

Bifid Rib: Anatomical Considerations in Three Cases

Wu-Chul Song,¹ Sang-Hyun Kim,¹ Dae-Kyoon Park,² and Ki-Seok Koh¹

¹Department of Anatomy, School of Medicine, Konkuk University, Seoul; ²Department of Anatomy, College of Medicine, Soonchunhyang University, Cheonan, Korea.

The present study involved a detailed investigation of 3 cases of bifid rib, focusing on anatomical features, and classified them into 2 types. The bifid ribs were in the right fourth rib of all 3 male cadavers. The upper intercostal spaces of the fourth bifid rib were considerably narrowed, whereas the lower intercostal spaces were widened. Although the size and shape of the bifid space between the upper and lower divisions of the bifid rib were different, the intercostal muscles were present in the bifid space in all cases. The third anterior intercostal artery from the internal thoracic artery supplied the bifid space in all cases. In 2 cases, the fourth intercostal nerve ran along the inferior margin of the fourth bifid rib and innervated the muscles of the bifid space. In the third case, there was another branch from the third intercostal nerve supplying the muscles of the bifid space as well as the fourth intercostal nerve. The bifid ribs are associated with other diseases or develop accidentally or sporadically. Knowledge of this malformation is needed for the differential diagnosis with other diseases, such as a chest wall tumor or costal fracture.

Key Words : Bifid rib, anatomy, development, variation

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Corresponding author: Dr. Ki-Seok Koh,
Department of Anatomy, School of Medicine,
Konkuk University, 1 Hwayang-dong,
Gwangjin-gu, Seoul 143-701, Korea.
Tel: 82-2-2030-7810, Fax: 82-2-2049-7845
E-mail: kskoh@kku.ac.kr

INTRODUCTION

A rib develops from the costal process of the developing thoracic vertebrae through the endochondral ossification.¹ Congenital abnormalities of the rib are relatively common, particularly in cervical, lumbar, and bifid ribs.²⁻⁶ Additional ribs such as the cervical rib are of particular interest to surgeons due to the clinical implications, such as thoracic outlet syndrome.⁷ As the structural abnormalities, the bifid rib is usually asymptomatic.⁸ It can present as an isolated abnormality or be associated with pathologic malformations.^{6,9-11}

Almost all reported cases of bifid rib were found in X-ray investigations or some symptomatic patients, with only 2 previous reports involving cadavers.^{12,13} Moreover, the reported cadaver findings were insufficient to evaluate the morphology of the bifid rib and the topography of the anatomically related structures. The present study involved a detailed investigation of bifid ribs, focusing on anatomical features.

CASE REPORT

Case 1

An 80-year-old male cadaver had a bifid right fourth rib around the costochondral joint (Fig. 1A). The bifurcation point was at the junction of the fourth rib and its costal cartilage. The bifid space between the upper and lower divisions was round, and contained intercostal muscles and fasciae. Because the bifid space was too small to allow the muscular layers to be distinguished, separation of these layers was not attempted. However, we considered that all layers were present. The 2 cartilaginous divisions reunited and articulated to the sternum. The breadth of the upper and lower divisions was smaller than those of the third and fifth

ribs. The upper intercostal space between the upper division and third rib was narrowed, but the lower intercostal space between the lower division and fifth rib was slightly widened (Figs. 1A and 2, Table 1). The surfaces of the costal cartilages of the third, fourth, and fifth ribs were covered with calcified cortex to their sternal ends (Fig. 1A).

Because the bifurcation point was near to the sternum, the third anterior intercostal artery that branched from the internal thoracic artery was the main artery supplying the bifid space. The posterior intercostal artery that branched from the thoracic descending aorta supplied other parts of the intercostal muscles. The venous distribution was almost the same as that of the arterial supply. The intercostal nerve ran along the costal groove of the lower division, but no branch ran along the upper division.

Case 2

A 59-year-old male cadaver also had a bifid right fourth rib around the costochondral joint (Fig. 1B). The morphology was similar to Case 1, but the bifid space was triangular, and the upper intercostal space was more narrowed and the lower intercostal space was more widened than in Case 1 (Figs. 1B and 2, Table 1). The vascular and nerve supplies were similar to those in Case 1.

Case 3

A 50-year-old male cadaver had a bifid right fourth rib, where the bifurcation developed already in the bony portion. The bifid space was very large and round. The upper intercostal space was considerably narrowed and almost came into contact. Because the bifid rib and cartilage were very large, the lower intercostal space was also considerably narrower than in Cases 1 and 2 (Figs. 2 and 3, Table 1). The cortex of the costal cartilage in this case was not calcified.

The vascular supply was the same as in cases 1 and 2, but the nerve innervation was different. The intercostal nerve from the fourth thoracic nerve ran along the costal groove and lower division, and another intercostal nerve ran along the superior margin of the fourth rib and upper division (Fig. 3). The latter was branched from the third intercostal nerve in the posterior intercostal space and innervated the muscles of the bifid space.

DISCUSSION

The anatomy of the bifid rib has a great effect on its development, but this has only been reported in Japanese cases.^{12,13} The anatomical findings in our cases 1 and 2 are consistent with the previous findings, and support the hypothesis that the upper division grows out of the lower division that formed the original rib.

The anatomical findings in the present study can be summarized as follows:

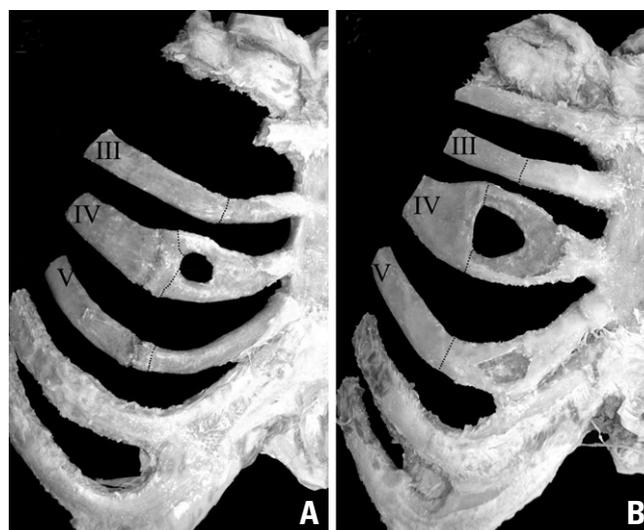


Fig. 1. External surfaces of Case 1 (A) and 2 (B). Upper intercostal space of the bifid fourth rib was narrow; otherwise lower intercostal space was widened in both cases. Dot lines, the junctions of the rib and its cartilage. III, third rib; IV, fourth rib; V, fifth rib.

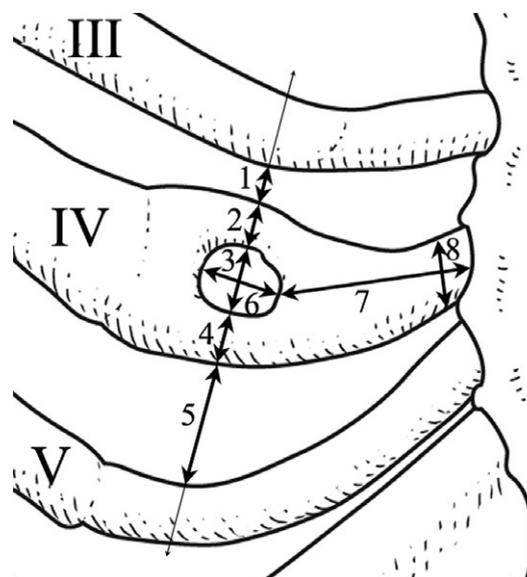


Fig. 2. Measurement items. 1, upper intercostal space between upper division of fourth bifid rib and third rib; 2, thickness of upper division; 3, vertical distance of the bifid space of bifid rib. 4, thickness of lower division; 5, lower intercostal space between lower division of fourth bifid rib and third rib; 6, transverse distance of the bifid space of bifid rib; 7, distance from sternum to bifid point; 8, thickness of sternal end of fourth costal cartilage. III, third rib; IV, fourth rib; V, fifth rib.

Table 1. Measurement Values (See Item Number in Fig. 2)

Item	Case 1	Case 2	Case 3
1	8.0	5.0	2.6
2	8.5	10.5	8.3
3	13.2	22.1	32.6
4	9.9	10.5	10.0
5	24.1	30.0	13.4
6	15.7	26.7	40.1
7	42.5	36.7	28.5
8	11.6	18.2	25.8

Unit: mm.

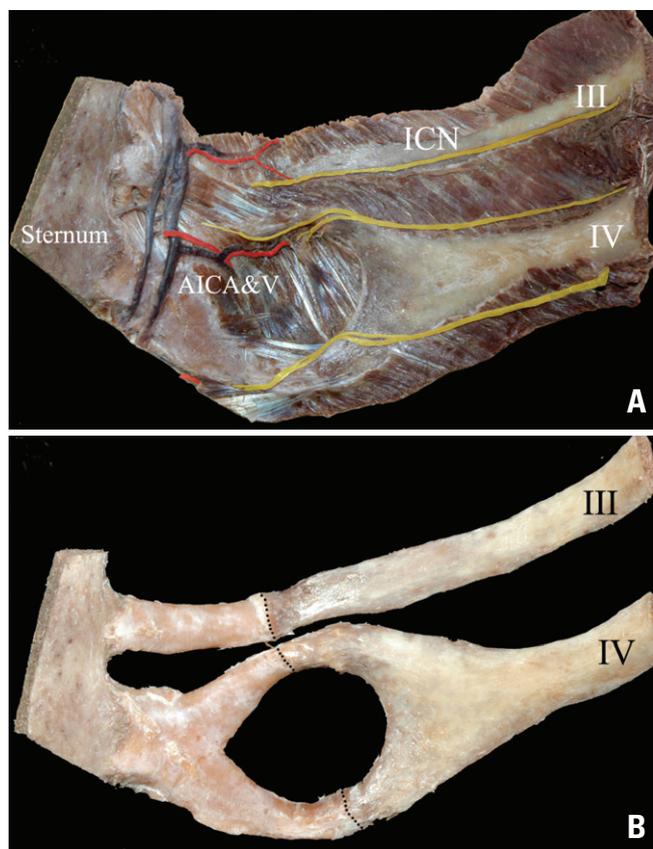


Fig. 3. Internal surface of Case 3. Structures around bifid rib (A) and bony components (B). Intercostal nerve (ICN) ran along the costal superior and inferior margin from lateral side to medial side. Note the intercostal nerve running along the superior margin and upper division of the fourth rib. It innervated to the muscles in the bifid space formed by upper and lower division of the fourth rib. Anterior intercostal arteries and veins (AICA & V) supplied the medial portion around the area of the bifid rib. Upper intercostal space was much narrowed. The arteries were painted reddish and the nerves were painted with yellowish to find easily. Dot lines, the junctions of the rib and its cartilage. III, third rib; IV, fourth rib.

1. The upper intercostal spaces were very narrow, and the lower intercostal spaces were relatively wide. The distance from the lower division to the third rib was similar to the width of the lower intercostal space (measurements: $1 + 2 + 3 \cong 5$; Case 1 in Table 1). Therefore, the upper division was designated as being abnormal.
2. The intercostal muscles were present in the bifid space of the bifid rib, and might not be present if the upper division divides from 1 rib into 2 divisions rather than growing out of the lower division.
3. The artery supplying the bifid space branched from one segment of the upper anterior intercostal artery (i.e., the third anterior intercostal artery supplied to the fourth bifid rib). This indicates that the muscles in the bifid space originated from muscles of the third intercostal space, and separated from each other by the upper division.
4. The intercostal nerve ran along the lower margin of the lower division, and no branches were present in the upper division, which indicates that the lower division did not grow out of the upper division.

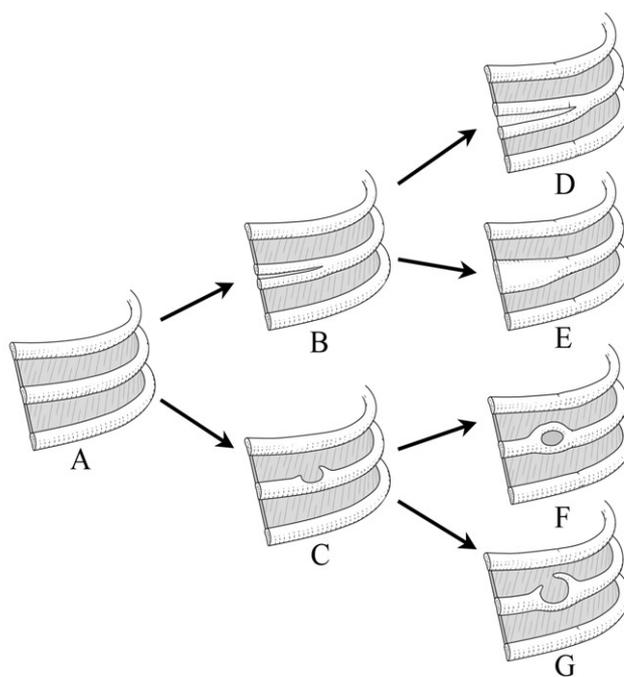


Fig. 4. Developmental course of bifid rib and its derivatives. A, Normally developing ribs; B, Cleavage of rib; C, Outgrowth of rib; D, Fork type of bifid rib; E, Widened rib-derivative of D; F, Hole type of bifid rib; G, Incomplete hole type of bifid rib.

It was difficult to determine whether the upper division grew out from the lateral side to the medial side or from the medial side to the lateral side. However, the dominant direction of growth is likely to be lateral to medial in bifid ribs with a nonfused upper division,¹³ because only the lateral part of the upper division is present.

Our case 3 (right fourth bifid rib) was different from previously reported bifid ribs found in cadavers.^{12,13} In addition to the original fourth intercostal nerve, a branch of the third intercostal nerve ran along the superior margin of the rib (Fig. 3), crossed the upper division, and innervated the muscles of the bifid space. This suggests that the muscles of the bifid space originated from muscles of the third intercostal space, with them being innervated by a branch of the third intercostal nerve.

Bifid ribs are more common in males than females, and occur most frequently in the third and fourth ribs (incidence: third \cong fourth > fifth > sixth > second).^{3-6,12,13} They are slightly more common on the right side than on the left,⁵ and bilateral bifid ribs can also be present.¹³

Various incidences and types of costal numerical and structural abnormalities have been reported. For example, the incidence of costal abnormalities based on X-ray investigations was 2.8% in Koreans⁵ and 0.15-5.7% in other populations.^{6,14} The most common type of costal abnormalities has also differed, with extra lumbar or cervical ribs being more common in some populations,^{14,15} and the bifid rib being the most common type in Koreans (1.7% in the general population, 59.6% in cases with total costal anomalies).⁵ Factors other than ethnicity, such as the skill in interpreting X-ray films and the

absence of calcification of the costal cartilage of the rib resulting in the bony sternal end of the rib appearing as a broadened rib in X-ray films (and hence being misdiagnosed as a bifid rib), might also contribute to the varying incidence, especially when this is not associated with other symptoms or malformations.

Bifid ribs have been reported to be an independent abnormality when they appear as accidentally or sporadically developed bifid ribs, and are mostly found in elderly cadavers^{12,13} or conventional X-ray studies.^{2,3,5} Such cases never appear as multiple bifid ribs on the same side, but there has been 1 reported case of bilateral bifid ribs.¹³ Bifid ribs associated with pathologic malformations such as Gorlin-Goltz syndrome^{9,10,16} and malignancy in childhood usually occur in the young,⁶ and might be characteristic of multiplicity of the bifid rib on the same side.

Besides the association with disease, the following 2 distinct morphological patterns were evident in the present cases: 1) long and slender (fissured) bifid spaces, with the bifid rib appearing as a two-pronged fork (fork type); and 2) more rounded bifid spaces (hole type). A long and slender fissure¹⁶ might develop through dividing of the rib in the anterior portion, whereas a more rounded pattern might develop through growing out of the upper division from the lower division, as mentioned previously (Fig. 4). These different developmental courses might also result in the formation of other derivatives (Fig. 4).

In conclusion, the bifid rib not associated with other disease in the elderly may present few clinical problems. However, knowledge of bifid ribs is necessary for the differential diagnosis with other diseases, such as tumors of the chest wall or costal fracture, because the various types of bifid rib are present with diverse appearances on normal chest X-rays.

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