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INTERVENTIONAL RADIOLOGY

ORIGINAL ARTICLE

Angiographic analysis of the lateral intercostal artery perforator of the posterior intercostal artery: anatomic variation and clinical significance

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PURPOSE
Knowledge of the anatomic variations of the posterior intercostal artery (PICA) and its major branches is important during transthoracic procedures and surgery. We aimed to identify the anatomic features and variations of the lateral intercostal artery perforator (LICAP) of the PICA with selective PICA arteriography.

METHODS
We retrospectively evaluated 353 PICAs in 75 patients with selective PICA arteriography for the following characteristics: incidence, length (as number of traversed intercostal spaces), distribution at the hemithorax (medial half vs. lateral half), and size as compared to the collateral intercostal artery of the PICA.

RESULTS
The incidence of LICAPs was 35.9% (127/353). LICAPs were most commonly observed in the right 8th–11th intercostal spaces (33%, 42/127) and in the medial half of the hemithorax (85%, 108/127). Most LICAPs were as long as two (35.4%, 45/127) or three intercostal spaces (60.6%, 77/127). Compared to the collateral intercostal artery, 42.5% of LICAPs were larger (54/127), with most of these observed in the right 4th–7th intercostal spaces (48.8%, 22/54).

CONCLUSION
We propose the clinical significance of the LICAP as a potential risk factor for iatrogenic injury during posterior transthoracic intervention and thoracic surgery. For example, skin incisions must be as superficial as possible and directed vertically at the right 4th–7th intercostal spaces and the medial half of the thorax. Awareness of the anatomical variations of the LICAPs of the PICA will allow surgeons and interventional radiologists to avoid iatrogenic arterial injuries during posterior transthoracic procedures and surgery.

The incidence of injury to the intercostal artery has increased with growing use of percutaneous transthoracic interventions (e.g., transthoracic biopsy, thoracentesis, thoracostomy, and therapeutic needle puncture procedure) through intercostal spaces. This inadvertent injury to the intercostal artery, especially the posterior intercostal artery (PICA), can result in high morbidity and mortality due to acute severe hemothorax (1–3). Since procedures through the posterior intercostal space have become more common, precise knowledge of anatomy is necessary to avoid injuring the PICA. Several studies have been conducted to evaluate PICA anatomy using computed tomography angiography (4, 5) or cross-sectional anatomy (6, 7).

The lateral intercostal artery perforator (LICAP), one of the major branches of the PICA, is well known as a major perforator of the latissimus dorsi muscle flap in the field of plastic surgery (8). It is frequently observed as a vertical branch of the PICA during bronchial artery embolization or transcatheter arterial chemoembolization and has been found frequently to be larger than the collateral intercostal artery, crossing several intercostal spaces. However, to the best of our knowledge, no previous study specifically addressed the anatomic features and clinical significance of the LICAP in the fields of angiography and transthoracic intervention.

The aim of this study was to identify the anatomic features and the clinical significance of the LICAP in the fields of angiography and transthoracic surgery through the analysis of various angiographic findings and a comparative analysis of cross-sectional anatomy.

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Methods

Our institutional review board approved this study, and the requirement for informed consent was waived because of the retrospective nature of the study.

We evaluated 353 posterior intercostal arteriographies that were performed in 75 patients in our institution from December 2013 through September 2014. The mean age of the patients was 53.6 years (23–80 years) and male:female ratio was 49:26. The underlying causes of posterior intercostal angiography were bronchial artery embolization for hemoptysis in 63 patients, transcatheter arterial chemoembolization for hepatocellular carcinoma (HCC) in 11 patients, and postoperative bleeding in one patient. The causes of hemoptysis were pulmonary tuberculosis (n=36), bronchitis (n=7), bronchiectasis (n=8), chronic obstructive pulmonary disease (n=5), pneumonia (n=5), arteriovenous malformation (n=1), and pulmonary edema (n=1).

The main trunk and the major branches of the PICAs were evaluated according to the level of intercostal space with selective PICA arteriography. In cases of multiple PICAs originating from the common trunk, each PICA was evaluated separately. Thus, a total of 353 PICAs were included in this retrospective study.

Two interventional radiologists evaluated the native state of the PICA and LICAPs, which were not secondarily hypertrophied or feeders for hemoptysis or hepatocellular carcinoma. The LICAP was evaluated as follows: (a) incidence at each hemithorax was calculated at each level of intercostal space (1st–11th thoracic posterior intercostal spaces and 12th subcostal space), which was divided into three groups at each hemithorax: upper (highest to 3rd intercostal space), middle (4th–7th intercostal space), and lower (8th–11th intercostal space); (b) length, as the number of traversed intercostal spaces, and the incidence of more than one intercostal space at each hemithorax; (c) distribution at the hemithorax (medial half vs. lateral half); and (d) size (gross diameter) of the LICAP compared to that of the collateral intercostal artery at the same PICA and the incidence for which the LICAP was larger than the collateral intercostal artery, which was obtained according to three groups of intercostal spaces at each hemithorax (Fig. 1).

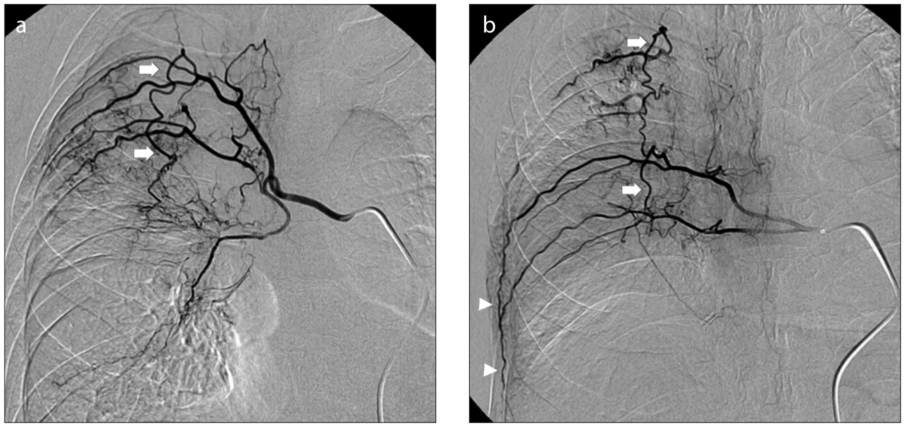

Figure 1. a, b. Selective angiography of the common trunk of the right highest intercostal and bronchial arteries **(a)** shows a large lateral intercostal artery perforator *(arrows)* originating from the hypertrophied 2nd and 3rd posterior intercostal artery which distributes to the medial half of the hemithorax and traverses three levels of intercostal spaces. Note the irregular parenchymal staining on the right upper lung. Selective angiography of the common trunk of the right 4th and 5th intercostal arteries **(b)** shows the lateral intercostal artery perforator *(arrows)* which distributes to the medial half of the hemithorax and traverses three levels of intercostal spaces. Note that the lateral intercostal artery perforator is larger than the collateral intercostal arteries *(arrowheads)*.

After thorough evaluation of the anatomic features of the LICAPs, a systematic literature review was performed using the following key words: posterior intercostal artery, posterior intercostal artery perforator, angiography, and cross-sectional anatomy. Databases included Medline, Embase, and the Cochrane databases. A total of 12 original articles were available for this subject from 2005 to 2014. All articles were in the field of plastic surgery; three articles in *Plastic Reconstruction Surgery*, two articles in the *Journal of Plastic Reconstruction Anesthetic Surgery*, two articles in *Annual Plastic Surgery*, and one article each in *Archives of Plastic Surgery*, *Annales de Chirurgie Plastique Esthétique*, and *Journal of Plastic Surgery and Hand Surgery*. Finally, four articles were available for comparing their cross-sectional anatomic results of the LICAP to our angiographic results (8–11).

Main points

- The lateral intercostal artery perforators (LICAP) of the posterior intercostal artery were most commonly observed in the right 8th–11th intercostal spaces and in the medial half of the hemithorax.
- Most LICAPs were as long as three intercostal spaces.
- Compared to the collateral intercostal artery, 42.5% of LICAPs were larger, and most of these observed in the right 4th–7th intercostal spaces.

Results

Two-hundred and twenty PICA arteriographies were performed in the right hemithorax and 133 in the left hemithorax; the detailed frequency is shown in Fig. 2. The incidence of LICAP was 37.2% (82/220) in the right hemithorax and 33.8% (45/133) in the left hemithorax, with an overall incidence of 35.9% (127/353) in both hemithoraces.

When the distribution of LICAPs was analyzed in three groups (upper, middle, and lower) in each hemithorax, LICAPs were most commonly observed in the right 8th–11th intercostal spaces (33%, 42/127), the right 4th–7th intercostal spaces (25.9%, 33/127), and the left 4th–7th intercostal spaces (23.6%, 30/127). The length of most LICAPs was two (35.4%, 45/127) or three intercostal spaces (60.6%, 77/127); length distribution was similar in both hemithoraces (Fig. 3).

The distribution of LICAPs in both hemithoraces was 85% (108/127) in the medial half and 15% (19/127) in the lateral half, with similar distribution in both hemithoraces (Fig. 4). The number of LICAPs larger than the collateral intercostal artery and the ratio of larger LICAPs to collateral intercostal arteries according to both hemithoraces are shown in Fig. 5. LICAPs larger than the collateral intercostal artery were most commonly observed in the right 4th–7th intercostal spaces (48.8%, 22/54), the left 5th–8th intercostal spaces (24%, 13/54), and the right 8th–11th intercostal spaces (24%, 13/54). LICAPs larger than the collateral intercostal artery were more common in the right hemithorax (right, 68.5%; left, 31.5%).

Discussion

In this retrospective study of PICA arteriographies, the incidence of LICAPs was

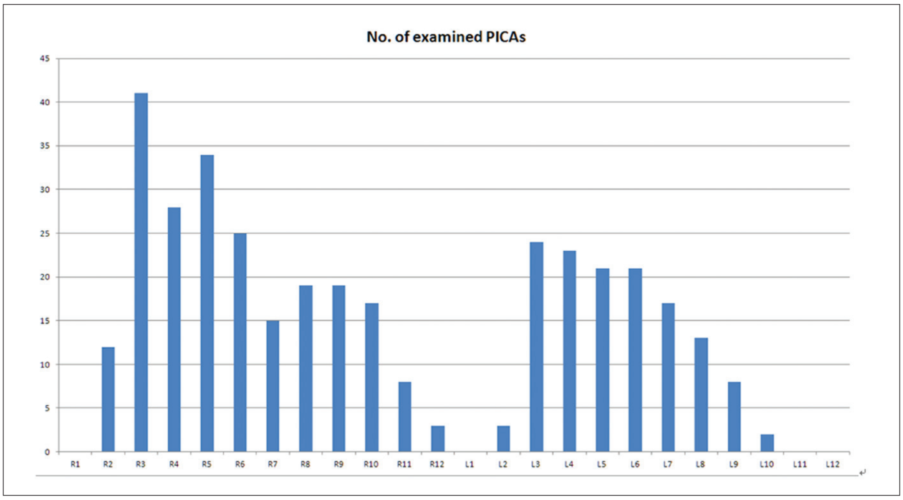

Figure 2. Number of posterior intercostal arteries observed according to each intercostal space at both hemithoraces (R, right; L, left).

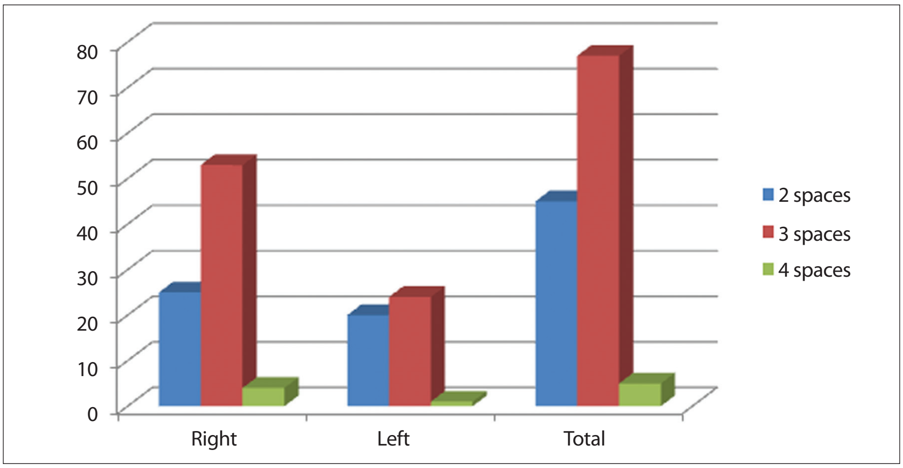

Figure 3. Length of the lateral intercostal artery perforator according to the number of traversed intercostal spaces at each hemithorax.

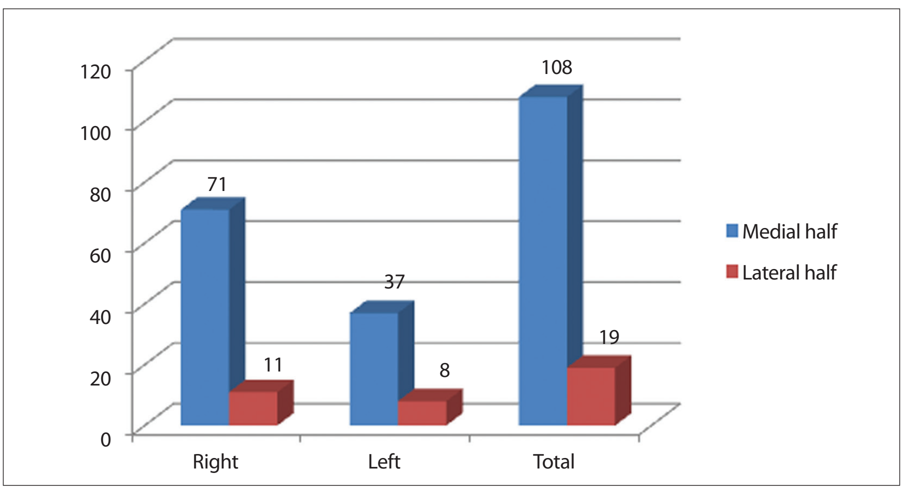

Figure 4. Distribution of the lateral intercostal artery perforators at each hemithorax.

35.9%, with 42.5% of them being larger than the collateral intercostal artery. Our results suggest that anatomical variation of the LICAPs of the PICA should be considered when planning posterior transthoracic procedures and surgery.

In contrast to the LICAP, the clinical significance of the collateral intercostal artery from the PICA has been well studied in the field of transthoracic intervention. Shimizu et al. (12) reported that it is usually located at the superior border of the rib angle on the mid- or posterior axillary line. Bae at al. (13) documented that the collateral intercostal artery was a major cause of severe bleeding after transthoracic intervention (in six of eight cases) and proposed the presence of a large collateral intercostal artery as the most important cause for iatrogenic injury during transthoracic intervention, despite several studies reporting pseudoaneurysm of the PICA as the major cause of massive bleeding after a procedure (1–3).

However, there have been only a few studies on the anatomical variation and clinical significance of the LICAP from the PICA in the English literature; the sample size of these studies was similar to ours. Because it was impossible to compare directly between previous cross-sectional anatomic findings of the LICAP and the results of our study, we attempted to confirm our results by systematically reviewing the literature of previous anatomical analyses of the LICAP. We identified four relevant articles (8–11) from our literature search. Prasad et al. (8) described that the LICAP was a lateral branch from the costal segment of the PICA that travelled caudally and laterally with perpendicular direction to the muscle fibers of the latissimus dorsi, which has been considered as an important feeding perforator of the latissimus dorsi muscle flap in plastic surgery.

The LICAP is believed to be an important and commonly encountered branch of both posterior hemithoraces that should be avoided to prevent injury during transthoracic procedures such as surgery, biopsy, and centesis. The LICAP was observed in 35.9% of our PICA angiographies; it was most commonly observed in the right 8th–11th intercostal spaces (33%, 42/127), covering three intercostal spaces in length (60.6%, 77/127), and distributed in the medial half of both hemithoraces 85% (108/127). Importantly, LICAPs larger than the collateral intercostal artery were most commonly observed in the right 4th–7th intercostal spaces (48.8%, 22/54), which showed a good correlation with the previous studies in the aspects of incidence, length, and common distribution (8–11).

Knowledge of the precise anatomy of the LICAP is essential in clinical practice to prevent iatrogenic injury of the PICA and LICAP, because many LICAPs were distributed in the right 8th–11th intercostal spaces and

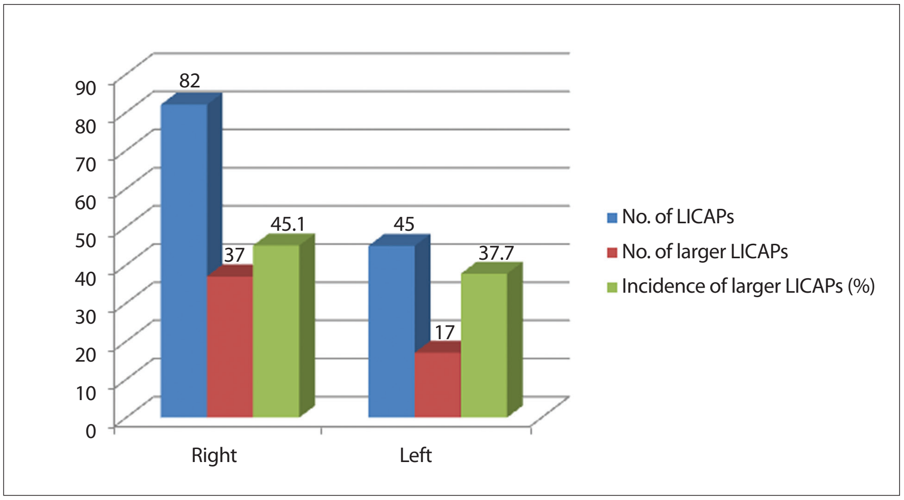

Figure 5. The comparative size of the lateral intercostal artery perforator to the collateral intercostal artery at each hemithorax.

LICAPs larger than the collateral intercostal artery were concentrically distributed in the right 4th–7th intercostal spaces. The size of the LICAP at this area can be proposed by the cross-sectional anatomic study of Da Rocha et al. (6), who documented that the average size of the collateral intercostal artery could be significantly larger when located near the lower level of the intercostal spaces; the average diameter of the collateral intercostal artery vs. the PICA on the mid-axillary line at the level of the 5th and 8th intercostal spaces was 0.6 mm and 0.5 mm vs. 1.5 mm and 3.8 mm, respectively.

Although we could not find any cases with injury to the LICAP, interventional treatment of the LICAP, or any direct comparative analysis of angiography and cross-sectional anatomy of the LICAP in the English literature, we propose the clinical significance of the LICAP as a potential risk factor for iatrogenic injury during posterior transthoracic intervention and thoracic surgery. For example, the skin incision must be made as superficially as possible and directed vertically at the right 4th–7th intercostal spaces and the medial half of the thorax.

This study has several limitations that need to be addressed. First, our retrospective design has inherent limitations, such as potential selection and recall biases that may have been present in our study. Second, the number of patients was small and drawn from a single institution, which may affect generalizability of the results. Third, the PICAs in both hemithoraces were not equally examined in all series used in this study. Fourth, we could not perform a direct comparative analysis of angiographic data and cross-sectional anatomy in the same human or cadaver subjects. Fifth, one may hypothesize that a small proportion of the LICAPs in our series may not be normal. Several LICAPs included in the study may have been possible feeding arteries to arteriopulmonary shunts or hepatocellular carcinomas occurring in the posterior portion of the lung or liver, causing them to appear larger than normal size. In order to overcome this limitation, further investigation with computed tomography angiography or angiography of the LICAP in humans or cadaveric subjects is needed.

In conclusion, awareness of anatomical variations of the LICAP is essential in clinical practice in order to avoid iatrogenic arterial injuries during posterior transthoracic procedures and surgery.

Conflict of interest disclosure

The authors declared no conflicts of interest.

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