FULL PAPER *Anatomy*

Anatomical Variations in Bovine Thoracic Ducts

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ABSTRACT. Gross anatomical observations of bovine thoracic duct pathways and the lymph-venous junctions revealed that 37% of these ducts connected to the left venous angle at one location, whereas the other terminal connected to other areas, such as the left internal jugular vein, the left subclavian vein and the right venous angle, at more than one location. The thoracic duct pathways were classified according to Adachi's classification as types III, VI and IX. The frequencies of types VI, IX and III were 76%, 15%, and 9%, respectively and 48% of cattle had more than one ring formation in the thoracic duct pathway. These findings demonstrate many anatomical variations in bovine thoracic duct pathways and lymph-venous junctions.
KEY WORDS: anatomical variation, cattle, thoracic duct.

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The thoracic duct is a large vessel that collects lymph from the hindlimb, pelvic and abdominal cavities, left forelimb and the left side of the thorax, neck and head and carries it to the veins. Valves that are located in the thoracic duct and the lymph-venous junction help to prevent blood reflux [8, 14]. Thoracic duct pathways in the thoracic cavity and lymph-venous junction of various animals have many anatomical variations [2, 3, 6, 10, 13, 17, 20, 22, 24]. During early fetal development, the thoracic duct comprises both right and left side ducts. In human, the upper one-third and lower two-thirds of the right and left ducts respectively regress, and then the remaining lower two-thirds of the right duct and the upper one-third of the left duct become connected [11, 23]. According to Adachi's classification, type VI is the major pathway of the human thoracic duct, which generates the combination of the upper one-third and lower two-thirds of the left and right ducts, respectively [1, 11]. Many human thoracic ducts connect to the left venous angle, although some thoracic ducts also connect to other veins, such as the internal jugular and the subclavian veins [10, 20, 24]. The lymph-venous junction is highly complex. Several investigators have examined the thoracic duct pathways and lymph-venous junctions of dogs and cats to treat chylothorax [15, 18]. However, such anatomical variations among cattle have not been yet studied although cattle comprise an important animal species for veterinary science, including clinics for especially large animals. The present study examines variations in cattle thoracic duct pathways and lymph-venous junctions via gross anatomical observations.

MATERIALS AND METHODS

We studied 65 Japanese black (male, 39; female, 22; unknown, 4), 2 male crossbreed and 3 Holstein (male, 2; female, 1) cattle (total, 70) aged from newborn to 322 days. All animal procedures were approved by the Institutional Animal Care and Use Committee of the University of Miyazaki, Miyazaki, Japan. The animals were intravenously injected with xylazine (0.2 mg/kg) and pentobarbital (15 mg/kg) and then killed by electric shock. After exsanguination, the cranial vena cava was ligated to prevent latex spilling into the heart. Different colors of latex (Showa Denko Chloroprene type 842A, Showa Denko Co., Ltd., Tokyo, Japan) were injected into the external jugular vein and then the thoracic duct (37 of 70 cattle) or cisterna chyli (33 of 70 cattle). The latex was allowed to harden over a period of about 24 hr at room temperature and then dissection was performed to identify the left subclavian, cephalic, internal jugular, external jugular and superficial cervical veins, the left superficial cervical artery and the thoracic duct. The localization and relationship of these vessels and the thoracic ducts were observed using a gross anatomical procedure.

RESULTS

Anatomical variations in the junction of the thoracic duct and veins: The thoracic ducts connected to a vein at one location in 33 (47%) cattle (Fig. 1a), branched into two ducts at the terminal region in 33 (47%) (Fig. 1b), or connected to a vein at three locations in 4 (6%). The major site where the thoracic duct connected to the vein at one location was the left venous angle (n=26, 37%; Fig. 2). Connection to the left venous angle at 2 locations was dominant (n=17, 24%). Thoracic ducts connected to the left venous angle and the left internal jugular vein in 13 (19%) cattle and to the left internal jugular vein in 5 (7%). The thoracic duct also connected to the left cephalic vein, the left subclavian vein, and/or the right venous angle.

Thoracic duct pathways in the thorax: Colored latex was injected into the cisterna chyli of 33 cattle and then anatom-

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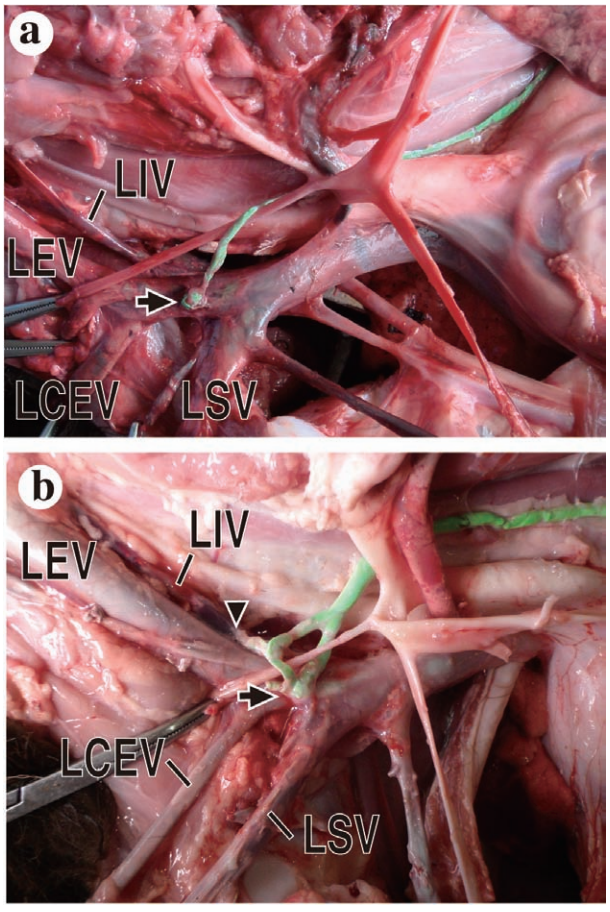


Fig. 1. Typical anatomical variations in lymph-venous junction visualized using green latex. Thoracic duct connected to the left venous angle at one location (a, arrow). Thoracic duct connected to the left venous angle (b, arrow) and left internal jugular vein (b, arrowhead). LCEV, left cephalic vein; LEV, left external jugular vein; LIV, left internal jugular vein; LSV, left subclavian vein.

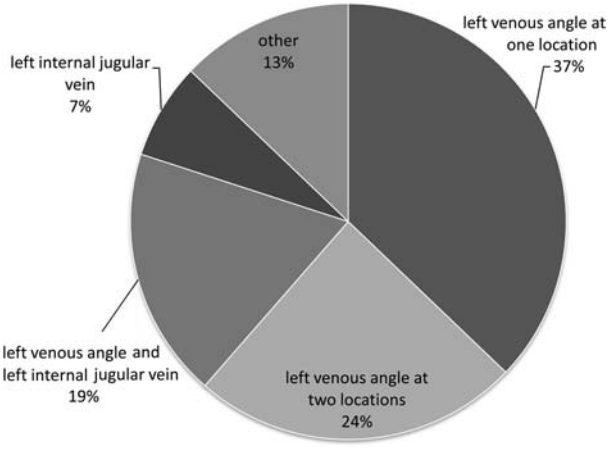


Fig. 2. Frequency of localization of thoracic duct connections to veins.

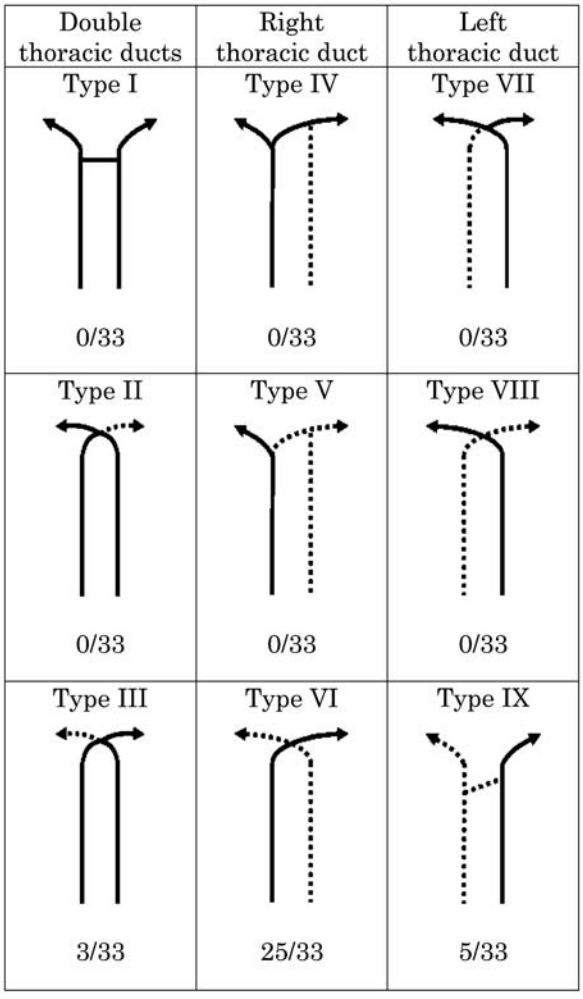


Fig. 3. Detection of bovine thoracic duct pathways according to Adachi's classification [1, 11].

ical variations in thoracic duct pathways were evaluated (Fig. 3 and Table 1).

The thoracic ducts in 25 of 33 (76%) cattle originated from the cisterna chyli and passed through the dorsal and right side of the thoracic aorta to the fifth or 6th thoracic vertebra. At the location, the duct crossed to the left side through the dorsal region of the trachea, passed the lateral side of the left costocervical vein transversely, and connected to the left vein at the terminal region. This thoracic duct pathway was type VI according to Adachi's classification [1, 11]. The thoracic ducts in 5 of 33 (15%) cattle passed along the dorsal and left side of the thoracic aorta after leaving the cisterna chyli and directly entered the vein on the left side; this was classified as type IX. The thoracic ducts in 3 of 33 (9%) cattle had two main ducts that merged and entered the left side of the terminal region; this was classified as type III.

The ring formation of thoracic duct: More than one ring was formed in the thoracic duct pathways of 16 of 33 (48%)

Table 1. Ring formation and Adachi's classification [1,11]

Sample ID No.	Adachi's classification (Type)	Ring formation*
37	IX	None
38	III	a
39	VI	None
40	VI	d
41	VI	a, d
42	VI	None
43	VI	None
44	VI	None
45	VI	b
46	VI	None
47	IX	b, c–d
48	IX	None
49	III	a, b
50	III	b
51	VI	None
52	VI	None
53	VI	d
54	VI	None
55	VI	None
56	IX	d
57	VI	b
58	VI	a
59	VI	None
60	VI	None
61	VI	None
62	VI	None
63	VI	a
65	VI	a
66	VI	None
67	VI	b–d
68	VI	b
69	VI	None
70	IX	c–d

* a-d: Classification shown in Fig. 4.

cattle. The region where the thoracic duct formed a ring was separated into four sections based on the thoracic duct pathway (Fig. 4). The high frequency regions of ring formations were sections a, b and d (Table 1). For example, the thoracic duct forms two rings through which the left azygos vein and the left costocervical artery passes (Fig. 5a), or one ring through which the right dorsal intercostal artery passes (Fig. 5b). The thoracic duct formed a ring through which the left superficial cervical artery passed at the terminal region in 36 of 70 (51%) cattle (Fig. 5c).

DISCUSSION

Anatomical variations in thoracic duct pathways and thoracic duct-vein junctions have been studied in humans, monkeys, cats, dogs, rats and pigs [3–7, 9, 10, 12, 15, 16, 20, 21, 24]. The present study found that the thoracic duct had 2 terminal regions in 53% of cattle, findings that were similar to those in cats (~35%) and green monkeys (11%) [12, 15]. Several investigators have examined terminal branching of the human thoracic duct, but the incident of variations was different depending on the researchers [10, 20, 24]. The incidence of anatomical variations in thoracic duct-vein junctions seems higher among cattle than among cats and green monkeys. The major locations of junctions where the thoracic duct connected in cattle comprised the left venous angle and/or the left internal jugular vein at more than one location. Minor junctional regions comprised the left cephalic vein, the left subclavian vein, and/or the right venous angle. The major regions where the thoracic duct connects in humans, green monkeys and cats comprise the venous angle and the left internal jugular vein [9, 10, 12, 15, 20]. Therefore, the major region where the thoracic ducts connected is similar in cattle and in humans, green monkeys and cats.

Adachi classified the thoracic duct pathway from the cisterna chyli to the junctional region into nine types [1, 11], of which type VI is found in 88% of humans. On the other

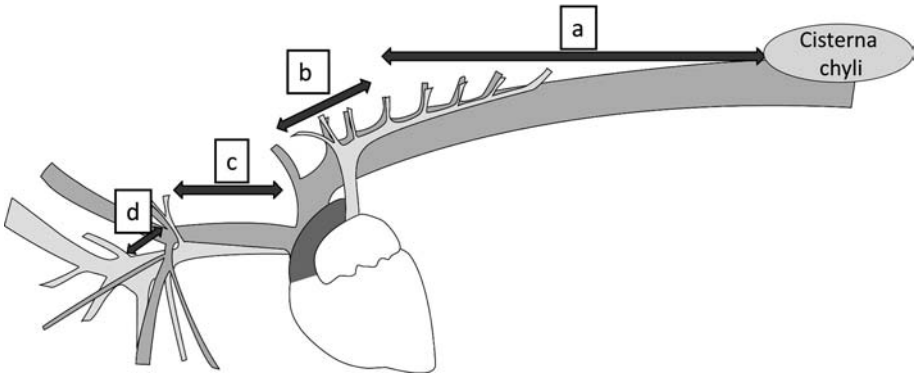


Fig. 4. Divisions of thoracic duct pathways. Thoracic duct pathways were classified as (a) between cisterna chyli and dorsal intercostal artery IV, (b) between dorsal intercostal artery IV and dorsal intercostal artery I, (c) between dorsal intercostal artery I and left costocervical vein, (d) between left costocervical vein and thoracic duct terminal region.

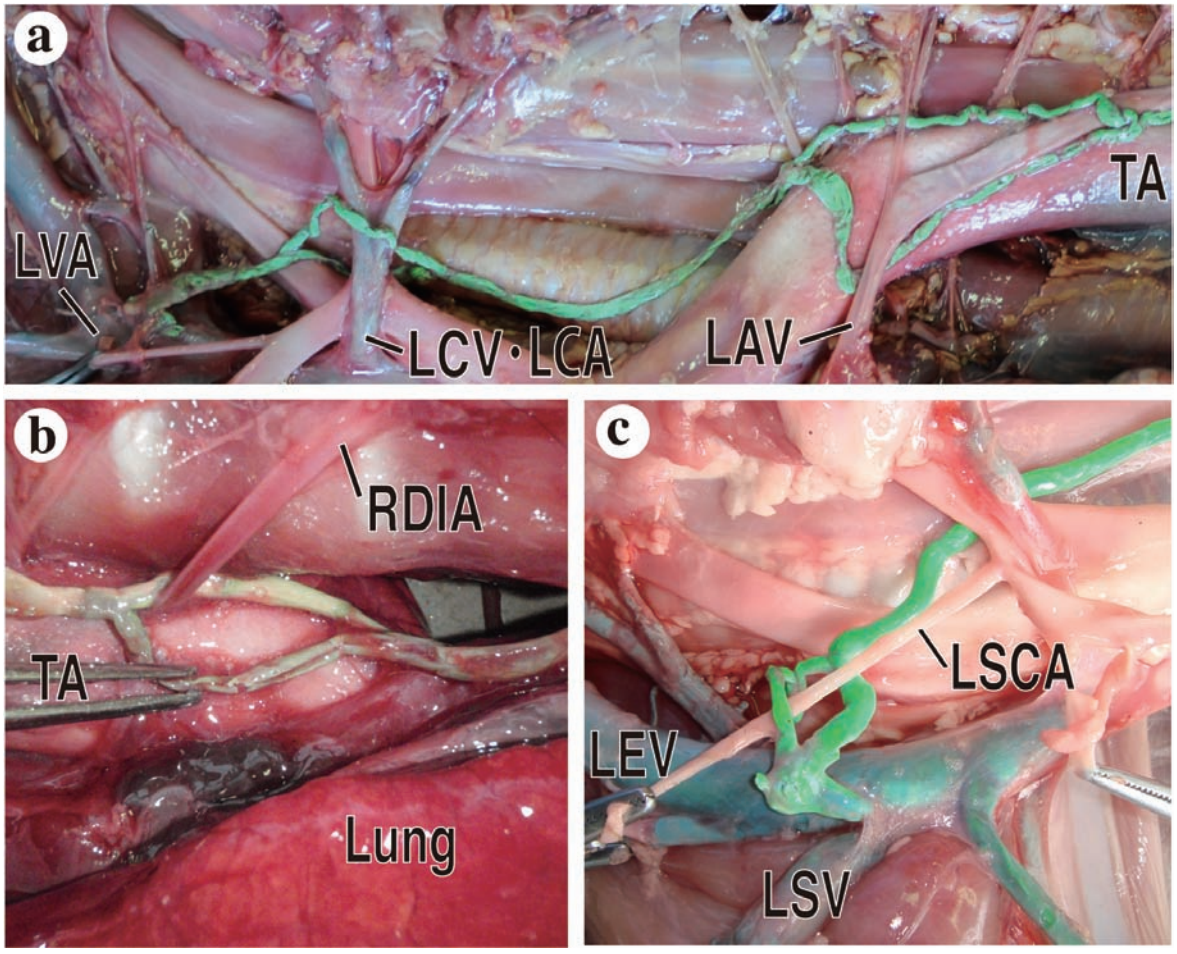


Fig. 5. Ring formation in thoracic duct pathway visualized using green latex. Thoracic duct also forms two rings through which the left azygos vein, left costocervical artery and left costocervical vein pass (a). Thoracic duct with ring through which the right dorsal intercostal artery passes (b). Thoracic duct with ring through which the left superficial cervical artery passes (c). LAV, left azygos vein; LCA, left costocervical artery; LCV, left costocervical vein; LEV, left external jugular vein; LSCA, left superficial cervical artery; LSV, left subclavian vein; LVA, left venous angle; TA, thoracic aorta; RDIA, right dorsal intercostal artery.

hand, the most common type among Japanese monkeys is type V (42%), followed by type IX (29%) [9]. The most common type of thoracic duct pathway in the present study of cattle was type VI (76%), which was similar to the ratio among humans. The frequency of type III was similar, whereas that of type IX was higher in cattle than in humans (9% vs. 6% and 15% vs. 3%, respectively) [1, 11]. Types IV and V that have been found in humans, were not found in the thoracic duct pathways of cattle. Therefore, we speculated that the thoracic duct pathways have interspecies features.

Human thoracic ducts often form rings between the ninth and twelfth thoracic vertebrae, between the third and fourth thoracic vertebrae, and the terminal region [2]. A ring formation was found in 24% of Japanese monkeys and most were located at the terminal region of the thoracic duct [9]. The present study found ring formations of the thoracic duct pathway in 48% of cattle, with most being located at regions a, b and d (Fig. 4 and Table 1). These findings were similar to those in humans. Bovine blood vessels such as the superficial cervical artery and the dorsal intercostal artery and vein, were located around the thoracic duct at regions a, b and d. In addition, the left superficial cervical artery passed through rings in 51% of bovine thoracic ducts. Two branches bifurcate from one thoracic duct and pass the right and left side of the left subclavian artery in pigs [17] and blood vessels such as the right subclavian artery pass through the thoracic duct ring in Japanese monkeys [9]. Two theories have evolved to explain the embryonic origin of lymphatic vessels that develop from embryonic veins or from mesenchymal precursor cells and then connect to veins [19]. Lymphatic vessels are generated behind other blood vessels. Therefore, we speculated why rings in the bovine thoracic duct pathway are formed at sites of vessel intersection. Anastomosis of the left and right thoracic ducts can also cause ring formation during early fetal development.

We found many anatomical variations in the thoracic duct

pathways and lymph-venous junctions of cattle. The relationship between the thoracic duct and blood vessels is important to prevent thoracic duct damage arising during thoracic surgery in cattle.

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