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CHEST IMAGING

ORIGINAL ARTICLE

The internal mammary vessels above and below the first rib on multidetector CT: implications for anatomical feasibility of lung biopsy via anterior approach

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PURPOSE
To provide the anatomical knowledge necessary to draw biopsy routes by using an anterior approach above and below the first rib to avoid internal mammary vessel damage.

MATERIALS AND METHODS
The anatomy of internal mammary vessels above and below the first rib was assessed by thin-section computed tomography (CT) analysis of 61 adults. The visibility of the internal mammary vessels, the relationship with the brachiocephalic vein, and the distance from the first rib (window width for biopsy) were determined above the first rib, whereas whether and where the internal mammary artery (IMA) and/or internal mammary vein (IMV) crossed the rib margin were assessed below the first rib.

RESULTS
There was no bony interval between the clavicle and the first rib on 5 sides (four patients). On the remaining 117 sides, 117 IMAs and no IMVs were seen (18 IMAs were seen on contrast-enhanced CT only). The window width for biopsy was 5 mm or greater on 82 sides (right: 30, left: 52) and was significantly wider on the left side (right: 4.7–5.7 mm, left: 8.2–9.0 mm) ($P < 0.05$). The inferolateral margin of the first rib was crossed by 99 IMAs and 93 IMVs, which were mostly within the caudalmost 5 mm.

CONCLUSION
Above the first rib, a biopsy route at least 5 mm away from the IMA often exists and is often identifiable by its characteristic appearance on noncontrast CT (nipple on lateral margin of the brachiocephalic vein). The internal mammary vessels are not present on the inferior margin of the first rib except in the caudalmost 5 mm of its cartilage.

Key words: • *tomography, X-ray* • *internal mammary artery*

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Internal mammary artery (IMA) damage has been reported in a number of image-guided procedures, such as pigtail drainage (1), central line insertion (2, 3), pacemaker implantation (4), and transthoracic lung biopsy (1). In patients who have undergone coronary artery bypass surgery, injuring the IMA may lead to myocardial infarction (5). Although the literature is sparse on the consequences of internal mammary vein (IMV) damage (6), the British Thoracic Surgery (BTS) guidelines recommend avoiding both the IMA and IMV when a biopsy is to be performed adjacent to the costal cartilage and sternum (7). However, radiological studies documenting the course of the internal mammary vessels are limited in number (8, 9). Moreover, those studies did not cover the vascular anatomy relevant to the needle biopsy of apical lung lesions. In Glassberg et al. (8), the axial anatomy of the internal mammary vessels was studied only at the levels between the aortic arch and the main pulmonary artery. Dursun et al. (9) did not study the relationship between the internal mammary vessels and the first rib on the axial plane or the relationship between the internal mammary vessels and the brachiocephalic vein on the axial plane.

When an anterior approach is used for the biopsy of an apical lung nodule, the needle enters the lung either between the clavicle and the first rib (defined as "above the first rib" here) or between the first and second ribs (defined as "below the first rib" here). In such a situation, knowledge of the distance between the sternal margin and the internal mammary vessels (8) is useless. The main question here is where the IMA and IMV are situated in those bony intervals. This question should be answered with a detailed knowledge of the anatomical relationship between the internal mammary vessels and the structures clearly visible on noncontrast computed tomography (CT), such as the first rib, the clavicle, and larger vessels. To date, however, little has been described in the radiology literature regarding the exact location, course, or CT visibility of the IMA and IMV adjacent to the first rib.

The goal of this study was to define in detail the anatomical paths of the IMA and IMV. This information is necessary to perform a lung biopsy via an anterior approach immediately above and below the first rib.

Materials and methods

Our institutional review board approved this study.

CT scan

All patients (n=61) who underwent contrast-enhanced chest CT under the routine-initial protocol on December 12th, 2009, for any reason were enrolled in the study (men:women, 30:31; age range, 18–86 years; mean age, 55 years). At our institution, a contrast-enhanced chest CT is performed without obtaining noncontrast images in all patients, ex-

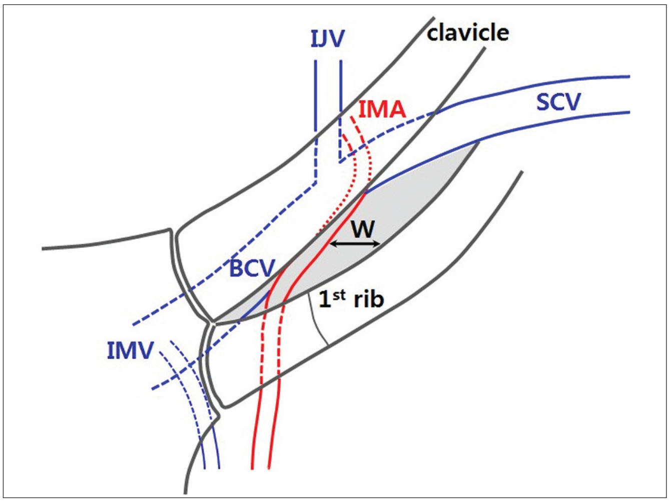

Figure 1. The illustration shows the anatomy of the internal mammary vessels and related structures. The internal mammary artery (IMA) and the brachiocephalic vein (BCV) are the two major vascular structures in the bony interval *(gray area)* between the clavicle and the first rib. The window width for biopsy was defined as the distance between the medial margin of the first rib and either the IMA or BCV (the actual width of the space traversable by a biopsy needle). On this diagram, the IMA projects outside the inferolateral margin of the first rib at the caudalmost level. The internal mammary vein drains to the brachiocephalic vein at the level below the bony interval. (BCV, brachiocephalic vein; IMA, internal mammary artery; IJV, internal jugular vein; W, window width for biopsy.)

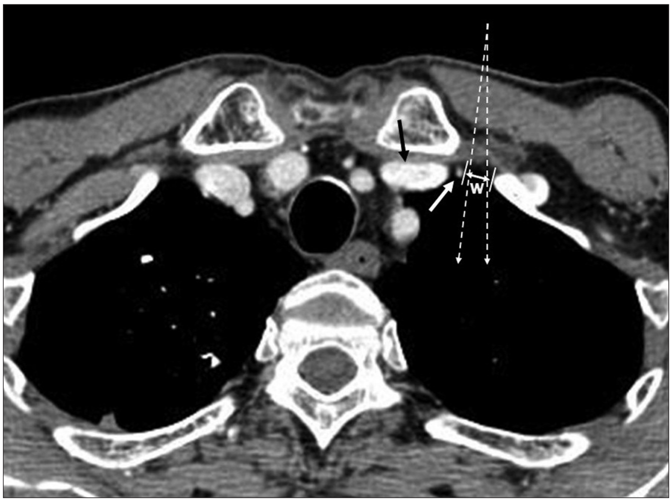

Figure 2. Contrast-enhanced CT image shows the window width for biopsy (W, *double-headed arrow)*, which serves as a biopsy route *(dotted arrows)* for apical lung lesions. The left internal mammary artery *(white arrow)* is lateral to the brachiocephalic vein *(black arrow).*

cept in those who have not undergone a chest CT before. Routine-Initial refers to the chest CT protocol recommended for patients who undergo chest CT for the first time at our institution and includes both noncontrast and contrast-enhanced CTs. Noncontrast and contrast-enhanced CT scans were obtained with the patients' arms raised over the head using a 128-row MDCT scanner (Somatom Definition AS+, Siemens, Forchheim, Germany) with the following parameters: 512 × 512 pixel matrix, 14 × 1.2 mm collimation, 130 mAs (effective) at 120 kV, 0.45 pitch, and 0.33 second rotation time. For the contrast-enhanced scanning, 100–120 mL of nonionic IV contrast medium was injected at a rate of 3 mL/s (with a start delay of 50 seconds) through a peripheral angiocatheter. All images were reconstructed with a standard kernel (0.75 mm slice thickness) and were then sent to a workstation (Aquarius Net, Tera Recon, San Mateo, California, USA). Two thoracic radiologists reviewed the 0.75-mm-thickness images on the workstation, analyzed the right and left sides separately and resolved any differences of opinion by consensus.

Image review

Noncontrast axial CT was reviewed between the inferior margin of the subclavian vein and the upper margin of the second rib.

Above the first rib

First, the width of the bony intervals between the clavicle and first rib was measured. The height between the subclavian vein and the first rib was also measured (Fig. 1). Then, the IMA was traced as it descended from its origin (usually the subclavian artery) ventral to the pleural cupola (10). The following parameters were assessed at 1.5, 3, 4.5, and 6 mm below the inferior margin of the subclavian vein: 1) visibility of the IMV and IMA (visible/not visible); 2) presence of contact between the brachiocephalic vein and the IMA; 3) direction (for example, five o'clock) and distance (only when present) of the IMA from the brachiocephalic vein; and 4) the window width for biopsy that was defined as the distance between the medial margin of the first rib and the lateral margin of either the IMA or the brachiocephalic vein (whichever was lateral) (Figs. 1 and 2).

Below the first rib

Because a segment of the IMA or IMV cannot be damaged by the inciting needle if it is located behind the rib, the relationship between the internal mammary vessels and the inferolateral margin of the first rib was studied. We focused on which segments of the inferolateral rib margin could safely be traversed without the risk of internal mammary vessel damage. First, we assessed whether the inferolateral margin of the first rib is entirely lateral to the IMA and IMV (Fig. 3). When the inferolateral rib margin was partially medial to the IMA or IMV, the vertical distance ("D" in Fig. 3) was measured between the lowest point of the first rib and the point at which the IMA or IMV (whichever is superior) crosses the rib margin.

Statistical analysis

The means±standard deviations for the measurements were calculated. The differences of all measurements between the right and left sides were assessed by Student's t-test because the data were normally distributed. Differences were considered to be statistically significant when $P < 0.05$.

Results

Above the first rib

In four patients (five sides), the CT analysis showed no bony interval between the clavicle and the first rib because of bony variations, including complex curvature of the 1st rib and an abnormally large head of the

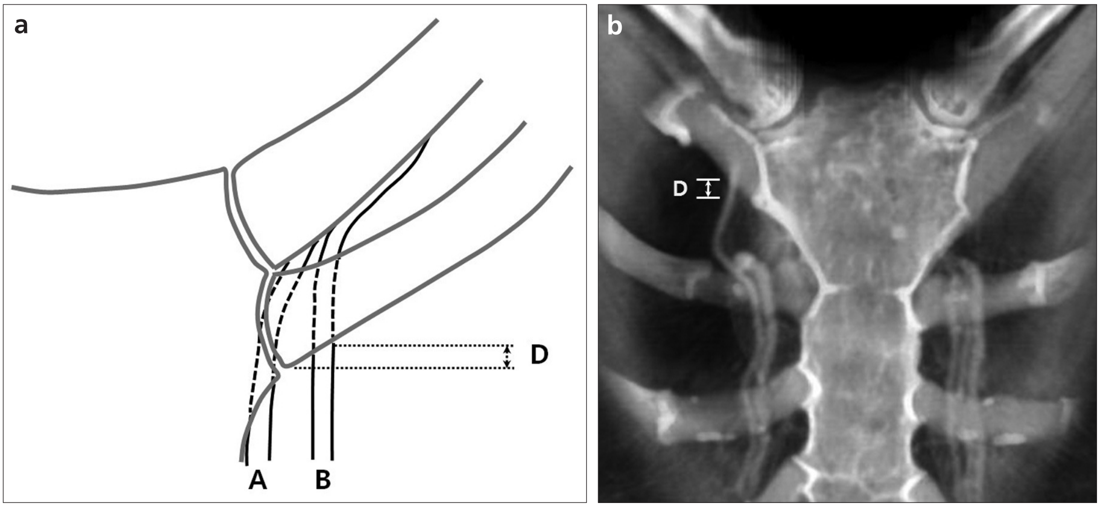

Figure 3. a, b. Two different courses of the internal mammary artery (IMA) **(a)** and the vertical distance between the lowest point of the first rib and the point at which the IMA crosses the inferolateral rib margin **(b)**. A, the IMA runs entirely medial to the inferolateral margin of the first rib, with no risk of damage by an inciting biopsy needle; B, the IMA crosses the inferolateral rib margin, with its lower portion lying lateral to the inferolateral margin; D, the vertical distance between the lowest point of the first rib and the point at which the IMA crosses the inferolateral rib margin **(a)**. D in the coronal CT **(b)**.

Figure 4. A 78-year-old man without a bony interval between the clavicle and the first rib. The lack of the bony interval is due to a complex curvature formed by the anterior rib and the costal cartilage *(white arrows)* in front of the clavicle *(black arrows)* in this patient.

Figure 5. Non-contrast CT shows the internal mammary artery (IMA, *arrow)* making contact with the brachiocephalic vein in a 42-year-old man. The IMA resembles a nipple projecting from the lateral margin of the brachiocephalic vein.

clavicle (Fig. 4). On the remaining 117 sides (57 patients), the CTs showed bony intervals with an average width of 9.23±3.09 mm (right, 9.34±3.06 mm; left, 9.14±3.13 mm). The average height between the subclavian vein and the first rib was 6.63±4.2 mm (right, 6.37±3.21 mm; left, 6.94±3.04 mm). There was no statistically significant difference between the right and left sides (P = 0.69 [width] and 0.26 [height]).

On 99 (84.6%) of the 117 sides, the IMA was seen on both noncontrast and contrast-enhanced CT, whereas on 18 sides (15.3%, 8 on the right and 10 on the left), the IMAs were seen on contrast-enhanced CT only.

Of 99 IMAs visible on noncontrast CT, 84 (71.8%; 48 on the right, 36 on the left) had contact with the brachiocephalic vein at all levels, producing a nipple-like appearance sitting on the lateral margin of that vein (Fig. 5). Fifteen IMAs (12.8%; 2 on the right, 13 on the left) had no contact with the brachiocephalic vein at all levels, producing a solitary dot-like appearance. Another 8 (1 on the right, 7 on the left; 9.5%) of the 84 IMAs had contact with the brachiocephalic vein 1.5 mm below the subclavian vein but diverged from the brachiocephalic vein 4.5 mm below the subclavian vein (Fig. 6). The distance between the brachiocephalic vein and the IMA is described in Table 1. The data showed no significant difference in the average distance between the two vessels on both sides.

The IMAs were mainly located lateral (between 8 and 10 o'clock on the right, between 2 and 4 o'clock on the left) to the brachiocephalic vein. However, they had a tendency to lie posterolateral (between 4 and 6 o'clock on the right, between 6 and 8 o'clock on the left; Fig 6a) and anterolateral (between 10 and 12 o'clock on the right,

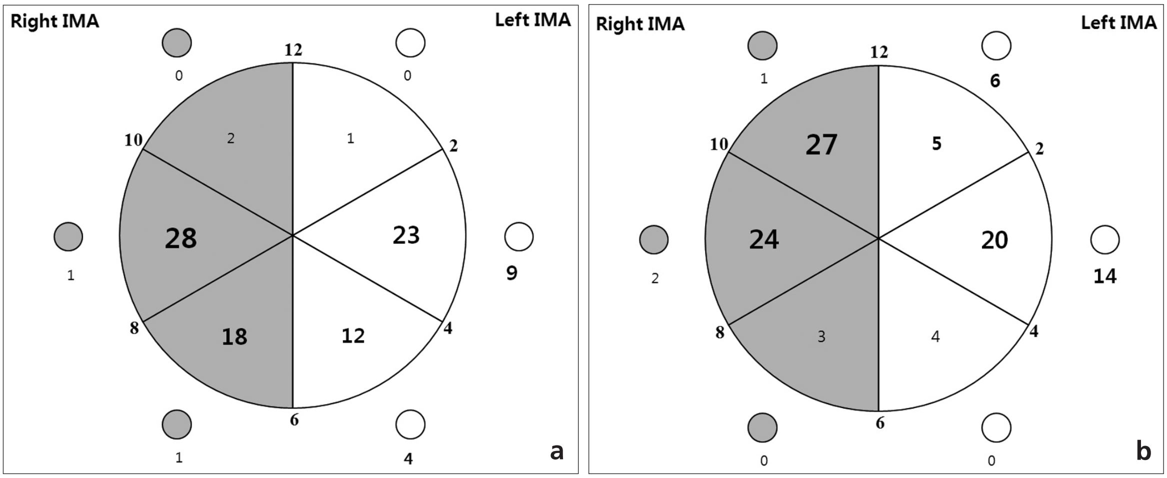

Figure 6. a, b. The diagrams show the location of the internal mammary artery (IMA) relative to the brachiocephalic vein (BCV) at 1.5 mm **(a)** and 4.5 mm **(b)** below the lower margin of the subclavian vein (SCV) on noncontrast CT. The numbers in the large circle represent the number of IMAs that are in contact with the BCV in each direction. The numbers below the small circles indicate the number of IMAs that are separated from the BCV in each direction. Fifteen IMAs (2 on the right, 13 on the left) are seen separately from the BCV, and 84 (48 on the right, 36 on the left) contact the BCV **(a)**. The majority of the IMAs are seen at the posterolateral aspect of the BCV 1.5 mm below the SCV. Eight (1 on the right, 7 on the left) of 84 IMAs diverge from the BCV as they coursed caudally. The majority of the IMAs are located at the anterolateral aspect of the BCV 4.5 mm below the SCV **(b)**.

between 12 and 2 o'clock on the left; Fig 6b) to the brachiocephalic vein 1.5 and 4.5 mm, respectively, below the subclavian vein.

The window width for biopsy was 5 mm wide or larger at one or more levels on 82 (right, 30; left, 52) sides (70.1%). The average window width for biopsy was significantly wider on the left side (right, 4.7 to 5.7 mm; left, 8.2 to 9.0 mm) at all levels ($P < 0.05$). The measurements of the window width for biopsy are described in Table 2.

Regardless of contrast enhancement, CT showed no IMV above the first rib; all IMVs drained to the brachiocephalic vein below the superior margin of the first rib.

Table 1. Average distances between each IMA and its respective BCV at 1.5, 3, 4.5, and 6 mm below the lower margin of the SCV

	Average distance between each IMA and its respective BCV (mm)		
Level[a]	Right	Left	*P*
1.5 mm below SCV	1.87±0.85	2.58±1.63	0.02
3 mm below SCV	2.6±0.87	3.12±2.06	0.08
4.5 mm below SCV	3.74±0.33	3.7±1.18	0.68
6 mm below SCV	5.01±1.44	4.5±1.87	0.72

IMA, internal mammary artery; BCV, brachiocephalic vein; SCV, subclavian vein
[a]Vertical distance from the lower margin of the SCV

Table 2. Average window width for biopsies measured on contrast-enhanced CT at 1.5, 3, 4.5, and 6 mm below the lower margin of the SCV

	Average window width for biopsy (mm)		
Level[a]	Right	Left	*P*
1.5 mm below SCV	4.17±2.88	8.18±3.91	<0.05
3 mm below SCV	4.54±2.9	8.94±3.8	<0.05
4.5 mm below SCV	4.75±3.2	8.61±3.64	<0.05
6 mm below SCV	5.02±3.73	8.96±3.68	<0.05

SCV, subclavian vein
[a]Vertical distance from the lower margin of the SCV

Below the first rib

At these levels, 118 (96.7%; 58 on the right and 60 on the left) of 122 IMAs were visualized on the noncontrast CT. Four IMAs were visualized only on contrast-enhanced CT. Of the 122 IMAs (99 visible on noncontrast CT), 101 descended medial to the inferolateral margin of the first rib until they crossed the rib margin to emerge from behind the rib (Fig. 3a). Of those 101 IMAs, 90 (89 visible on noncontrast CT) were closely accompanied by the IMV and manifested as either a pair of discrete dots (n=55, 61.1%) or as an hourglass appearance (n=35, 38.9%). The other 21 of the 122 IMAs (19 visible on noncontrast CT; 17.2%) descended entirely behind the first rib without crossing the inferolateral rib margin.

Of the 122 IMVs, 115 (112 visible on noncontrast CT) ascended entirely (n=22) or partially (n=93; crossing the inferolateral rib margin) behind the first rib, whereas the other 7 ended below the inferior margin of the first rib.

The segments of the four IMVs and three IMAs that were visible on contrast-enhanced CT only were adjacent to areas of tuberculous scarring, pneumonia or idiopathic pulmonary fibrosis that were associated with soft-tissue infiltration of the extrapleural fat layer.

The inferolateral margin of the first rib was entirely lateral to both the IMA

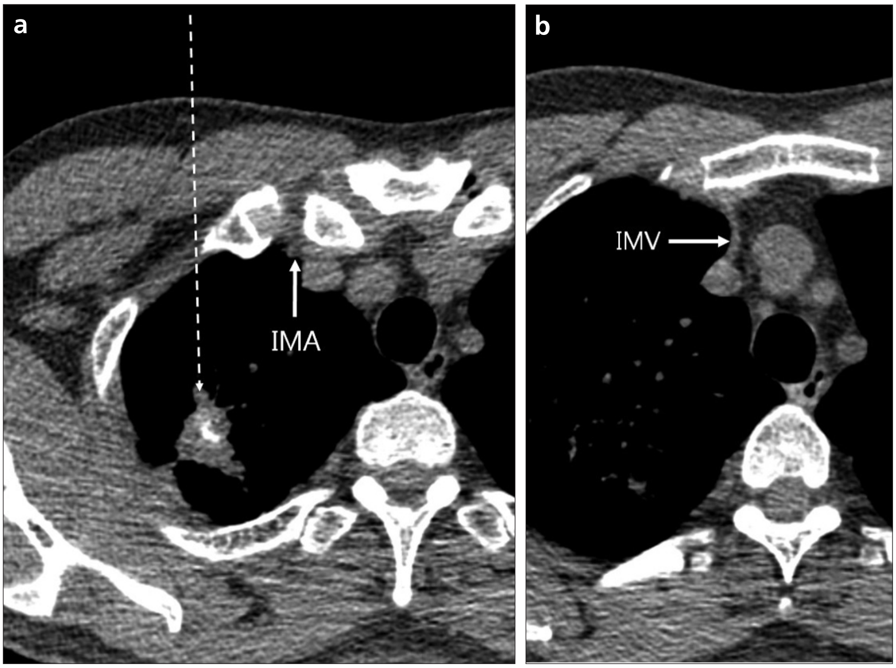

Figure 7. a, b. A 44-year-old man with an apical lung nodule. Non-contrast CT through the lung nodule **(a)** shows that a vertical biopsy path can be set along the inferolateral margin of the first rib, which is free from the internal mammary artery (IMA). The IMA is easily identifiable in the 10 o'clock direction to the brachiocephalic vein. Non-contrast CT **(b)** shows the right internal mammary vein (IMV) draining into the right brachiocephalic vein, far below the level of the lung nodule.

and IMV on 21 sides, whereas it was crossed by the IMA and/or IMV on 101 sides.

The vertical distances between the lowest point of the first rib and the point at which either the IMA or IMV (whichever is cephalic) crosses the inferolateral rib margin were 3.16±2.37 and 2.22±1.99 mm above the lowest point of the rib on the right and left sides, respectively (Fig. 3a and 3b). There was no significant difference between the right and left sides ($P = 0.15$).

Discussion

Regardless of the type of procedure, IMA damage is a complication that is potentially fatal and should be avoided at all costs. Although the literature does not indicate whether apical lung lesions are related to an increased risk of biopsy-related IMA or IMV trauma, we believe that it is still important to identify and avoid those vessels when obtaining a biopsy from apical lung lesions. For the biopsy of an apical lung nodule, an anterior approach is sometimes chosen to avoid aerated lung tissue or axillary sagging of the subclavian vein, to bypass the bony structures, or simply to take the shortest path. With an anterior approach, the needle path is often set immediately above or below (Fig. 7) the sternal extremity of the first rib (usually costal cartilage), demanding extra care to avoid the internal mammary vessels (7).

This study focused on noncontrast CT, chiefly because transthoracic biopsy is usually performed without contrast administration. In addition, biopsy-planning CT or CT fluoroscopy covers a limited range of the thorax, making it difficult to trace the internal mammary vessels from serial axial images. Therefore, radiologists sometimes rely solely on the anatomical relationships to the larger structures to find these extremely small vessels on axial noncontrast CT. However, this study showed that the relationship between the sternum and the internal mammary vessels, which is well known in the midthoracic levels (7, 8), does not apply to the higher levels. Moreover, in contrast to the midsternal levels, the IMA and IMV do not always manifest as a pair of dots at the higher levels. In fact, as has been revealed by this study, the IMVs do not even reach the levels above the first rib. Furthermore, a small number of IMVs (7 of 122; 5.7%) traveled no higher than the inferior margin of the first rib. Therefore, although this "pair-of-dots" sign is often useful for identifying the internal mammary vessels at the level of the first rib and below, radiologists should not rely on it when performing a biopsy of an apical lung lesion via an anterior approach. Above the first rib, the brachiocephalic vein is a good landmark for indentifying the IMA. This large vein is formed by the junction of the internal jugular and subclavian veins behind the sternoclavicular joint and manifests itself as an easily recognizable ovoid vascular structure that is the least likely to be injured. This study showed that the vast majority of IMAs are in contact with the lateral margin of the brachiocephalic vein and have a tendency to lie posterolaterally at 1.5 mm and anterolaterally at 4.5 mm below the inferior margin of the subclavian vein. When there is contact between the IMA and the brachiocephalic vein, the axial CT shows the former as a nipple-like shadow on the lateral margin of the latter. Thus, the IMA is proximally related to the brachiocephalic vein and diverges farther below the subclavian vein.

Between the first rib and the IMA (or brachiocephalic vein), there was a safe distance for needle passage (window width for biopsy of 5 mm or more) in many patients (on the left side in 63.4% and on the right side in 36.6%). The reason for such a difference between the right and left sides may be that the right brachiocephalic vein is located more laterally than the left vein, thereby pushing the IMA in the lateral direction. In any case, we believe that the IMA should be more carefully identified on the right side when a biopsy is performed above the first rib.

The bony interval between the clavicle and the first rib contains the costoclavicular ligament, which is an important stabilizer of the sternoclavicular joint (11). Although the radiology literature does not carefully examine the safety of traversing the costoclavicular ligament with needles, this procedure was successfully performed in one of our patients with no complications. In fact, a study blames the costoclavicular ligament for fractures of pacemaker leads (12) but does not describe any damage to that ligament. If the ligament is strong enough to damage pacemaker leads, we believe that it will not be damaged by smaller objects, such as a biopsy needle. However, we also believe that it would be wiser to use a small-gauge (e.g., 22 gauge) needle when a biopsy is to be performed above or below the first rib not only to avoid damaging the costoclavicular ligament but also to reduce the risk of damaging the internal mammary vessels.

The present study reveals that the vast majority of the internal mammary vessels can be found at the inferolateral margin of the first rib on noncontrast CT. Most of the IMAs are accompanied by the IMV as they cross the inferolateral rib margin and appear as either a pair of dots or an hourglass form near (caudalmost 5 mm) the lower margin of the first costosternal junction. Once identified, the internal mammary vessels can safely be avoided. Sometimes, noncontrast CT can show that the IMA and/or IMV are entirely hidden behind the first rib and that they are not at risk for biopsy-related damage. Although the BTS guidelines suggest that care should be taken to avoid the internal mammary vessels if the biopsy is performed adjacent to the costal cartilage (7), the results of the current study suggest that the risk of internal mammary vessel damage depends on the level of the biopsy route and the individual anatomy of the IMV. Tsai et al. (5) recommended a posterior approach for the biopsy of apical lung lesions behind the IMVs. However, the results of the present study show that a biopsy via an anterior approach can be performed as long as the operator is familiar with the relevant vascular anatomy above and below the first rib.

This study is limited by the small number of clinical cases supporting the feasibility of needle passage above and below the first rib. This should be investigated in a large series of patients undergoing lung biopsy. Another limitation is that all of the subjects were scanned with their arms over their heads, which may not reflect the situation of some patients who would undergo biopsy with their arms at their sides rather than over their heads.

In conclusion, using the anatomical knowledge studied herein, the biopsy of an apical lung lesion can be planned above and below the first rib via an anterior approach. The vast majority of the internal mammary vessels can be accurately identified above or below the first rib on noncontrast CT. Above the first rib, there is a safe biopsy window on the majority of sides (70.1%). The vast majority of the IMAs are in contact with the brachiocephalic vein and can be identified from its typical appearance. The IMA has a tendency to be intimately related to the brachiocephalic vein in the proximal portion and diverges from it in the distal portion. There is no risk of IMV damage at this level. The internal mammary vessels are not present on the inferior margin of the first rib except in the caudalmost 5 mm of its cartilage.

Conflict of interest disclosure

The authors declared no conflicts of interest.

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