Methods of Counting Ribs on Chest CT: The Modified Sternomanubrial Approach[1]

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Purpose: The purpose of this study was to evaluate the accuracy of each method of counting ribs on chest CT and to propose a new method: the anterior approach with using the sternocostal joints.

Materials and Methods: CT scans of 38 rib lesions of 27 patients were analyzed (fracture: 25, metastasis: 11, benign bone disease: 2). Each lesion was independently counted by three radiologists with using three different methods for counting ribs: the sternoclavicular approach, the xiphisternal approach and the modified sternomanubrial approach. The rib lesions were divided into three parts for evaluation of each method according to the location of the lesion as follows: the upper part (between the first and fourth thoracic vertebra), the middle part (between the fifth and eighth) and the lower part (between the ninth and twelfth).

Results: The most accurate method was a modified sternomanubrial approach (99.1%). The accuracies of a xiphisternal approach and a sternoclavicular approach were 95.6% and 88.6%, respectively. A modified sternomanubrial approach showed the highest accuracies in all three parts (100%, 100% and 97.9%, respectively).

Conclusion: We propose a new method for counting ribs, the modified sternomanubrial approach, which was more accurate than the known methods in any parts of the bony thorax, and it may be an easier and quicker method than the others in clinical practice.

Computed tomography (CT) is a useful imaging method for detecting lesions in the ribs, sternum and vertebrae. However, it is difficult to count the ribs as the ribs are arranged obliquely in the axial plane. With the introduction of multidetector-row CT (MDCT), the bones of thorax can be clearly examined in three-dimensional images, although the axial images are most commonly used in clinical practice.

There are three known methods for counting ribs on axial images. One is the method of counting from the first rib seen below the proximal end of the clavicle (Bhalla et al. 1990) (1). Another is the method of counting, from the seventh costal cartilages, those ribs that

are attached to the distal ends of the sternal body at the xiphisternal joint (Kim et al. 1993) (2). The other is the method of counting, from the second costal cartilages, those ribs that are attached to the sternal angle (Yasuyuki et al. 1995) (3). However, all these methods should use the costovertebral joints for counting the ribs rather than other landmarks, and these landmarks may have some deformities that can result in incorrect counting.

In this study, we will propose a new modified sternomanubrial method that starts from the sternomanubrial junction, yet this method uses the sternocostal joints instead of the costovertebral joints. Also, we will evaluate the accuracy of each method for counting ribs, including the new method.

Materials and Methods

The subjects of this study were 27 patients, who underwent chest CT in our hospital during the period from April to September, 2006. Twenty two were male and five were female, and their age ranged from 15 to 75 (mean: 53.4). Thirty eight rib lesions were selected in these 27 patients. Of the 38 lesions, 25 were fractures, 11 were metastases and 2 were benign bony diseases.

All the CT scans were performed on a Brilliance 64 CT scanner (Philips Medical Systems, Cleveland, U.S.A.), with a 2mm thickness, a 1mm overlap, 120 kVp and 250mAs, from the apex of the lung to the level of the second lumbar vertebral body at the end of full inspiration. We evaluated all the lesions on the reconstructed 5 mm thick axial images by using a PACS monitor.
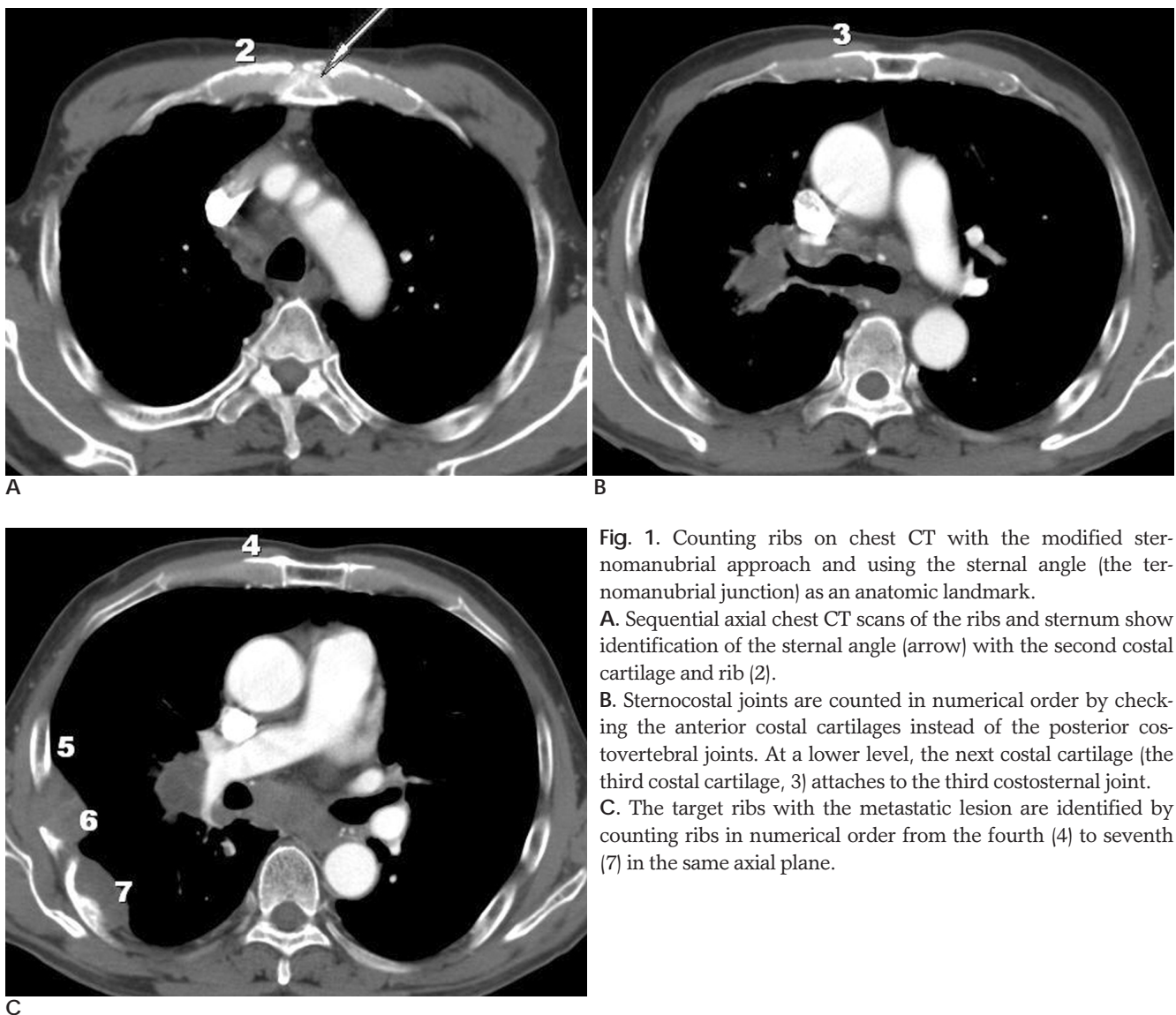
A

B

C

Fig. 1. Counting ribs on chest CT with the modified sternomanubrial approach and using the sternal angle (the sternomanubrial junction) as an anatomic landmark.
A. Sequential axial chest CT scans of the ribs and sternum show identification of the sternal angle (arrow) with the second costal cartilage and rib (2).
B. Sternocostal joints are counted in numerical order by checking the anterior costal cartilages instead of the posterior costovertebral joints. At a lower level, the next costal cartilage (the third costal cartilage, 3) attaches to the third costosternal joint.
C. The target ribs with the metastatic lesion are identified by counting ribs in numerical order from the fourth (4) to seventh (7) in the same axial plane.

To count the ribs in the axial images, we used the sternoclavicular approach proposed by Bhalla et al. (1), the xiphisternal approach proposed by Kim et al. (2), and the modified sternomanubrial approach, which was a modification of the method proposed by Yasuyuki et al. (3). The modified sternomanubrial approach started from the second costal cartilage that was attached to the sternomanubrial junction (4). The sternocostal joints were then counted in numerical order to the fifth sternocostal joint by checking the anterior costal cartilages instead of the posterior costovertebral joints. If lesion was visible between the first and the fifth sternocostal joint, then the ribs were counted in numerical order from the corresponding sternocostal joint. For the lesion located below the fifth sternocostal joint, the ribs were counted in numerical order to the costovertebral joint at the level of the fifth sternocostal joint. After that, the remaining method was same as the other methods (Fig. 1).

All the images were evaluated by three radiologists who worked independently. Each radiologist counted the selected lesions, that is, those were marked by arrows, by using the different three methods. In order to prevent any bias by the counter when counting the ribs, the results of each method were unknown to the radiologists and there was a one week interval after the first method of counting ribs, and then another method was used. The accuracy of each method was evaluated from these results. Also, in order to evaluate the accuracy of each method according to the level of the bony thorax, we divided the bony thorax into three parts: upper (thoracic vertebra 1-4), middle (thoracic vertebra 5-8) and lower (thoracic vertebra 9-12). The number of lesions of each part was 8 in the upper, 14 in the middle and 16 in the lower.

The exact positions of the lesions were identified by using the three-dimensional (3D) images obtained from a commercial 3D program (Lucion 1.1, Mevisys, Seoul, Korea).

Results

Using the three counting methods, all the radiologists showed a high level of accuracy: 97.4% (111/114), 95.6% (109/114) and 90.4% (103/114), respectively. The most accurate method was the modified sternomanubrial approach (99.1%; 113/114) and then came the xiphisternal approach (95.6%; 109/114) and the sternoclavicular approach (88.6%; 101/114) (Table 1). All three radiologists showed the highest accuracy with using the modified sternomanubrial approach (100%, 97.4%, and 100%, respectively) and the lowest accuracy with using the sternoclavicular approach (92.1%, 94.7% and 78.9%).

When the bony thorax was divided into three parts, the mean accuracy of all three methods was 91.7% (66/72) for the upper part, 94.4% (119/126) for the middle part, and 95.8% (138/144) for the lower part. Thus, the upper part showed relatively low accuracy compared with the other parts. The sternoclavicular approach showed relatively low accuracy for the upper (83.3%) and the middle parts (85.7%), and the xiphisternal approach showed relatively low accuracy for the up-

Table 1. Accuracy of Counting Ribs on Chest CT According to Each Method (%)

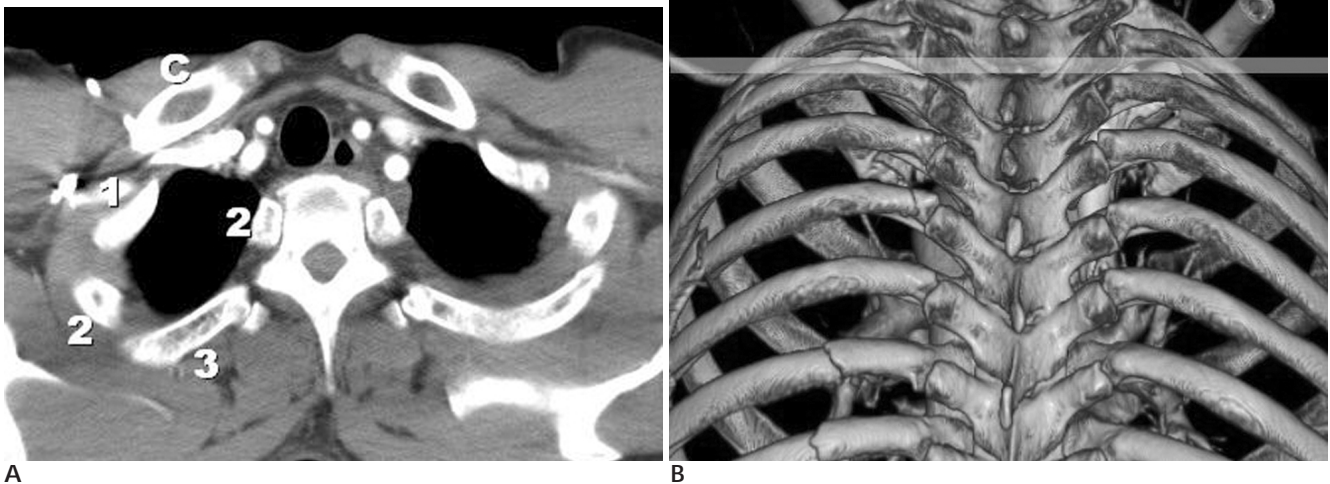|	Sternoclavicular Approach	Xiphisternal Approach	Sternomanubrial Approach	Total
Upper throax	83.3 (20/24)	91.7 (22/24)	100 (24/24)	91.7 (66/72)
Radiologist 1	87.5 (7/8)	100 (8/8)	100 (8/8)	
Radiologist 2	87.5 (7/8)	100 (8/8)	100 (8/8)	
Radiologist 3	75 (6/8)	75 (6/8)	100 (8/8)	
Mid throax	85.7 (36/42)	97.6 (41/42)	100 (42/42)	94.4 (7/126)
Radiologist 1	81.7 (12/14)	100 (14/14)	100 (14/14)	
Radiologist 2	92.9 (13/14)	100 (1414)	100 (14/14)	
Radiologist 3	78.6 (11/14)	92.9 (13/14)	100 (14/14)	
Lower thorax	93.6 (45/48)	95.8 (46/48)	97.9 (47/48)	95.8(6/144)
Radiologist 1	100 (16/16)	100 (16/16)	100 (16/16)	
Radiologist 2	100 (16/16)	87.5 (14/16)	93.8 (15/16)	
Radiologist 3	81.3 (13/16)	100 (16/16)	100 (16/16)	
Total	88.6 (8/11)	95.6 (109/114)	99.1 (113/114)	
Radiologist 1	92.1 (35/38)	100 (38/38)	100 (38/38)	
Radiologist 2	94.7 (36/38)	94.7 (36/38)	97.4 (37/38)	
Radiologist 3	78.9 (30/38)	92.1 (35/38)	100 (38/38)	

A   **B**

Fig. 2. Pitfall of the sternoclavicular approach (using the clavicle as an anatomic landmark).
At the level of sternoclavicular joint, the number of costovertebral joints may be confusing due to the partial volume effect. Compared with the three dimensional reconstruction image, the posterior portion of the fifth ribs (large arrow) are upward convex and located higher than the costovertebral joint of the fourth rib (small arrow).

per part (91.7%). However, the modified sternomanubrial approach showed high accuracy for all three parts (100%, 100% and 97.9%, respectively).

Discussion

CT is the most convenient method for examining lesions in the ribs, vertebrae and chest wall. However, it is difficult to count ribs because of the oblique arrangement of the ribs on the axial images. To solve this problem, a special method is needed for counting the ribs on the axial images. With the introduction of multidetector-row CT (MDCT), the bones of thorax can be clearly examined on three-dimensional images, yet it is hard to make and confirm all cases via the three-dimensional image.

Bhalla et al. proposed a rib counting method based on the relation between the clavicle and the first rib and using the costovertebral joint (1). However, the method requires counting the costovertebral joints, and this can result in errors because of the partial volume effect when counting the upper thoracic vertebrae and it also has the limitation that the ribs cannot be counted on CT when the thoracic vertebrae are deformed or the clavicle is not included. In our study, the sternoclavicular approach was less accurate (88.6%) than the other methods. Almost all cases with incorrect analysis or difficulty in counting the ribs were the cases those rear parts of the upper ribs were positioned higher than the corre-
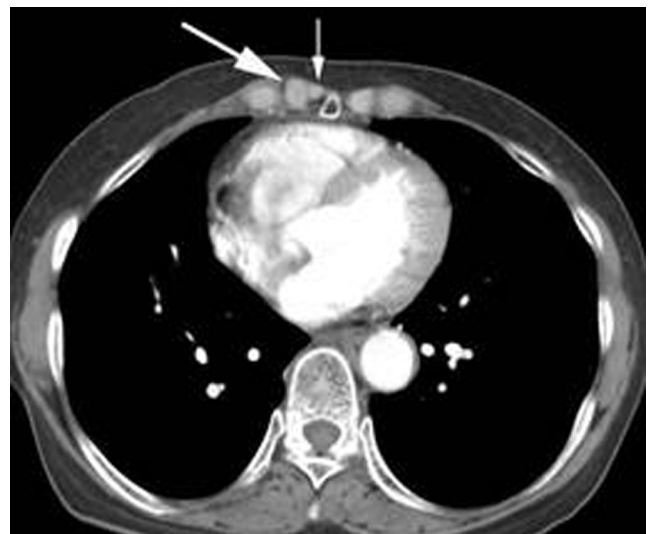

Fig. 3. Pitfall of the xiphisternal approach (with using the xiphoid process as an anatomic landmark).
At the level of the xiphisternal joint, the right seventh costal cartilage (small arrow) is smaller than the left one. Therefore, the sixth costal cartilage (large arrow) looks like the seventh costal cartilage.

sponding costovertebral joints, and as a consequence, the partial volume effect occurred (Fig. 2).

Kim et al. suggested the xiphisternal approach (2). This method, which is based on the anatomical fact that the seventh costal cartilage is attached to the xiphisternal joint, is designed to be able counting the ribs even when CT does not include the clavicle. However, this method has been known as an inaccurate method because it is difficult to identify the seventh costal cartilage (Fig. 3),

and counting the costal cartilages and ribs on the same axial images may be confusing due to reverse order, and, in rare cases, the eighth costal cartilage sticks to the xiphoid process and this may be confused with the seventh costal cartilage (5). However, in our study, this method was more accurate (95.6%) than the sternoclavicular approach. The reason for this result might be that the thin section CT scans with 5-mm thickness that were used in our study clearly showed the anatomy at the level of the xiphisternal joint.

Yasuyuki et al. suggested using the sternomanubrial approach because the second costal cartilages are attached to the sternal angle (the sternomanubrial junction) (3). This method is advantageous in that it may avoid the complicated xiphisternal relationship. However, because Yasuyuki et al. used the second rib to identify the costovertebral joints on the same image, their method could not completely overcome problems that occurred due to the variations of the thoracic vertebrae. Thus, we proposed a modified sternomanubrial approach that counts the ribs with using the costal cartilages on the anterior chest wall instead of using the costovertebral joints, which are complex structures. Using this method, we could skip the step of counting the ribs backward to the costovertebral joints and the step of counting the many complicated costovertebral joints on the image where the lesion was visible. In addition, because the sternocostal joints are anatomically simpler than the costovertebral joints, this method can count the ribs more easily and reduce errors. In our study, the modified sternomanubrial approach showed outstanding accuracy (99.1%), and it was the easiest and quickest counting method for clinical application. This method should be used between the first and the fifth or sixth sternocostal joints because the costal cartilages are no longer straight below these levels . However, because the fifth sternocostal joint usually corresponded with

the seventh to the ninth thoracic vertebrae, almost all the ribs could be easily counted.

We thought that there would be more incorrect counting when the lesions in the lower part were counted by the sternoclavicular approach. However, in our study, the accuracy for the lesions in the lower part (93.6%) was higher than that for the upper part (83.3%). Also, the xiphisternal approach, which also counted the costovertebral joints, was more accurate (91.7%) for the lesions of the upper part than that of the sternoclavicular approach. Yet the modified sternomanubrial approach, which did not count the costovertebral joints, was the most accurate for all three parts. These results show that the partial volume effect of the upwardly convex upper ribs may be the major cause of incorrect counting.

The limitations of this study are that the number of the lesions was small, and any severe deformity of the thoracic vertebrae or the sternum was not encountered.

Conclusively, we propose a new method for counting ribs, the modified sternomanubrial approach, which was more accurate than the other known methods in any parts of the bony thorax, and it was the easiest and the quickest to perform in clinical practice.

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(xiphisternal approach),   (modified sternomanubrial approach)   3
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100%, 100%, and 97.9%).
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