MRI Examination of Trachea and Bronchi in the Ganges River Dolphin (*Platanista gangetica*)

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ABSTRACT. The MRI examination was carried out in a formalin-fixed specimen of the Ganges River dolphin (*Platanista gangetica*), one of the evolutionary primitive species of cetaceans. We could morphologically elucidate the tracheobronchial ramification in the intact whole body. We demonstrated from the MRI sections that the characteristic tracheal bronchus branches from the trachea at the cranial portion. These findings suggest the phylogenetic relationships between cetaceans and artiodactyls. The left bronchus is obviously larger in diameter than the right one. We suggest that the right bronchus has smaller capacity of gas exchange than the left one, because the dolphin possesses the tracheal bronchus in the right lung. The MRI method will be important in the non-invasive study of the anatomy in endangered animal carcass as Ganges River dolphin.—**KEY WORDS:** Ganges River dolphin, MRI, phylogeny, tracheobronchial tree.

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The morphological pattern of tracheobronchial tree is noticeable in whales and dolphins, since the occurrence of tracheal bronchus suggests the phylogenetical relationships between cetaceans and artiodactyls. Indeed, the tracheal branching pattern has been anatomically examined in the some species of cetaceans [2, 7, 9–12, 15]. It has been suggested that the five living species of Platanistoidea (*Lipotes vexillifer*, *Platanista gangetica*, *Platanista minor*, *Inia geoffrensis*, *Pontoporia blainvillei*) have some original morphological characters and may belong to the primitive groups of whales [6, 16]. So, while the detailed morphological data of tracheobronchial tree has been expected in the primitive dolphins, although Kida [7] reported the occurrence of tracheal bronchus in the Ganges River dolphin (*Platanista gangetica*). Since obtaining the carcasses of these endangered species is difficult, we applied the MRI (Magnetic Resonance Imaging) techniques to the formalin-fixed specimen of *Platanista gangetica* to observe the trachea and the bronchi in its intact whole body.

MATERIALS AND METHODS

We used the formalin-fixed specimen of the male Gages River dolphin (*Platanista gangetica*), that was collected in East Pakistan (Bangladesh) and brought to Japan in 1970 under the cooperative research program of The University of Tokyo, and has been fixed and stored in The University Museum, The University of Tokyo. The biological data shows that it had 126 cm in body length and 24 kg in body weight.

The thoracic area was serially sectioned with the MRI (Magnetic resonance imaging) system (VISART, Toshiba Medical Co., Ltd., Tokyo, Japan) at 32 mm in interval. We

obtained the series of dorsal plane images. From the serial sections, we described the trachea, bronchi, lung, and aorta together with neighboring structures.

RESULTS

A series of dorsal sections are shown in the thoracic region (Fig. 1). The figures of dorsal aspect are arranged from the distal end of the scapula to the level of dorsal aorta.

The trachea of about 25 mm in diameter runs cranio-caudally (Fig. 1A, B). It gives the first branch, tracheal bronchus (*Bronchus eparterialis*), to right-dorsal direction. The branching point is located cranially at 50 mm to the apex of lung (Fig. 1C, D), and situated far from the area of the first rib. The tracheal bronchus is less than 15 mm in diameter and completely separated from the trachea (Fig. 1E, F). At the portion of the most cranial region of the lung, the trachea branches into left and right main bronchus, respectively. The branching point is situated caudally at about 70 mm from the origin of the tracheal bronchus. The branching rapidly finishes, and the left bronchus is larger in diameter than the right one (Fig. 1F, G, H). The three branches can be observed in the portion of the first rib (Fig. 1H).

The pleural cavity is enlarged caudally from the branching point of the tracheal bronchus. In the ventral region, the cavity is compressed cranio-caudally between the forelimb level and the diaphragm (Fig. 1A, B, C, D).

The bronchus enters into intrapulmonary regions. At first, the left bronchus gives some secondary branches to dorso-lateral direction (Fig. 1I, J, K, M). The main bronchus caudally runs to the base of the lung, and gradually

diminishes in diameter (Fig. 1N, O, P). At a deeper dorsal level, many secondary branches originate also from the right bronchus in the intrapulmonary regions (Fig. 1L, M). The right main trunk also extends toward the direction of the base of the lung. It does not so dorsally run as left main bronchus.

The tracheal bronchus sharply curves to the dorso-lateral direction. It enters to the cranio-lateral area of the right lung and bend to the lateral direction (Fig. 1K, L). It runs ventrally and immediately diminishes in diameter (Fig. 1M).

At a deeper dorsal level of the trachea and the main bronchi, the aorta runs cranio-caudally in the left side of the sagittal line (Fig. 1N, O, P). The brachiocephalic trunk can be recognized in the cranial portion (Fig. 1H, I, J), and the common carotid arteries are discernible in both sides of the neck region (Fig. 1F).

DISCUSSION

The fresh-water dolphins has been considered primitive in the cetacean evolution [6, 16]. Since the tracheal bronchus can be confirmed in both cetaceans and artiodactyls [4, 7, 9–12, 15], it suggests the phylogenetical relationships between them. The river dolphins actually have the tracheal bronchus developed in the right lung [2,

7]. Kida [7] undertook the macroscopic anatomy in the Ganges River dolphin, and described the tracheobronchial ramifications. In the branching pattern of tracheal bronchus, the data of Ganges River dolphin is consistent with those of the MRI examination. Although the lung lobes cannot be distinguished in the MRI images, the tracheal bronchus may supply branches to the region corresponding the right cranial lobe.

The present MRI data indicate not only the tracheobronchial ramification, but also the location and the size of trachea, bronchi and tracheal bronchus in the intact body. The large left bronchus and the smaller right one suggest the difference of gas exchange capacity related to each bronchus. In the right lung, we suggest that the function of the tracheal bronchus may partially replace that of the right main bronchus.

The MRI data suggests that the lung and rib structure moved relatively to caudal area, whereas bronchi and tracheal bronchus to cranial part, in the body plan of cetacea in comparison with that of artiodactyls. The branching point of the tracheal bronchus is situated cranially to the lung and the ribs. We suggest that the reconstruction in respiratory system may be related to the exchange of body external shape in the origin of whales from land mammals.

The Ganges River dolphin is seriously endangered in

some rivers of south Asian countries [8, 13, 14]. Because this species is hard to obtain and store for the future, the MRI methods will contribute to the non-invasive study of the anatomy of rare carcass as well as CT examinations in other marine mammals [1, 3, 5].

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REFERENCES

1. Aroyan, J. L., Cranford, T. W., Kent, J. and Norris, K. S. 1992. Computer modeling of acoustic beam formation in *Delphinus delphis*. *J. Acoust. Soc. Amer.* 92: 2539–2545.
2. Burmeister, H. 1867. Preliminary observations on the anatomy of *Pontoporia blainvillii*. *Proc. Zool. Soc. Lond.* 1867: 484–489.
3. Cranford, T. W., Amundin, M. and Norris, K. S. 1996. Functional morphology and homology in the odontocete nasal complex: Implications for sound generation. *J. Morphol.* 228: 223–285.
4. Dyce, K. M., Sack, W. O. and Wensing, C. J. G. 1987. Textbook of Veterinary Anatomy, W. B. Saunders, Philadelphia.
5. Endo, H., Sasaki, H., Hayashi, Y., Petrov, E. A., Amano, M., Suzuki, N. and Miyazaki, N. 1999. CT Examination of the head of Baikal seal (*Phoca sibirica*). *J. Anat.* (in press).
6. Kamiya, T. and Pirlot, P. 1974. Brain organization in *Platanista gangetica*. *Sci. Rep. Whales Res. Inst.* 26: 245–253.
7. Kida, M. 1990. Morphology of the tracheobronchial tree of the Ganges River dolphin (*Platanista gangetica*). *Okajimas Folia Anat. Jpn.* 67: 289–296.
8. Mohan, R. S. R., Dey, S. C., Bairagi, S. P. and Roy, S. 1997. On a survey of the Ganges River dolphin *Platanista gangetica* of Bramaputra River, Assam. *J. Bombay Nat. Hist. Soc.* 94: 483–495.
9. Nakakuki, S. 1980. Comparative anatomical studies on the mammalian lung. *Bull. Facult. Agri., Tokyo Univ. Agri. Technol.* 21: 1–74.
10. Nakakuki, S. 1994. The bronchial tree and lobular division of the lung in the striped dolphin (*Stenella coeruleoalba*). *J. Vet. Med. Sci.* 56: 1209–1211.
11. Ping, C. 1926. On some parts of the visceral anatomy of the porpoise, *Neomeris phocaenoides*. *Anat. Rec.* 33: 13–28.
12. Qian, W. 1986. Study on the anatomy and histology of trachea and lung of *Neophocaena asiaeorientalis*. *Acta. Theriol. Sinica* 6: 183–189.
13. Smith, B. D. 1993. 1990 status and conservation of the Ganges

River dolphin *Platanista gangetica* in the Karnali River, Nepal. *Biol. Conserv.* 66: 156–169.

14. Smith, B. D., Haque, A. K. M. A., Hossain M. S. and Khan, A. 1998. River dolphins in Bangladesh: Conservation and the effects of water development. *Environ. Manage.* 22: 323–335.
15. Yamasaki, Y., Takahashi, K. and Kamiya, T. 1977. Lungs of

Franciscana (*Pontoporia blainvillei*), with special references to their external aspects, weights and bronchial ramifications. *Okajimas Folia Anat. Jpn.* 53: 337–358.

16. Zhou, K. 1982. Classification and phylogeny of the superfamily Platanistoidea, with notes on evidence of the monophyly of the cetacea. *Sci. Rep. Whales Res. Inst.* 34: 93–108.

Fig. 1. A-P, Dorsal MRI sections are serially shown in the thoracic region. The figures of dorsal aspect are arranged from the ventral to dorsal level. Cranial direction at the top. A, The trachea (large arrow) of about 25 mm in diameter runs cranio-caudally. The distal end of the scapula (S) is observed in forelimb. F, the first rib; L, lung; H, heart; Arrowhead, diaphragm. Bar=50 mm. B-D, The trachea (arrow) gives the first branch, tracheal bronchus (arrowhead), to right-dorsal direction. The branching point is located cranially of 40 mm from the apex of the lung. F, the first rib. E, The tracheal bronchus (arrowhead) is less than 15 mm in diameter and completely separated from the trachea. At the level of the most cranial region of the lung, the trachea branches into left (large arrow) and right main bronchus (small arrow). F, the first rib. F, The common carotid artery (C) is observed in both sides. F, the first rib. G-H, The branching of tracheal bronchus rapidly finishes, and the left bronchus (large arrow) is larger in diameter than right one (small arrow). The three branches (tracheal bronchus and both bronchi) can be observed in the portion of the first rib. Arrowhead, tracheal bronchus. The brachiocephalic trunk (B) can be seen in the cranial portion of the bronchi. F, the first rib. I, The left bronchus enters into the intrapulmonary region and gives some secondary branches into dorso-lateral direction (large arrow). The scapula (S) becomes thin and enlarged in dorsal level of pleural cavity. F, the first rib; 4, the fourth rib; E, esophagus; small arrow, intercostal muscles. J-K, The left main bronchus (large arrow) dorso-caudally runs to the base of lung, and has some branches distributed into left lung. Small arrow, right bronchus; Arrowheads, tracheal bronchus. F, the first rib; 4, the fourth rib. L, One of the secondary branches originates from the right bronchus in the intrapulmonary regions (small arrow). The tracheal bronchus is sharply curved into lateral direction and enters to the lateral area of right lung (arrowhead). Large arrow, left bronchus; F, the first rib; 4, the fourth rib. M, The branching of the right bronchus can be seen in a single section (small arrow). Large arrow, left bronchus; F, the first rib; 4, the fourth rib. N-P, The bronchial tree can be serially confirmed. The aorta (A) runs cranio-caudally in the left side of sagittal line. F, the first rib; 4, the fourth rib.