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Origins of the Segmental Arteries in the Aorta: An Anatomic Study for Selective Catheterization with Spinal Arteriography

Satoru Shimizu, Ryusui Tanaka, Shinichi Kan, Sachio Suzuki, Akira Kurata, and Kiyotaka Fujii

BACKGROUND AND PURPOSE: The segmental arteries, which include the posterior intercostal, subcostal, and lumbar arteries, are gateways for performance of selective spinal arteriography of the thoracolumbar level. We performed a cadaveric study to clarify the anatomic relationship between the origins of the segmental arteries in the aorta and the vertebral column.

METHODS: Five adult cadaveric aortas with intact thoracolumbar spines were dissected under magnification. In each specimen, nine pairs of posterior intercostal arteries, one pair of subcostal arteries, and four pairs of lumbar arteries were examined in detail.

RESULTS: The origin of the posterior intercostal arteries in the upper thoracic level was situated at most about two levels caudal to the feeding level, whereas the origins in the lower levels were just caudal to the corresponding levels. The position of the bilateral orifices of the segmental arteries in the axial plane of the aorta was on the medial side at the thoracic levels, whereas it was on the dorsal side at the lumbar level. The horizontal distance between the orifices in the lumen of aorta was found to be wider at the thoracic level than the lumbar level, and the longitudinal distance was higher at the lower level, corresponding to the height of the vertebra.

CONCLUSION: Understanding the 3D relationship of the initial segment of the segmental arteries with reference to the aorta and vertebral column is necessary for performance of the selective spinal arteriographic examination rationally by using a two-dimensional fluorescent display.

Selective spinal arteriography is indicated for evaluation of vascular malformations or vascular tumors of the spinal cord, spinal meninges, or vertebral column, as well as for endovascular intervention (1). Although less invasive imaging techniques have been developed, it is still a useful method because of the high resonance. Below the cervical level, the segmental arteries that originate from the descending aorta, and which consist of the posterior intercostal artery and subcostal artery at the thoracic level and the lumbar artery at the lumbar level, are the gateways to obtain images of the vasculature in this region (2, 3). The anatomy of the branches of the segmental arteries, especially the radiculomedullary artery represented by the artery of Adamkiewicz, has been well docu-

mented (4–7). However, the anatomy of the segmental arteries in the proximal region, including the orifices in the aorta, has received less attention, despite the necessity to access the region in selective spinal arteriography (8). Our purpose was to perform a cadaveric study to clarify the anatomic relationship between the origins of the segmental arteries in the aorta and the vertebral column, from the standpoint of catheterization for selective spinal arteriography.

Methods

Five adult cadaveric aortas with intact thoracolumbar spines were examined. No specimens had aortic disease or deformity of the spinal column except one with marked atherosclerosis and an abdominal aortic aneurysm. Microscopic exposure of the segmental arteries by removal of the surrounding fat tissue was performed, with care taken to preserve the anatomic relationship to the aorta. One of the specimens was dissected following perfusion of the aorta with colored silicone. After observation of the course of each artery, the anterior wall of the aorta was removed and the orifices of the arteries were identified. Axial and longitudinal locations of the orifices with reference to the spine were examined at each level, and longitudinal and horizontal distances between the orifices were measured by using a divider and a caliper. Also, axial and

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FIG 1. (Continued on next page).

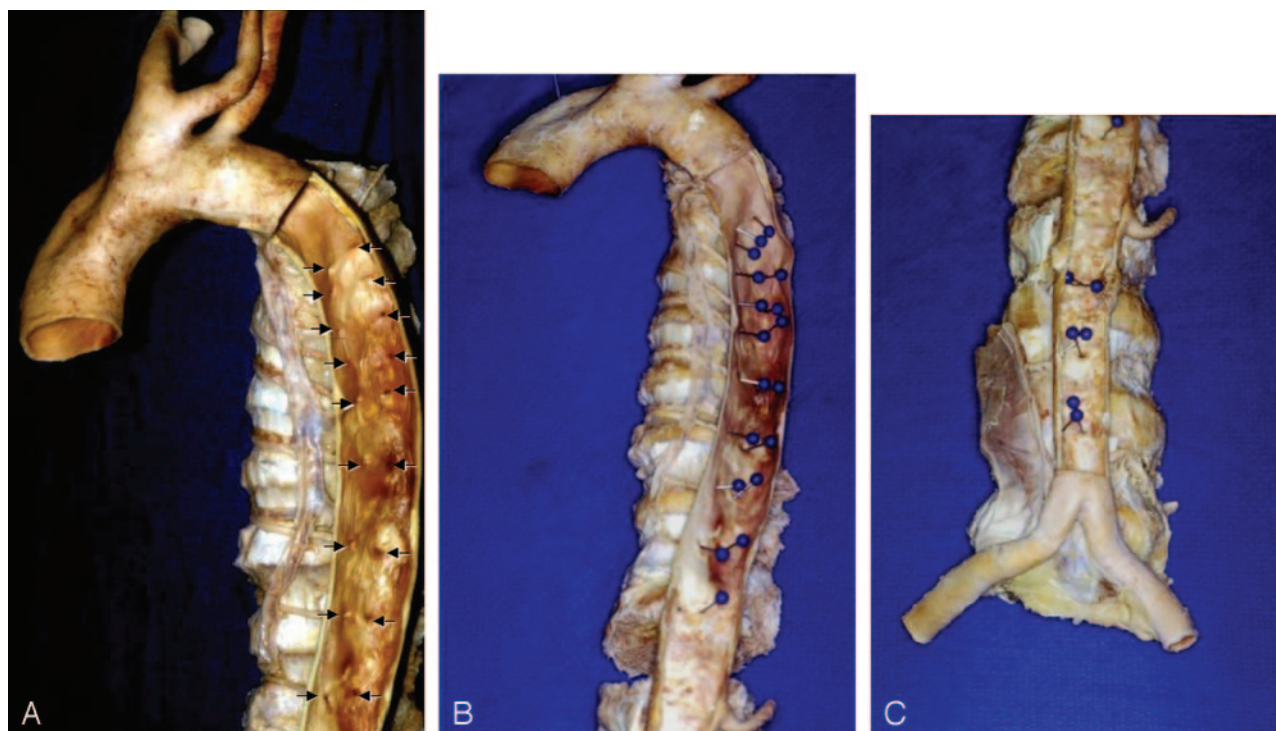


FIG 2. Photographs of specimens of a cadaveric aorta.

A, Left anterior oblique view of the inner lumen of the thoracic aorta shows the locations of the orifices (arrows) of the posterior intercostal arteries. The longitudinal distances between adjacent orifices are shorter in the upper level, and orifices on the left at this level are situated in a higher position than those on the right side, depending on the curve of the aortic arch.

B and C, Pins are placed in the initial segment of the segmental arteries at the thoracic (B) and lumbar (C) levels to show the direction of each vessel. Differences in direction of the initial segment between the spinal levels can be seen, with a medial course where the aorta is lying to the left of the spinal column, but the course is dorsolateral where the aorta is anterior to the spinal column.

longitudinal directions of the initial segment of the segmental arteries just after passing from the orifice were recorded.

Results

The descending aorta began on the left side of the fourth thoracic vertebra as a continuation of the aortic arch. It was situated on the left side of the spinal column in the upper thoracic region and descends anteromedially to become situated anterior to the lumbar column, a little left of the midline. The descending aorta ended just below the fourth lumbar vertebra by dividing into the two common iliac arteries (Fig 1A). Nine pairs of posterior intercostal arteries, one pair of subcostal arteries, and four pairs of lumbar arteries arose from the aspect of the descending aorta, adjacent to the spinal column (Fig 1B–G).

The posterior intercostal arteries passed from the third to the 11th intercostal spaces, the subcostal arteries run below the 12th rib, and the lumbar arteries ran from the first to the fourth vertebral bodies, respectively, corresponding to each segmental level. The origin of the most cephalad segmental arteries branching from the aorta, the third posterior intercostal arteries, was situated at the level between the fifth and sixth thoracic vertebra, and that of the most caudal, the fourth lumbar arteries, was situated in the middle portion at the height of the fourth lumbar vertebral body. The origin of the cephalad posterior intercostal arteries was situated about two segmental levels at most below their feeding levels (Fig 1C and D), whereas the segmental arteries originate just below the corresponding vertebra except for the last two

FIG 1. Photographs of specimens of a cadaveric aorta with intact thoracolumbar spine.

A, Anterior view shows the whole aorta, which is situated on the left side of the spinal column at the upper thoracic levels and descends medially to be situated anterior to the lumbar column, a little to the left of the midline. This specimen has an abdominal aortic aneurysm.

B–D, Anterior (B), right lateral (C), and left lateral (D) views of the thoracic aorta show the course of the posterior intercostal arteries (PIAs). In the lateral views, white and black numbers indicate the levels of the posterior intercostal arteries and thoracic vertebrae, respectively. The arteries at the upper thoracic levels, originating below the corresponding feeding levels, run upward, whereas those of the middle to lower thoracic levels originate just below the feeding levels and ascend for a short distance. On the right side, the initial segment runs straight after branching from the aorta, whereas that on the left exhibits angulation just distal to the origin.

E–G, Anterior (E), right lateral (F), and left lateral (G) views of the lumbar aorta show the lumbar arteries (LAs) originating at the levels of the corresponding vertebrae. The first two lumbar arteries run upward, whereas the last two run almost horizontally. The first lumbar artery on the left is absent in this specimen. IVC indicates inferior vena cava.

H, Left anterior view of the lower thoracic level after vertebrectomy shows the common origin of the 10th and 11th posterior intercostal arteries (PIAs). The major trunks can be identified.

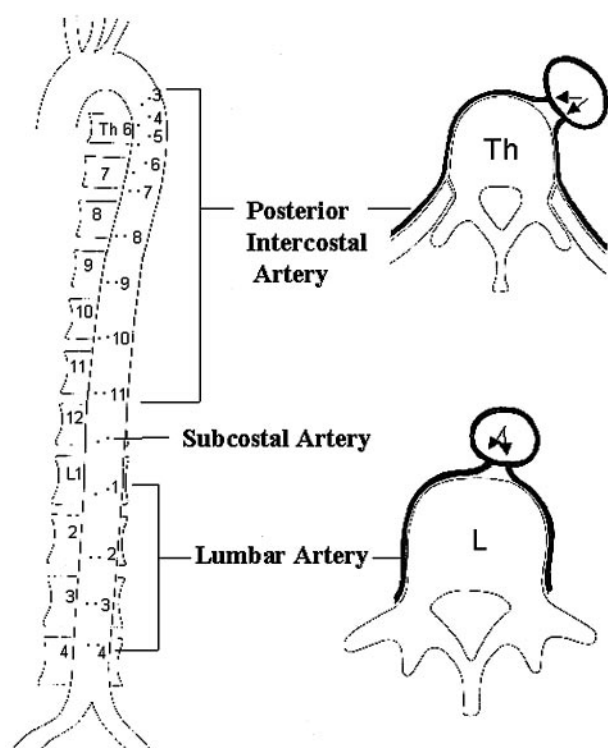


FIG 3. Schematic drawing shows the locations of the orifices of the segmental arteries in the aorta relative to the spine (left) and the directions (arrows) of the initial segment in axial sections at each level (right). The directions of the initial segment are nearly parallel to the coronal plane in the upper thoracic (Th) region and are dorsolateral in the lumbar (L) region.

lumbar arteries. The levels of origin of the third and fourth lumbar arteries were at the centers of the third and fourth lumbar vertebrae, respectively (Fig 1E–G). Each segmental artery ran upward to reach the middle region of the corresponding vertebral body, so the ascending course was more apparent in the upper thoracic region. As a result of the location of the origin, the arteries in the upper thoracic level, the third to sixth, ran upward markedly to reach the corresponding feeding levels, whereas the arteries in the middle to lower thoracic and lumbar levels ran upward for only a short course until the middle portion of the vertebra and then almost horizontally. The courses of the arteries in the initial segment were different in the upper thoracic level on the right side than in the other regions. In the former, the initial segment ran straight after branching from the aorta (Fig 1B and C), whereas the latter showed angulation just distal to the origin (Fig 1D).

One of the specimens showed absence of segmental arteries at four levels (the third and fourth posterior intercostal arteries, the subcostal artery on the right, and the first lumbar artery on the left) and common origins of adjacent posterior intercostal arteries in two regions (the third and fourth, and the 10th and 11th) on the left side (Fig 1H). Obliteration of the orifices of the arteries due to atherosclerosis was observed at three levels. The positions of the orifices in the axial plane of the aorta were on the medial side at the thoracic level, but on the dorsal side at the

TABLE 1: Horizontal distances between orifices of the segmental arteries in the lumen of the aorta from five cadaveric specimens

Artery and Level	Distance (mm)
Posterior intercostal	
3	9.10–10.23 (9.83)
4	11.00–12.03 (11.17)
5	13.56–20.90 (17.22)
6	12.64–18.08 (15.34)
7	10.25–12.18 (11.20)
8	10.40–10.55 (10.47)
9	10.98–13.00 (11.73)
10	8.18–14.42 (11.25)
11	8.90–11.24 (10.14)
Subcostal	6.66–7.88 (6.72)
Lumbar	
1	7.38–7.81 (7.56)
2	5.39–8.20 (6.74)
3	7.58–10.44 (8.96)
4	7.95–20.28 (14.12)

Note.—Data are the range. Numbers in parentheses are the mean.

TABLE 2: Longitudinal distances between orifices of the segmental arteries in the lumen of the aorta from five cadaveric specimens

Artery and Level	Distances (mm)	
	Right	Left
Posterior intercostal		
3–4	5.70–7.25 (6.45)	9.88–11.20 (10.66)
4–5	10.96–12.44 (11.84)	12.96–20.60 (16.75)
5–6	11.22–13.74 (12.43)	13.24–18.64 (15.84)
6–7	11.00–17.34 (14.07)	10.48–18.45 (14.43)
7–8	20.20–20.67 (20.33)	20.68–22.44 (21.50)
8–9	24.02–24.48 (24.23)	25.14–26.66 (25.84)
9–10	22.16–24.72 (23.38)	20.10–25.29 (22.70)
10–11	25.48–25.78 (25.52)	22.74–24.92 (23.00)
11–Subcostal	22.65–26.44 (23.84)	23.56–28.61 (27.27)
Subcostal–lumbar 1	30.23–33.57 (32.44)	28.20–33.52 (30.79)
Lumbar		
1–2	25.96–30.20 (27.92)	23.12–32.38 (27.79)
2–3	25.94–26.90 (26.32)	26.48–31.08 (28.28)
3–4	15.87–30.44 (27.99)	27.36–31.30 (29.83)

Note.—Data are the range. Numbers in parentheses are the mean.

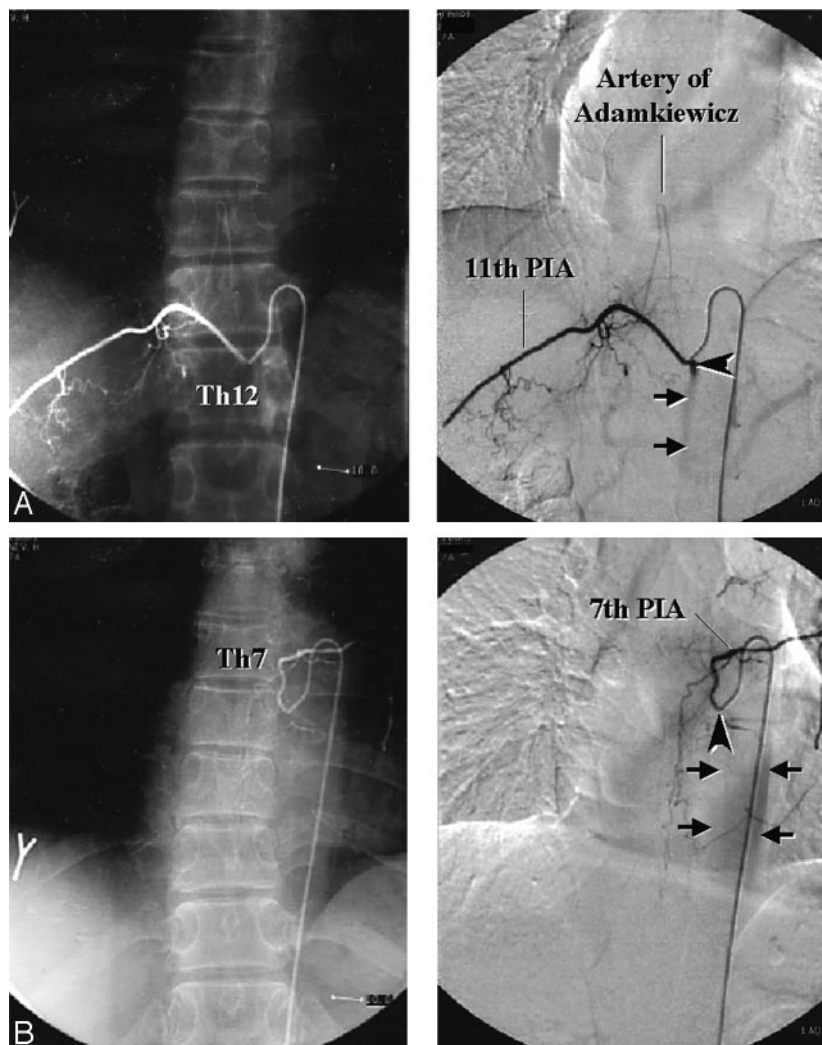
lumbar level (Fig 2A–C). The locations and directions of the origin of the arteries are schematically illustrated in Fig 3. Horizontal and longitudinal distances among the orifices of the arteries in the lumen of the aorta are summarized in Tables 1 and 2. The horizontal distance was wider at the thoracic level than the lumbar level, and the longitudinal distance was greater at the lower level, corresponding to the heights of vertebrae.

Discussion

The segmental arteries have three major trunks: lateral (posterior intercostal artery or lumbar artery), middle (muscular and dorsal branches), and medial (radicular artery, radiculomedullary artery, or radiculopial artery) (Fig 1H). They supply intercostal muscle and fat, the caudal aspect of the intervertebral foramen, and the nerve roots and spinal cord, respec-

FIG 4.

A and B, Selective arteriograms of the posterior intercostal arteries (PIA) on the right (A) and left (B) show arteries arising on the right side of the thoracic aorta, and the left one runs posterior to the aorta. Arrowheads indicate the orifices of the arteries; arrows, the lateral rim of the aorta. Th indicates thoracic vertebra. (Figure 4 continues.)



tively (4). Selective catheterization of the initial segment of the segmental arteries is important to assess the branches by sufficient opacification, and the present study revealed some anatomic points for adequate catheterization. The orifices of the segmental arteries are situated on the right side (medial side) in the inner lumen of the aorta in the upper thoracic level, and the position gradually changes to the dorsal side from the cephalad to the caudal level, and finally the orifices are situated on the dorsal aspect of the aorta. Experienced neuroradiologists have described that all of the orifices can be found by moving the catheter tip upward or downward straight along the aorta after identification of one orifice (8); however, in the present study, we showed that the course for seeking the longitudinally neighboring orifices was not straight but twisted. The directions of the initial segment of the segmental arteries just after branching from the aorta are nearly parallel to the coronal plane at the upper thoracic level, and dorsolateral at the lumbar level, running to the surface of the vertebral bodies.

Differences in location of the orifices in the axial plane and direction of the initial segment at each level contributed to the anatomic relationships between the spinal column and aorta. The aorta is situated on

the left side of the spinal column in the upper thoracic level and descends anteromedially to ride on the lumbar spinal column. Thus, the arteries reach the vertebra by the nearest course from each origin. Dissociation of the levels between the origin of segmental arteries and their corresponding vertebral column is apparent at the upper thoracic level, with the third to sixth posterior intercostal arteries. In the human embryo, segmental arteries belonging to each somite arise from the dorsal aorta at about 3 weeks of age, and their origins are situated at the same levels (9). The dissociation may be the result of relatively greater longitudinal growth of the vertebral column as compared with the aorta in later development. The distances between the orifices on both sides are wider at the upper thoracic than the lumbar level, and the longitudinal distances between neighboring levels increase from cephalad to caudal, depending on the increments in height of vertebrae. At the upper thoracic level, the longitudinal distance is shorter.

The distance is longer on the left than on the opposite side, due to the origins of cephalad arteries at the end of the aortic arch being situated at a higher position on the left side. The long mean horizontal distance between the last lumbar arteries and the

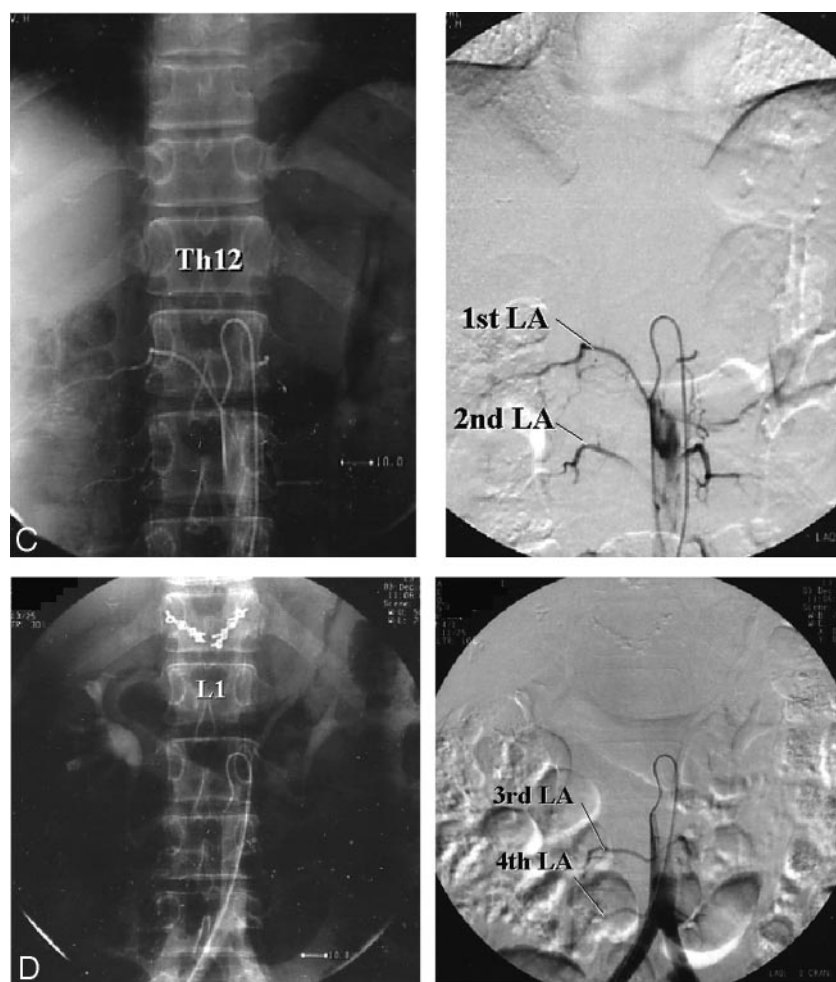


Fig 4 continued.

C and D, Lumbar arteriograms at the upper (C) and lower (D) levels show that the first two lumbar arteries (LAs) arise just below the corresponding vertebrae, whereas the last two arteries arise in the middle regions of the vertebrae. Th indicates thoracic vertebra; L, lumbar vertebra.

short mean longitudinal distance between the right third and fourth lumbar arteries are influenced by the high position of the fourth lumbar artery, between the third and fourth lumbar vertebrae.

Although the roadmap method is popular to facilitate catheterization, its application is difficult in cases that require selective arteriography for large numbers of segmental arteries, because specification of the feeding artery of vascular malformation, time, large amounts of contrast medium and x rays are needed. Understanding the 3D relationship of the initial segments of segmental arteries close to the aorta and spine is thus very important to determine the level of the spine corresponding to the artery of interest (Fig 4).

Finally, the presence of unusual anatomic relationships between the segmental arteries and the aorta, due to variation or pathologic conditions (atherosclerosis and elongation of the aorta, fracture and abnormal alignment of the spinal column), should be borne in mind in clinical practice.

Conclusion

The three-dimensional anatomy of the initial segment of the segmental arteries at each spinal level

needs to be taken into consideration for performance of selective spinal arteriography. Understanding the spatial relationships may be helpful to conduct examinations that require fluoroscopic guidance in as short a period as possible, thus minimizing the contrast medium needed.

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