Anatomical Notes on the Course of the Esophagus in Thoracic Cavity in Bovine Fetuses and Neonates Based on Observation of Resin-Casts of Thoracic Hollow Organs

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Abstract. The thoracic course of the esophagus of bovine fetuses and neonates was examined by resin-casts of the thoracic hollow organs with a comparison of the formalin-hardened organs, with special reference to the site of constriction, curvature and ampulla. Resin and formalin injections were made into the esophagus, and trachea and the axillary artery and vein. The esophagus in the thorax had three constrictions. The first was located at the site pressed by the dorso-caudal end of the developing thymus and by the anterior border of the left anterior pulmonary lobe. The second was located at the site where the aortic arch was attached on its left side, just before the bifurcation of the trachea. The third was located very closely to the hiatus esophageus of the diaphragm, surrounded by the left and right posterior and the accessory pulmonary lobes and the muscular diaphragmatic crura which were well-developed characteristically in this species. The esophagus in the thorax had three curvatures. The first was concave ventrally, located between the level of the seventh cervical vertebra and that of the second thoracic vertebra. The second curvature was convex dorsally, beginning at the site of the attachment of the aorta to bend slightly ventro-caudad. The third was horizontal, beginning shortly behind the bifurcation of the trachea in the median plane of the body axis to bend gently toward the left-biased hiatus esophageus. The esophagus had an ampulla in the way of passing the posterior mediastenum.

The esophagus is that part of alimentary tract which links the pharynx with the stomach, divisible into cervical, thoracic and abdominal parts. Although the esophagus has long been a subject of much research in mammals, most of the emphasis has been on its histologic structure with a little attention paid to its macroscopic course in the thoracic cavity, particularly in domestic animals. According to the immensely accumulated information of the human esophagus, it has several sites showing slight curvature,

constriction and ampulla which may occasionally constitute the cause of malignant tumor formation, abnormal food stagnation and pathologic constriction [5]. In this sense, a detailed survey of existence of such similar sites in domestic animals would be fundamental and very important for biomechanical studies as well as for clinical studies.

Descriptions of such curvature, constriction and ampulla in domestic animals can be encountered only very briefly in some

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textbooks [1,6, 8, 10,12]. The present study, therefore, was undertaken to clarify in more detail the sites of curvature, constriction and ampulla of the esophagus in bovine fetuses and neonates with observation of resin-casts of hollow organs in the thoracic cavity. The essential method of preparation of casts is an injection of synthetic resin into the esophagus as well as into the trachea and the axillary vessels, being very advantageous in understanding the mutual locational interrelations of these organs, for they are hardened as they were in their living state.

Materials and Methods

Ten bovine fetuses, 43 cm to 95 cm in Crown-Rump-Length (CRL), obtained from the Tama Meat Inspectors Station and two newborn calves shortly after birth obtained from an owner in the environs of our College were used in this study.

The first catheter was introduced into the esophagus and the 2nd one into the trachea. The 3rd and the 4th catheters were introduced into the axillary artery and vein respectively after the exposure of these vessels at their site. Through each catheter, synthetic resin was injected with an appropriate pressure according to the organ to be injected. Resin to be injected had been colored differently in order to make it easy to differentiate each organ-cast, red for the esophagus, yellow for the trachea and green for both arteries and veins.

Before the injection into the esophagus, a part of the duodenum was exposed from the abdominal cavity. When the injected resin seemingly filled the duodenum, the injection was stopped and the duodenum was ligated. At the same time, the esophagus was ligated at the level of the 3rd cervical vertebra.

As to the injection into the trachea, with a view of the surface of the lung through a small opening of the thoracic wall which had been made beforehand, the injection was stopped at the time when the injected resin was seemingly seeped out on the pulmonary surface. Immediately after the stoppage, the trachea was ligated at the level of the 3rd cervical vertebra as was the esophagus ligated.

As to the injection into axillary vessels, with a view of the femoral vessels which had been exposed and cut beforehand, the injection was stopped at the time when no trace of blood was seen in the

liquid flowing out of the cut openings of these femoral vessels. Immediately after the stoppage, the femoral artery and vein were ligated.

After polymerization and hardening of the injected resin were completed, the animal body was put into hydrochloric acid to remove soft tissues and then the aimed resin-casts were obtained.

In addition, each of some fetuses and newborn calves was given an injection of formalin-gelatin solution instead of resin in the same manner. This procedure was made for macroscopic observation of locational interrelation of formalin-hardened thoracic organs and for confirmative comparison with the resin-casts.

Results

In both fetuses and newborn calves, before the inlet of the thorax the esophagus was located on the left surface of the trachea, passing caudad on the ventral side of the left *M. longus colli*. After the inlet of the thorax, the esophagus was slightly shifted on the left dorsal surface of the trachea (Figs. 1, 2), running caudad along the left *M. longus colli* to the level of the 6th thoracic vertebra where that muscle terminated. In this course, the esophagus was accompanied by the left common carotid artery on its left side (Fig. 1) until the level of the 5th cervical vertebra, where the artery moved to the ventral side of the esophagus and left it soon. Near the inlet of the thorax at the level of the 7th cervical vertebra, the esophagus was closely in contact with the left vertebral artery and vein only for a short distance (Figs. 2, 4). Thus, in the cervical part below the level of the 3rd cervical vertebra which we examined, the esophagus had a constant caliber with neither a constriction nor an ampulla, being located on the left side of the body axis.

Before and after the inlet of the thorax, between the 7th cervical vertebra and the 2nd thoracic vertebra, the esophagus curved downward and then upward (Fig. 3). This concave curvature was also accompanied by a slight torsion in such a manner that

passing just into the inlet of the thorax, the esophagus curved upward from the left side of the back surface of the trachea to be placed between the trachea and the left *M. longus colli*.

At the level of the 4th thoracic vertebra, the esophagus had a constricted part, as the first constriction in this study (1 in Figs. 2 to 5). In the observed fetuses and newborn calves, the thymus was well developed at the level of the 1st to the 4th thoracic vertebrae. This constriction was observed at the site between the dorso-caudal part of the developing thymus and the anterior border of the left anterior pulmonary lobe, seemingly caused by the pressure of these two organs.

At the level of the 5th to the 6th thoracic vertebrae, the esophagus was shifted and compactly placed on the back of the trachea until the trachea was bifurcated at the level of the 6th thoracic vertebra, passing backward in the median plane of the body axis (Figs. 3, 4). At this site, the esophagus was in contact with the dorsally bending aortic arch on its left side (Figs. 3, 4), showing the second constriction perhaps with the pressure of the aorta (2 in Figs. 2, 4, 5). At the same time, the esophagus gradually ran downward, detaching from the vertebral column to be placed in the center of the mediastinum. As a result, the esophagus showed a slight curvature, convex dorsally and forwarding obliquely downward from this site (Figs. 3, 4). Thereafter, the esophagus passed backward in the mediastinum and again was biased to the left side of the body axis toward the hiatus esophageus which was located in the left part of the diaphragm, showing as a result a slight horizontal curvature in the posterior mediastinum (Figs. 1, 5).

At the level of the 10th to the 11th thoracic vertebrae, the esophagus was in

contact with *Lymphonodi mediastinales caudales* on its dorsal side. At the level of the 11th thoracic vertebra from the dorsal view and at the level between the 9th and the 10th ribs from the lateral view, the esophagus was surrounded by both left and right lobes of the lung and muscles of the diaphragm, showing the third constriction (3 in Fig. 5). Between the second and the third constrictions, the esophagus in many samples was relatively thick and swollen, seeming to show a part of ampulla (am in Figs. 4, 5).

In the observed fetal and newborn calves, since the diaphragm was compactly attached to the cardia of the rumen of the stomach, the abdominal part of the esophagus failed to be observed.

Discussion

Constriction: The constricted parts of the esophagus have so far been observed often in the human subjects by roentgenography [4, 5, 11], by plaster-casting [2] and by many macroscopic dissecting examinations [3, 9]. There are three constrictions, at the upper cervical part, at the level of bifurcation of the trachea, and near the hiatus esophageus of the diaphragm.

In contrast to vast information available in the human subjects, the course of the esophagus in the thoracic cavity in the cattle seems to have been escaped from exact observation. The present study, however, made it clear for the first time that the esophagus of the cattle has three constricted parts even in its thoracic course.

The first constriction in the thoracic course was located at the level of the 4th thoracic vertebra where the esophagus was pushed by the anterior border of the left anterior pulmonary lobe and by the developing large thymus, with a question of whether it can be found also in the adult

cattle in which the thymus is shrunken.

The second constriction was found at the level of the 6th thoracic vertebra where the trachea began to be bifurcated and where the dorsally bending aortic arch was attached on the left side of the esophagus. At this site, the esophagus was tightly attached to the underlying trachea, a phenomenon which leads us to assume that the esophagus is inflated dorsally when the food materials pass through this part. Since the esophagus may be given a pressure from the aorta by the pumping of the heart, the pass of food materials seem to be restricted more or less at every pumping moment.

In the human subjects, Pratzie [11] removed the esophagus to test whether this constriction could disappear when the esophagus was freed from the surrounding organs such as the aorta and the trachea. When freed in such a way and filled with a liquid, it still showed a constriction at the site where the aorta had been attached. From this, he considered that this constriction observable *in situ* was caused by a stunt in growth of the esophageal wall at this place by the pressures of the aorta and trachea already existing from the intra-uterine life. Katsuyama [5] argued that this constriction might not be strictly due to the pressure of the aorta, showing a line of evidence that the constriction appeared without the formation of the aorta at that place. To be noted in particular is an opinion presented by Mehnert [7] in that the constrictions of the esophagus may be remnants of the segmental nature of the foregut, a nature resembling that of the branchial clefts and the branchial arteries. Mehnert [7] further pointed out that during the early embryonic development of the human esophagus, there appeared 12 constrictions which corresponded to the number of the vertebral discs. In this sense, it

would be needed to follow the esophageal development in younger stages of cattle embryos to confirm the existence of such a segmental nature as well.

The third constriction was located very closely to the hiatus esophagus where the esophagus was given pressures by the left and right posterior pulmonary lobes, by the accessory pulmonary lobe and by the muscular crura of the diaphragm. In the human subjects, a similar constriction located near the hiatus is said to be due to a pressure by diaphragmatic muscles which act like an esophageal sphincter [13]. In the cattle, Ellenberger and Baum [1] described that the part of the diaphragm around the hiatus esophagus consisted of an especially well-developed and thick muscular architecture as compared with that in any other mammal. Nickel et al. [8] considered this condition to be very important in the rumination mechanism in the ruminants.

Curvature: According to Nickel et al. [8] the esophagus of the cattle has three curvatures. One is convex dorsally, located between the pharynx and the proximal part of the esophagus. The next is concave ventrally and is situated before the inlet of the thorax, extending to the level of the first 2 or 3 thoracic vertebrae. These two curvatures are flexible and easily vary in location according to the up-and-down movement of the head. The remaining one is convex dorsally and is located approximately in the center of the thorax, passing above the base of the heart and on the bifurcation part of the trachea. In the present study in which we observed the esophagus in the lower portion than that part ligated at the level of the 3rd cervical vertebra, the concave curvature just before and after the inlet of the thorax and the convex curvature beginning from the site on the base of the heart were confirmed to be located at the same

places as they pointed out. The present authors, however, found another curvature located in such a manner that the esophagus gently curved horizontally just after the bifurcation of the trachea toward the left-biased hiatus esophageus of the diaphragm.

Incidentally, the hiatus esophageus was seen to be located approximately at the level of the 11th thoracic vertebra, an observation being not in harmony with that of Sisson and Grossman [12] who mentioned its location at the level of the 8th thoracic vertebra. From the lateral view in the present study the hiatus was located between the 9th and the 10th ribs, also not in accord with the finding of Nickel et al. [8] who stated its location between the 8th and the 9th ribs. These conflictions in location are presumably due to the difference in the size of the parts of the stomach between the adult and the young, in the latter of which the rumen is not well developed and far smaller than the abomasum. As the animals grow with an extreme enlargement of the rumen, the diaphragm may be pushed forward, resulting in the forwarding shift of the hiatus esophageus.

Ampulla: In the thoracic course of the esophagus, there was observed an ampulla between the constriction at the place attached to the bending aortic arch and the constriction near the hiatus esophageus of the diaphragm. Nickel et al. [8] also noted such an ampulla in the adult cattle, considering it concerned with the rumination of the animal. According to our observation of the esophagus of fetuses, the finding of the ampulla seems to constitute a line of evidence that it is formed at so early a stage before the commencement of food intake.

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要 約

鋳型標本による牛胎仔および新生仔の食道の胸腔内における走行について：深谷幸作・猪股智夫・浅利昌男・江口保暢・鹿野 胖（麻布獣医科大学獣医学部家畜解剖学教室）——牛胎仔および新生仔の食道，気管，血管に合成樹脂を注入して鋳型標本をつくり，別にホルマリンで固めた標本と比較しながら，食道の胸腔内における走行を，とくにその狭窄，彎曲および膨大との関連について立体的にしらべた。食道は胸腔内を経過する間に，三ヶ所に狭窄と彎曲が，また一ヶ所に膨大がみとめられた。狭窄は胸腺と左肺前葉前端とに挟まれた部位，大動脈に接する部位，および横隔膜食道裂孔直前の部位にみられた。彎曲は胸郭前口から第2胸椎付近にかけ腹方への曲りと，大動脈弓との接触部から始まる腹後方への曲り，および後縦隔膜を通過し，食道裂孔に向かう間に生ずる緩い側彎である。膨大は後縦隔膜に含まれる部分に一ヶ所認められた。

Explanation of Figures

Abbreviations: Ab, abomasum; Ao, aorta; A.v., vertebral artery; am, ampulla; Ca, common carotid aretery; Es, esophagus; He, heart; Li, liver; L-lu, left lung; M, midplane of body axis; Om, omasum; Re, reticulum; R-lu, right lung; Ru, rumen; Sp, spleen; Tr, trachea; 1, the first constriction; 2, the 2nd constriction; 3, the 3rd constriction; 1, the first curvature; 2, the 2nd curvature; 3, the 3rd curvature.

Fig. 1. Dorsal view of resin-casts of thoracic organs with some abdominal organs. The spleen and the liver are both capable of being casted be-

cause of the presence of small blood vascular networks in these organs. $\times 1/5$.

Fig. 2. Enlarged picture in the rectangle shown in Fig. 1. $\times 2/5$.

Fig. 3. Left lateral view of resin-casts of thoracic organs after removal of the left lung. $\times 1/4$.

Fig. 4. Enlarged picture in the rectangle shown in Fig. 3. $\times 1/2$.

Fig. 5. Showing the running manner of the esophagus to the cardia of the rumen of the stomach after removal of all other thoracic organs as well as of the liver and spleen. With a dorsal view. $\times 1/5$.