated from the skin ectoderm and the endolymphatic duct had begun to form. Eye primordium observed was the optic cup. The well established lense placode impended to invaginate. Although this embryo showed a few characteristics of stage 14, it may be reasonable to regard this embryo as an older member of stage 13, considering the overall developmental status.**

Key Words: *Human embryo, Carnegie stage*

INTRCDUCTION

Many studies of human embryological development have been usually made based on a detailed observation of histologically prepared human embryos. Many embryonic collections are present worldwide, which offer invaluable basis for morphological studies of human embryos. The Patten embryo collection (Severn 1972) and the Carnegie collection (O'Rahilly and Müller 1987) are such examples in the USA. Austria (Sgalitzer 1941) and Spain (Puerta Fonolá and Orts Llorca 1978) also have similar collections. In Korea, two groups of investigators are known to make their own embryonic collections (Chi and Lee 1980; Kang and Park 1990). These studies apply staging systems , which reflect an accurate developmental status compared to the embryonic age or crown-rump

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length (Moore *et al.* 1981). Staging systems also enable comparisons not only between human studies but between human and animal studies (Butler and Juurlink 1987).

An embryo of Carnegie stage 13 is characterized by the presence of the septum primum and ostium primum, and recognizable right and left lung buds. It also has four visible limb buds and closed otic vesicle with impending formation of the endolymphatic duct. Until now, only five cases of this group have been reported in our country (Chi and Ham 1985; Park 1988; Kang and Park 1990). We report here a human embryo of Carnegie stage 13, adding one case to the previous ones.

MATERIALS AND METHODS

A human embryo was obtained from the resected uterine tube of a 26-year old female for the treatment of an ectopic gestation at a local clinic. The last menstruation period began on June 3, 1992, and the operation was done on July 14, 1992. The resected tube were immediately submerged in 10 % formalin solution, and transferred to our laboratory. The fixative was changed for the discovered embryo. After gross examination, the embryo was processed in a usual histological method. Frontal serial sections were made with 5 μm thickness and the total number of sections was 455. All sections were stained with hematoxylin and eosin, and observed under light microscopy.

RESULTS

External Appearance

The embryo had a dorsal convexity at the thorax and the tail part was on the right side of the body (Fig. 1). The greatest length was about 6 mm after fixation, and the length measured on a histological section was 4.45 mm. The optic cup, the otocyst, and four pharyngeal arches were distinctive. A cervical sinus was observed caudal to the third pharyngeal arch. The heart formed a prominent bulging in the anterior chest wall and was in contact with the pharyngeal arches. However, the liver bud did not bulge out. Both limb buds were well formed, the upper limb bud being a tapering cone and the lower limb bud being only an elevated hump.

Cardiovascular System

Each chamber of the heart could be definitely delineated but still formed a single continuous channel, the cardiac loop (Fig. 2). Judging from the observations in the serial sections, the common atrium was located posterior to the ventricles and the initial portion of the outflow tract. The boundary between the future left and right ventricles could be delineated by the presence of the interventricular septum which was just forming as a slightly elevated ridge (Fig. 3). The atrioventricular canal was positioned in an

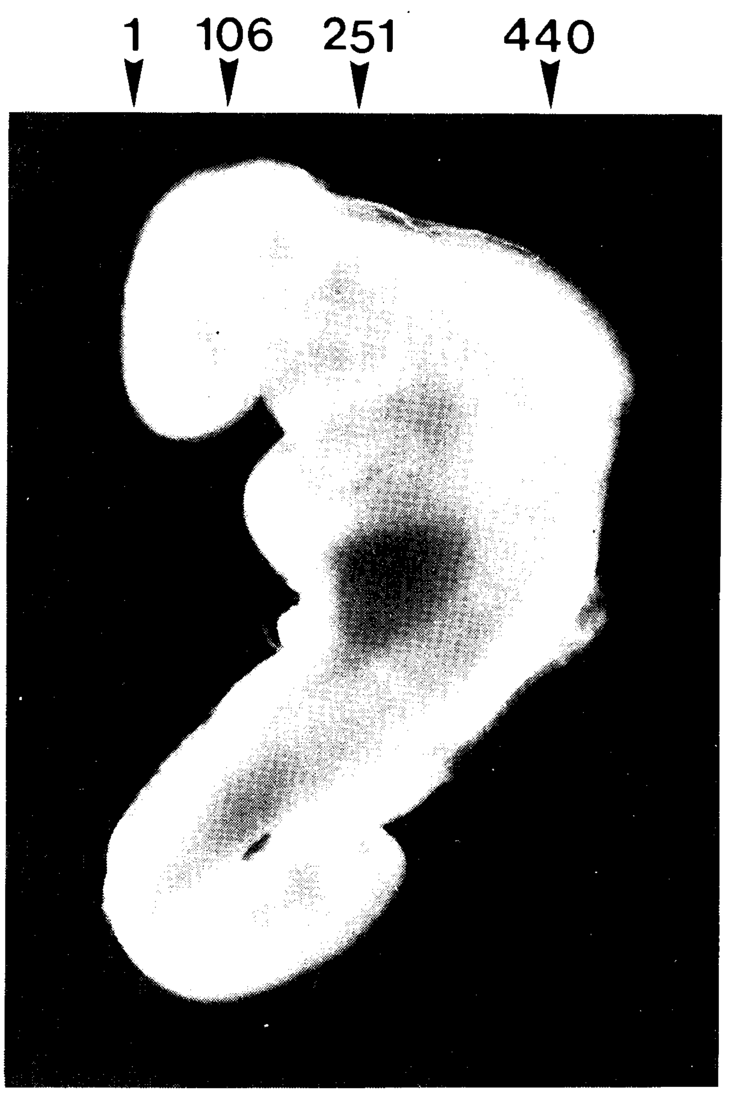


Fig. 1. A left lateral view of the embryo. The numbers indicate the approximate section numbers.

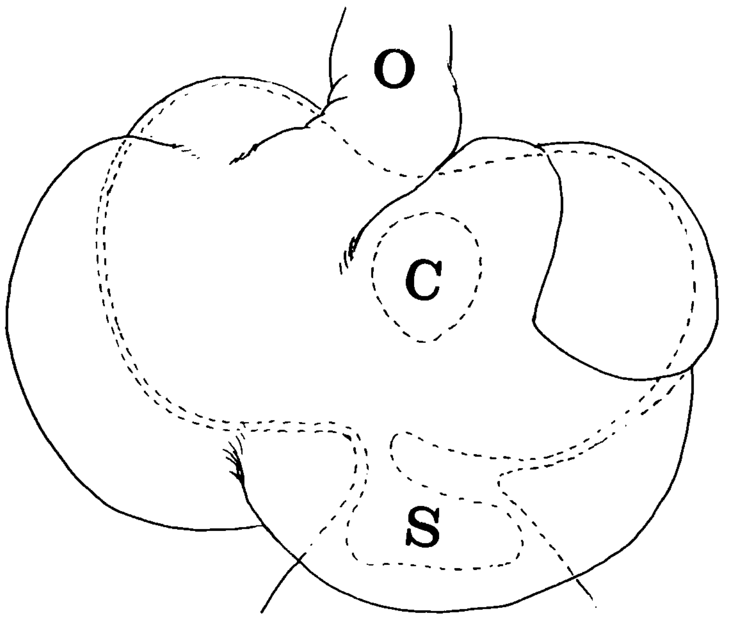


Fig. 2. Schematic drawing of the heart. Anterior view. The posteriorly located atrium is outlined by an interrupted line. 0: outflow tract, C: AV canal S: sinus venosus

anteroposterior direction. The cushion materials occupied the canal so extensively that the orifice was only a slit. Anterosuperior and posteroinferior cushions were recognized. These cushions were not in continuity with those of the outflow tract at the bulboventricular flange. The canal was on the just left side of the primitive interventricular foramen. The outflow tract, beginning at the distal end of the right ventricle, coursed initially leftward then backward to became the aortic sac. As in the AV canal, cushion materials largely filled the muscular canals of the tract, but they showed less cellularity compared to those of the AV canal. The wall of the ventricle was very thick and trabeculated. Although most cells in the muscle layer were round in shape, a few cells were elongated and had eosinophilic materials in their cytoplasm. Striations, however, were not distinct. The wall of the common atrium was thin and had no trabeculations. The atrium had a primary septation, which was found at the superoposterior wall, as a small crescent-like structure projecting into the chamber (Fig. 4).

The venous sinus was formed by the convergence of the flanking sinus horns and located posteroinferior to the heart and in direct contact with common atrium. Two apparent aortic arches ran out from the aortic sac, coursed through the mesenchymal cores of the 3rd and 4th aortic arches respectively (Fig. 5), and finally continued to the dorsal aorta. Although minute vessels were observed in the mesenchyme of the 1st and 2nd aortic arches, they were in continuity with neither the aortic sac nor the dorsal aorta. Any additional vessels thought to be aortic arches were not identifiable. The diameter of the dorsal aorta suddenly diminished cephalic to the connection with the 3rd aortic arch, and the dorsal aorta farther continued rostrally.

Gastrointestinal System

At the floor of the pharynx and on the inner aspect of the mandibular arch, there were two large elevations bilaterally-the distal tongue buds. There was a midline groove between the elevations. Another tongue primordium, the median tongue bud, was also found behind the distal buds. The foramen cecum was located just posterior to it, from which the thyroglossal duct extended downward and backward. The duct was tiny with a small lumen. The thyroid primordium was a cell mass already bilobed (Fig. 6), and surrounded by a reticular tissue. Four pharyngeal pouches were defined. Among them, the first three pouches extended so far laterally that their lining endothelium actually reached the skin ectoderm covering their corresponding pharyngeal clefts, thus resulting in a membrane-like structure (Fig. 5). The oral roof presented another prominent pouch, the adenohypophyseal pocket, just inside the stomodeum. The pocket was V-shaped in its cut surface. Between the roof of the oral or pharyngeal cavity and the neural tube intervened the remnant of the notochord.

The wall of the esophagus, consisting of 3-5 cell layers, was thicker than that of the pharynx. The esophagus outbudded the respiratory diverticulum at about halfway along its course.

The stomach could be recognized by its slightly dilated lumen compared to that of the other part of the gut distal to it, and by the presence of the omental bursa on its right side. The

Table 1. Summary of developmental events in each age group. Findings observed in this embryo are in talic.

organ \ stage	12	13	14	15
Heart	*septum primum right venous valve*	*left venous valve*	apposition of the AV canal between the ventricles	foramen secundum
Gastro intestinal tract	*dorsal pancreas*	ventral pancreas (*possibly*)	ventral pancreas *cecal dilatation* *dorsal mesentery*	intestinal loop
Liver	*spreading of the diverticular cells into the stroma*	*completion of spreading*	*hepatic capsule*	
Respiratory system	*lung bud*	*primary bronchus*	mesenchymal reaction	lobar bud
Urinary system	*connection of the mesonephric duct with cloaca*	*S-shaped nephric tubule*	S-shaped nephric tubule	ureteric pelvis
Eye	*optic vesicle*	*optic cup* *lens disc*	lens disc indentation	lens vesicle closing
Ear	*open or closed but attached otocyst*	*endolymphatic appendage*	endolymphatic appendage	slender endolymphatic duct
Limb bud	*upper limb buds appearing*	*all four limb buds visible*	*elongation and tapering of upper limb bud*	hand plate

wall of the stomach was about 3-4 cell layer thick. Distal to the stomach, the hepatic diverticulum outbudded from and was perpendicular to the anterior wall of the duodenum and extended anteriorly. The superior wall of the diverticulum lacked basement membrane, and the cells of the wall looked like spreading out into the septum transversum (Fig. 7). The cystic duct-gall bladder existed as a ventral continuation of the diverticulum for a short distance. The hepatocyte with eosinophilic cytoplasm formed cell cords and nests intermingled with mesenchymal cells. There were numerous minute venous sinuses intermingled, too. The liver parenchyme occupied almost all the septum transversum, and in some areas, the mesenchyme of the septum transversum reduced to a capsule-like structure surrounding the parenchyme.

The dorsal pancreas could be identified dorsal to the duodenum, but, it was hard to identify the ventral one. The gut distal to the duodenum was anchored to the posterior body wall by a well developed dorsal mesentery, which bore occasional vitelline arteries (Fig. 8). Above the duodenum, including it, and below the esophagus, both the ventral and dorsal mesentery equivalents were present.

In the hindgut, the ileocecal junction could not be clearly identified. That is, the lumen of the cecum was not distended yet. The cloca had a dilated lumen and was connected by the allantois and mesonephric ducts (Fig. 9 and 10). A portion of the clocal endoderm directly made contact with the skin ectoderm to form the clocal membrane. The postanal gut extended distal to the cloca into the tail portion. The wall of the

LEGENDS FOR FIGURES

Fig. 3. Section #182. The section of the heart revealing both ventricles. The interventricular septum (arrowheads) appears as a hump on the ventricular wall. Prominent interventricular sulcus (arrow) and flange are also seen. O: outflow tract, A: anterosuperior atrioventricular cushion, P: posteroinferior atrioventricular cushion. ×80

Fig. 4. Section #249. Posterior part of the heart. The septum primum (arrowhead) divides the common atrium into the left and right ones. Below the heart is the liver. P: pericardial cavity, R: right sinus horn, L: left sinus horn. ×80

Fig. **5.** Section #251. The pharyngeal cavity with the 3rd and 4th pharyngeal arches. Each pharyngeal arch is pierced by an aortic arch (III and IV). The pharyngeal cleft extends laterally so that its lining endoderm closely contacts the skin ectoderm to make a membrane-like structure (arrowhead). On the floor of the pharynx, the arytenoid swellings are seen (asterisks). ×160

Fig. 6. Section #212. The thyroid gland is a bilobed cell mass surrounded by a loose, reticular tissue. ×320

Fig. 7. Section #221. The hepatic diverticulum (H) and the duodenum (D). The superior portion of the diverticular wall looks like bursting out, and the cells of the wall are spreading outwards into the hepatic parenchyme ×160

Fig. 8. Section #106. The probable midgut portion is attached to the posterior body wall by a well-formed dorsal mesentery (M). A vitelline artery is projecting into the mesentery from the dorsal aorta (A). The arrowhead marks the presumptive site for the detached vitelline duct. ×100

Fig. 9. Section #152. The cloaca (C) connected with the allantois (A). The epithelia of the two lumina are different from each other. Lateral to the cloaca is the future ureteric bud (U) which is yet a localized dilatation of the mesonephric duct. Compare its diameter with that of the opposite side ×160

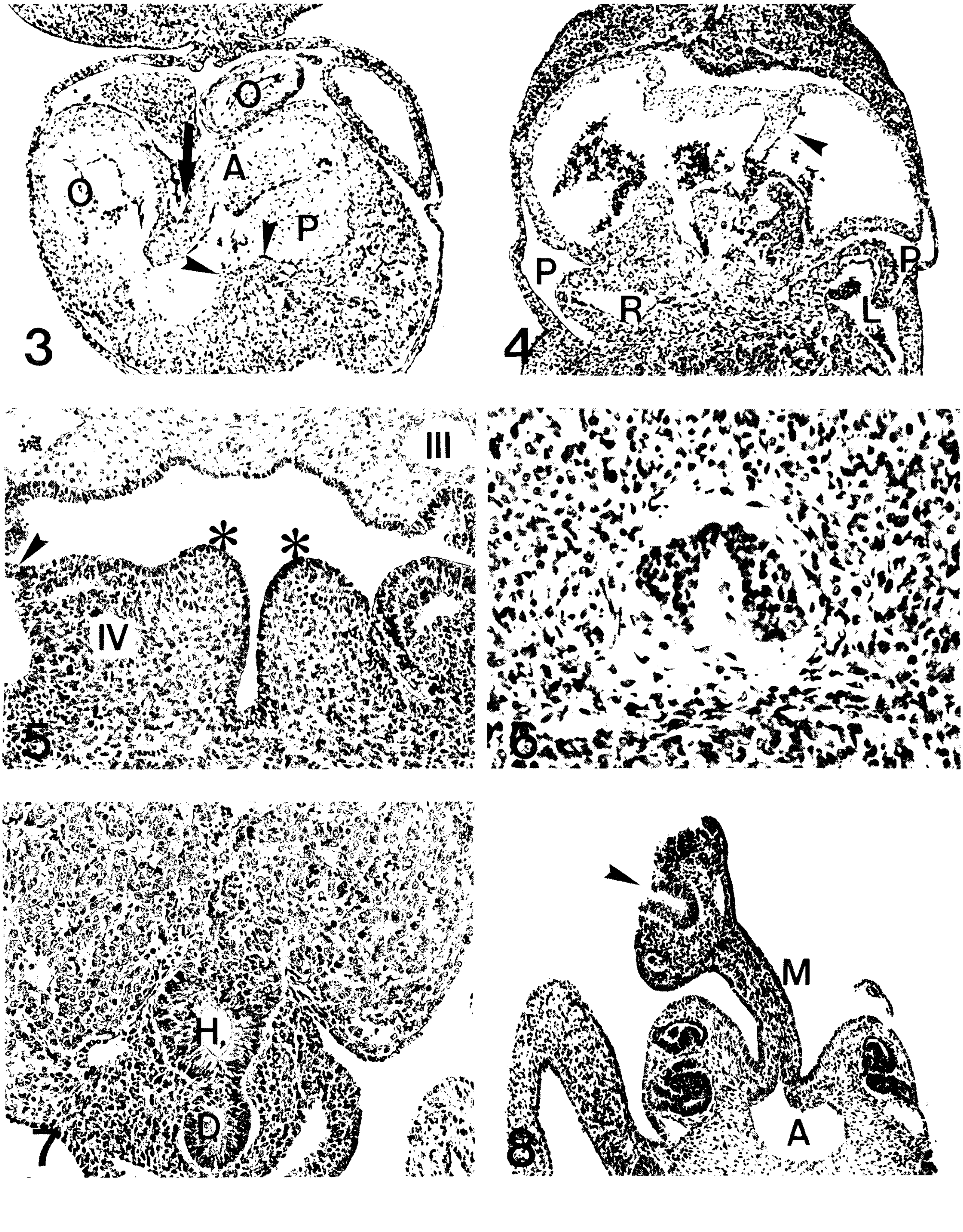
Fig. 10. Section #171. The cloca (C) receiving the mesonephric duct (M). The duct is tangentially sectioned, and the lumen is not seen in this figure. Arrowhead indicates the cloacal membrane. ×160

Fig. 11. Section #222. A representative section through the rhombencephalon. The dorsal wall of the neural tube (arrowhead), corresponding to the roof of the 4th ventricle, has extremely thinned out to become one cell layer thick. On both side of the tube, otocysts (O) are present. The dorsal aspect of the right otocyst shows somewhat tapering lumen, presaging the formation of the endolymphatic appendage. ×100

Fig. 12. Section # 68. The optic cup and the lens placode. The optic stalk (OS) is very wide-open. ×160

Fig. 13. Section #283. The trachea(T) and the bifurcated primary bronchi. P: pharyngeal cavity, S: stomach. ×80

Fig. 14. Section #241. The representative of the rostrally located mesonephros. It looks S-shaped with one end forming Bowman's capsule (arrow). Arrowhead: mesonephric duct, P: posterior cardinal vein. ×320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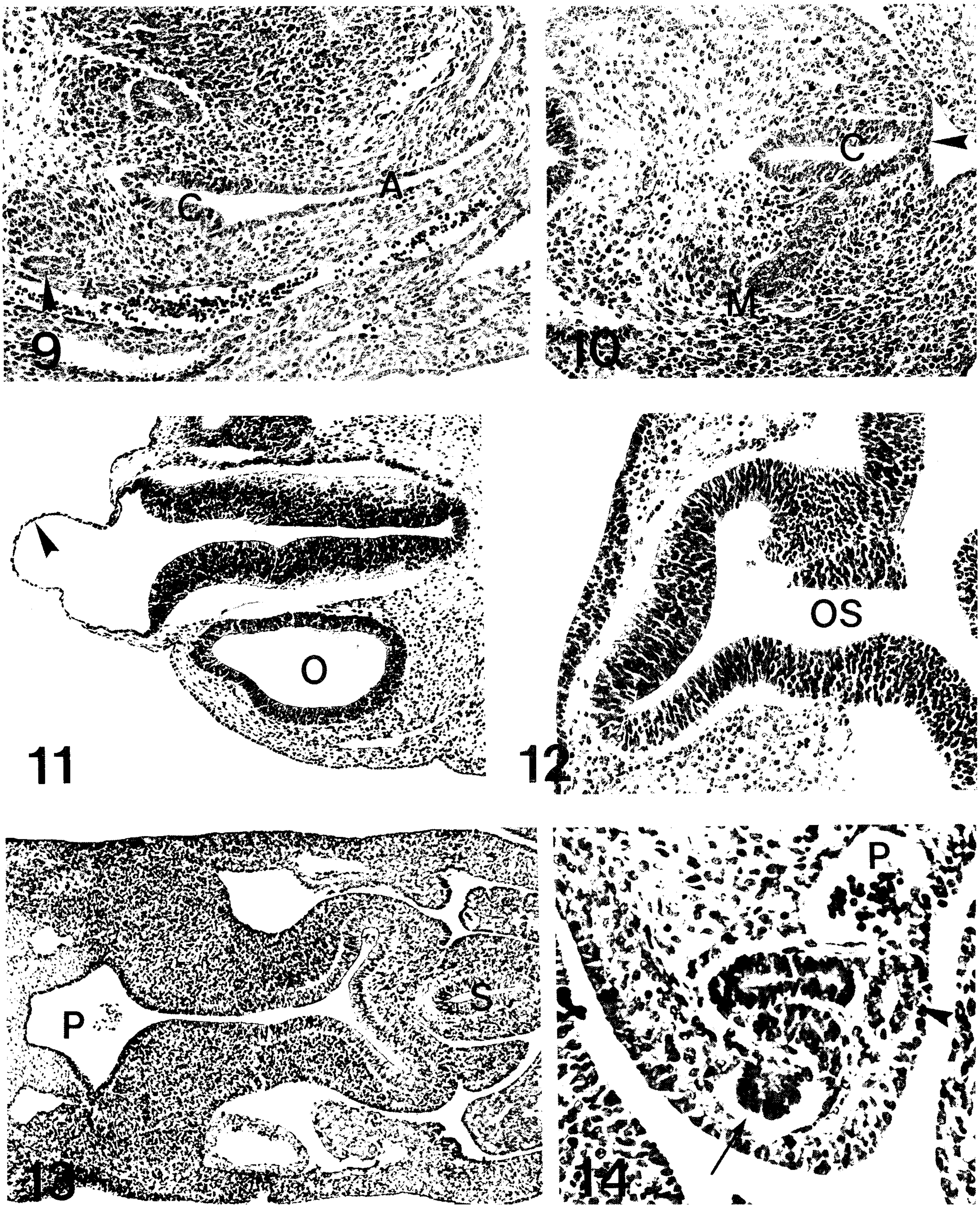
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allantois was single cell layer thick, differing from the general feature of the gastrointestinal wall.

The yolk sac and the vitelline duct were detached from the gut, leaving it with a defective wall (arrow in Fig. 8).

Nervous System

Two prominent flexures, the cerebral and cervical, could be estimated and the main subdivisions of the brain were also demarcated. The rhombencephalon had a characteristic roof of one cell layer, which made its identification easy (Fig. 11). The wall of the neural tube largely consisted of the ependymal and mantle layers. However, some areas, especially the ventral side of the distal rhombencephalon, began to show the cell-free marginal layer. The distal part of the rhombencephalon was also the area where the sulcus limitans was definitely observed. Vascular network was forming around the entire neural tube.

The optic vesicle had been indented to form an optic cup (Fig. 12). The inner layer of the cup was largely thickened with a distinct marginal layer. The cup was connected to the prosencephalon by a wide-open optic stalk. The skin ectoderm apposing the optic cup was thickened to form a lens placode. Its free surface was flat or slightly depressed and its basal surface apparently bulged inward, indicating that the indentation of the placode was impending.

Alongside the rhombencephalon, several cranial ganglia were observed. Frontal to the otocyst, two ganglia were identified, those of the trigeminal and the facial nerves. Large portions of the ganglia were still in contact with the neural tube. It seemed likely that many cells were migrating from the tube to contribute to the ganglia. Just posterior to the otocyst, another small minute ganglion was observed and that was thought to be the glossopharyngeal ganglion. Far posterior to it, the vagus ganglion was located.

There was no evidence of cerebral evagination.

Spinal ganglions were just forming. From the ventral half of the spinal cord, tiny nerve fibers emerged. They were highly eosinophilic and directed laterally towards the condensed cell masses just beneath the skin ectoderm-the myotome.

Respiratory Tract

Arytenoid swellings were already formed bilaterally in the laryngeal region but not the epithelial lamina. The trachea extended downward from about the middle of the esophagus and bifurcated into the left and right main bronchus (Fig. 13). The right bronchus was a little longer than the left. It was more vertical than the left as in adults. Neither mesenchymal condensations nor pulmonary vascular plexuses were recognized yet. The luminal diameter of the respiratory tract was similar to or somewhat larger than that of the esophagus.

Urinary System

A series of mesonephric units were rostrocaudally arranged in the urogenital ridge, with the most rostral one found in the section #291 and down to the caudal end of the body. The rostrally located mesonephric units were more differentiated than the caudal ones. They took an S-shaped appearance, with one end connected to the laterally located mesonephric duct and the other one forming a Bowman's capsule with a crescentic lumen (Fig. 14). The arched outer membrane of the capsule was a single layer of flattened cells, and its counterpart was a hump of cells located in the center of the crescent. Meanwhile, the caudal ones were dumbbell-shaped. One end attached to the mesonephric duct representing the impending connection with it, while the other end was vesicular. The most caudally located mesonephric units were still in a round vesicular form. The mesonephric duct continued caudally to meet the cloca. The ureter had not been distinctly established. However, a localized dilatation of the lumen of the mesonephric duct in the vicinity of the cloca was observed, and this was presumed to be the site of the future ureteric bud. Around the dilatation, mesenchymal cells condensated to form the metanephric blastema.The coelomic epithelium of the genital ridge did not yet show proliferating features. Typical germinal cells, that were somewhat larger than the somatic cells and with a nucleus showing one or two conspicuous nucleoli, were very hardly observed with difficulty either in the dorsal mesentery or in the germinal ridge.

Ear

The otocyst was completely separated from the skin ectoderm, and no remnant of the ectodermal stalk could be seen. The cyst assumed a round vesicular appearance. The huge vesicle was located just lateral to the rhombencephalon and posterior to the facial ganglion. It appeared on about 40 consecutive sections. The wall of the otocyst was 3-5 cell layer thick. The endolymphatic appendage began to be formed as a narrowed recess from the main vesicular cavity on its dorsal aspect (Fig. 11). Mesenchymal tissue surrounding the cyst showed no changes such as condensation to form the otic capsule, or the formation of vascular network.

Miscellenous

The arm bud possessed an apical ectodermal ridge and a marginal vein.

The nasal plate could be delineated as a thickened ectoderm.

DISCUSSION

A brief summary of the results (Table 1) definitely refer this embryo to be older than stage 12, and again, make it easy to mention that this embryo is younger than stage 15. However, more careful consideration is required to decide between stage 13 and 14.

The original paper of Streeter (1945) defines age group XIV as a "period of indentation of the lens vesicle". This means that "when the lens plate begins to invaginate, the specimen is generally alloted to stage 14" (O'Rahilly and Müller 1987). The paper also illustrates consecutive developmental features of the lens placode and vesicle during age groups 13 and 14. However, it's very disappointing that he did not precisely define "the beginning of indentation". Furthermore, unfortunately, the lens primordium in this embryo showed transitional developmental features between the oldest form of age group XIII (Fig. 8, xiii) and the youngest of XIV (Fig. 5, xiv). Therefore, this does not help us decide the stage.

With respect to the otocyst, any novel events that can discriminate between stages 13 and 14 have not been described. The closure of the otocyst, the disappearance of the epidermal stalk and even the appearance of the endolymphatic ducts are already achieved in stage 13, although not as fully as stage 14, and no additional events are known to occur during stage 14 (Streeter 1945; O'Rahilly 1963). Therefore, those aforementioned findings, all observable in this embryo, also do not seem to be helpful in determining the stage. However, we obtain a few clues from other findings. One of the characteristics of horizon XIII is a mesenchymal reaction around the otocyst (Streeter 1945), the angiogenesis and the mesodermal proliferation. Since this embryo lacked such mesenchymal changes, it favors putting this embryo into stage 13 rather than 14.

In the heart, the AV canal closely approximated to the bulboventricular flange, but did not expand over it. In stage 14, the AV canal has been reported to expand toward the right, thus, to override the interventricular septum (Goor *et al.* 1972; Magovern *et al.* 1986), or to be appositioned between the ventricles (O'Rahilly and Müller 1987), findings not clearly identified in this embryo. In contrast, the canal is said to be restricted to the left of the interventricular flange in stage 13 (McBride *et al.* 1981), as in our embryo. In other words, these all support the view that this embryo was a member of stage 13. Identifiable dorsal and ventral AV cushions, as was shown in this embryo, are another finding of stage 13 (O'Rahilly 1971), though some controversies are present (McBride *et al.* 1981). It seems likely that the developmental status of the heart comprehensively reflects that of stage 13 rather than 14. Despite these, there were also conflicting findings. This embryo showed the AV cushion materials discontinuous with those of the outflow tract at the bulboventricular flange, while continuous jelly is sometimes reported at stage 13 (McBride *et al.* 1981). Another example of contradiction was the histogenesis of the ventricular myocytes. Although this embryo did not show striation in cardiac myocytes, it revealed eosinophilic cytoplasm representing the deposition of myofibrills, which was, with the striations, mentioned as a characteristics of horizon XIV by Streeter (1945). Although the AV cushions are described to be widely separated by an enlarged canal in stage 14 (McBride *et al.* 1981), some investigators depict them as being closely apposed (Kramer 1942; Grant 1962). Therefore, the close apposition of the AV cushions in this embryo might be misunderstood as an indication for stage 14. However, even in this case, the cushions appose in the manner that they divide the AV outflow into right and left channels, a situation different from our embryo's, where the apposed cushions remained only as one slit-like opening.

The respiratory tract generally showed developmental status corresponding to stage 13. The plane of the primary bronchi was anterior to that of the esophagus, which means that the bronchi did not yet curve dorsally to reside lateral to the esophagus. This is one of the findings that favor this embryo being of stage 13 (O'Rahilly and Müller 1987). Furthermore, any obvious mesenchymal condensations or vascular plexuses, known to be present in stage 14 (O'Rahilly and Müller 1987), were hardly identified. Namely, the lung was still an epithelial tube without distinct mesenchymal investment. The interesting finding that the right main brochus was more vertical than the left as in adults has already been described (O'Rahilly and Müller 1987). That the right was a little longer than the left seemed to be in contrast with adults, at a glance. However, the right main bronchus tends to remain longer than the left during development (O'Rahilly and Müller 1987).

Several developmental aspects of the gastrointestinal tract supported the view that this embryo was in stage 13. The dorsal pancreas was observed, but not the ventral one. The dorsal pancreas begins to appear in stage 12 (Streeter 1942), and the ventral one may be distinguishable in stage 13 (O'Rahilly 1983; Kang and Park 1990). The dilatation of the cecum, which was not achieved by this embryo, becomes distinct in Horizon XIV (Streeter 1945). In stage 13, the hepatic parenchyme occupies almost all the septum transversum, and the mesenchyme of the septum transversum is reduced to a capsule surrounding the entire liver (Severn 1972). A liver capsule appeared in our embryo, too, but did not totally cover the entire liver. An advancing finding observed was the presence of the dorsal mesentery which had been first described in horizon XIV (Yokoh 1970). What is strange is that the constriction of the dorsal pancreas from the intestine, a feature expected in stage 13 (Streeter 1945), was not definitely recognized. However, the possibility of having passed it over can not be ruled out, because the plane of the section was tangential to the still tiny pancreas.

As discussed above, this embryo shows many findings compatible with those of stage 13. Although this embryo possesses a few characteristics of stage 14, it may be reasonable to regard them as localized developmental advancements in an individual of stage 13. Therefore, we think that this embryo is an older member of Carnegie stage 13.

The estimated postovulatory age for embryos in stage 13 is 28 $\pm$ 1 days (Streeter 1945) or approximately 28 days (O"Rahilly and Müller 1987). In our case, if we textbook-wisely assume that the ovulation occurred 2 weeks after the onset of menstruation, the ovulation day would be June, 17, 1992. Because the operation was done on July, 14, 1992, the calculation yields that the postovulatory age for this embryo is 27 days, which agrees well with that previously assigned.

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REFERENCES

Butler H. Juurlink BH. An atlas for staging for mammalian and chick embryos. CRC Press, Boca Raton, 1987

Chi JG, Ham DI. A human embryo of Streeter age group XIII. Seoul J Med 1985; 46: 269-75

Chi JG, Lee JD. A human embryo of Streeter age group XII. Seoul J Med 1980; 21: 307-12

Goor DA, Dicsche R, Lillehei CW. The conotruncus. I. Its normal inversion and conus absorption. Circulation 1972; 46: 375-89

Grant RP. The embryology of ventricular flow pathways in man. Circulation 1962; 25: 756-79

Kang YS, Park HW. Human embryos of Cargenie stage 13. Kor J Phy Anthropol 1990; 3: 145-55

Kramer TC. The partitioning of the truncus and conus and the formation of the membranous portion of the interventricular septum in the human heart. Am J Anat 1942; 71: 343-70

Magovern JH, Moore GL, Hutchins GM. Development of the atrioventricular valve region in the human embryo. Anat Rec 1986; 215: 167-81

McBride RE, Moore GW, Hutchins GM. Developmemnt of the outflow tract and closure of the interventricular septum in the normal human heart. Am J Anat 1981; 160: 309-31

Moore GW, Hutchins GM, O'Rahilly R. The estimated age of staged human embryos and early fetuses. Am J Obstet Gynecol 1981; 139: 500-6

O'Rahilly R. The early development of the otic vesicle in staged human embryos. J Embryol Exp Morph 1963; 11: 741-55

O'Rahilly R. The timing and sequence of events in human cardiogenesis. Acta Anat 1971; 79:70-5

O'Rahilly R. The timing and sequence of events in the development of the human endocrine system during the embryonic period proper. Anat Embryol 1983; 166: 439-51

O'Rahilly R, Müller F. Developmental stages in human embryos. Meriden, Conneticut, Meriden-Stinehour Press, 1987

Park KH. A human embryo of Streeter age group XIII. Seoul J Med 1988; 29: 77-81

Puerta Fonolá AJ, Orts Llorca. Origin and development of the septum primum. Acta Anat 1978; 100:250-7

Severn CB. A morphological study of the development of the human liver. II. Establishment of liver parenchyma, extrahepatic ducts and associated venous chambers. Am J Anat 1972; 133: 85-108

Sgalitzer KE. Contribution to the study of the morphogenesis of the thyroid gland. J Anat 1941; 75: 389-405

Streeter GL. Developmental horizons in human embryos. Description of age group XI, 13 to 20 somites, and age group XII, 21 to 29 somites. Contrib Embryol 1942; 30: 211-45

Streeter GL. Developmental horizons in human embryos. Description of age group XIII, embryos about 4 or 5 millimeters long, and age group XIV, period of indentation of the lens vesicles. Contrib Embryol 1945; 31: 27-63

Streeter GL: Developmental horizons in human embryos. Description of age group XV, XVI, XVII, XVIII, being the third issue of a survey of the Carnegie collection. Contrib Embryol 1948; 32: 133-203

Yokoh Y. Differentiation of the dorsal mesentery in man. Acta Anat 1970; 76: 56-67