Lung ultrasound for diagnosing pulmonary embolism

A. REISSIG

Pulmonary embolism (PE) remains a challenge for any physician because its clinical presentation covers a broad spectrum and is often similar to other cardio-pulmonary disorders. PE is still under-diagnosed due to its various/atypical clinical presentations, the dynamic of embolic processes and due to the fact that we have several diagnostic methods without 100% sensitivity and specificity.

About 5% of patients with acute PE suffer from circulatory collapse without comorbidity, about 10% from syncope with cardiovascular comorbidity, about 25% from isolated dyspnea and about 60% from pleuritic pain and/or hemoptysis [1, 2]. According to the ERC guidelines, PE is stratified for high (>15%), intermediate (3-1%) and low (<1%) mortality risk [3]. Patients with high mortality risk reveal shock or hypotension, those with intermediate risk show right ventricular dysfunction or myocardial injury, whereas patients with low risk have no evidence of these symptoms [3]. However, it has been demonstrated that the outcome of PE depends on the size of the emboli as well as on comorbidity [4].

The dynamic of embolic processes is characterised by incomplete and complete infarctions. Incomplete infarctions may disappear completely within 2 to 4 days, in accordance with resolution of the intra-alveolar haemorrhage [5]. Infarctions are visible by LUS as well as by CT [5].

Computed tomographic pulmonary angiography (CTPA) is regarded as the method of choice for diagnosing PE. Nevertheless, CTPA is limited by radiation dose, application of contrast medium and availability. Therefore, lung sonography (LUS), as a non-invasive technique, is recommended by German AWMF guidelines in patients with renal failure, pregnancy or contrast agent allergy [6].

Detection of thromboembolic lesions in the lung using ultrasound was first described by Joyner and Miller in 1966 [7, 8]. They created experimental PE in dogs and monitored changes in reflected ultrasound in the affected peripheral lung areas. In recent years, several studies have investigated the role of LUS in diagnosing PE [9-11].

Sonomorphology of pulmonary embolism

As in all other lung disorders, sonographic criteria may be categorized into parenchymal, pleural and vascular criteria.

Parenchymal criteria

Typical sonographic findings are pleural-based, wedge-shaped parenchymal lesions (Tab. I, Fig. 1). In 44 to 74% of patients, more than one lesion was detectable, ranging from 1 to 9 per patient [9, 11] with an average size of 14 x 11 mm [9] to 16 x 12 mm [11]. As a result of the multicentre study, PE is confirmed by two or more typical triangular or rounded pleural-based lesions and is considered probable in cases of one typical lesion with an accompanying pleural effusion [11]. The lesions are mostly found on the right side (43%) and occur in 27% on the left side and in about 30% on both sides of the lung [12]. About 66% of the lesions are located in the posterior basal segment of the lung [11] (Tabl. II).

Fig. 1. - Pulmonary embolism – lung sonogram. 46-year-old woman with sudden onset of dyspnea. The sonogram depicts two triangular, hypoechoic, pleural-based parenchymal lesions within the region of thoracic pain.

Pleural criteria

As in pneumonia, localized effusion and basal effusion as well as a thinned and/or fragmented hypoechoic visceral pleura line corresponding to the affected area may be detected. A localized effusion was found in about 23% of patients, a basal effusion in about 21% and both localized and basal effusion in 17% [9, 11]. Data from a multicentre study revealed pleural effusions in 49%, basal effusions in 33% and focal effusion in 16% of patients [11].

Vascular criteria

Normally, pulmonary infarction does not show any vascularity in qualitative colour Doppler sonography or contrast-enhanced sonography. Nevertheless, a congested thromboembolic vessel (vascular sign) may be visible in some cases [16, 17].

In table I, sonomorphology of patients with pulmonary embolism from two studies is compared.

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Table I

Comparison of sonomorphology in patients with pulmonary embolism.

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td>Study design</td>
<td>Patients with suspected PE, comparison to CTPA</td>
<td>Patients with suspected PE, comparison to CTPA</td>
</tr>
<tr>
<td>Established diagnosis of PE</td>
<td>N = 44 (63.8%)</td>
<td>n = 194 (55%)</td>
</tr>
<tr>
<td>Mean lesions per patient (range)</td>
<td>2.6 (1-9)</td>
<td>2.3 (1-5)</td>
</tr>
<tr>
<td>Two or more lesions per patient</td>
<td>in 74%</td>
<td>in 44%</td>
</tr>
<tr>
<td>Average size of the lesions</td>
<td>14 x 11 mm</td>
<td>16 x 12 mm</td>
</tr>
<tr>
<td>Shape of the lesions</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wedge-shaped</td>
<td>86%</td>
<td>58%</td>
</tr>
<tr>
<td>Round</td>
<td>11%</td>
<td>42%</td>
</tr>
<tr>
<td>Polygon</td>
<td>3%</td>
<td>no data</td>
</tr>
<tr>
<td>Localisation</td>
<td>80% in the lower lobes</td>
<td>66% in the posterior-basal segments</td>
</tr>
<tr>
<td>Evidence of single central echo</td>
<td>17%</td>
<td>no data</td>
</tr>
<tr>
<td>Pleural effusion</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Localised pleural effusion in LUS</td>
<td>61%</td>
<td>49%</td>
</tr>
<tr>
<td>Basal pleural effusion in LUS</td>
<td>23%</td>
<td>16%</td>
</tr>
<tr>
<td>Basal and localized effusion</td>
<td>21%</td>
<td>33%</td>
</tr>
</tbody>
</table>

CTPA : computed tomographic pulmonary angiography

Table II

Lung sonography results in detecting pulmonary embolism, comparison of current studies.

<table>
<thead>
<tr>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of patients</td>
<td>119</td>
<td>69</td>
<td>352</td>
<td>652</td>
<td>33</td>
</tr>
<tr>
<td>Study design</td>
<td>Patients with suspected PE, comparison to CTPA</td>
<td>Patients with suspected PE, comparison to CTPA</td>
<td>Patients with suspected PE, comparison to CTPA</td>
<td>Medical literature (from 1990 to 2006) in PubMed and EMBASE databases</td>
<td>Patients with suspected PE, comparison to Multi-slice-CTPA</td>
</tr>
<tr>
<td>Sensitivity</td>
<td>94%</td>
<td>80%</td>
<td>74%</td>
<td>80%; CI: 75-83*</td>
<td>70%</td>
</tr>
<tr>
<td>Specificity</td>
<td>87%</td>
<td>92%</td>
<td>95%</td>
<td>93%; CI: 89-96*</td>
<td>70%</td>
</tr>
<tr>
<td>PPW</td>
<td>92%</td>
<td>95%</td>
<td>95%</td>
<td>50%</td>
<td></td>
</tr>
<tr>
<td>NPW</td>
<td>91%</td>
<td>72%</td>
<td>75%</td>
<td>84%</td>
<td></td>
</tr>
<tr>
<td>Accuracy</td>
<td>91%</td>
<td>84%</td>
<td>84%</td>
<td>not reported</td>
<td></td>
</tr>
</tbody>
</table>

PPW: Positive predictive value; NPW: Negative predictive value; CI: 95% confidence interval; CTPA: computed tomographic pulmonary angiography

Diagnostic accuracy of lung ultrasound in diagnosing pulmonary embolism

Table II summarizes of results of current studies of LUS in diagnosing PE.

Diagnostic strategy for acute pulmonary embolism

Diagnostic strategy depends on clinical appearance. Patients with shock or hypotension are at high (>15%) mortality risk. They should immediately undergo echocardiography and, depending on the echo-result, CTPA should be performed to establish PE and rule out/in other differential diagnosis like dissection of aortic aneurysm.

In cardiopulmonary-stable patients (intermediate and low mortality risk), LUS, venous ultrasound and transthoracic echocardiography should be preferred. Combining these three ultrasound techniques, sensitivity for PE-detection increases to 92% [18]. LUS is especially helpful in patients with (often recurrent) attacks of thoracic pain. Normally, the localisation of thoracic pain changes, depending on the dynamic of new emboli and local thrombolysis of infarction.

In a study with hemodynamically stable patients with CT-confirmed PE, a flexible bronchoscopy with endobronchial ultrasound (EBUS) was performed [19]. Ninety-six percent of the thrombi detected by CT were also seen by EBUS [19]. Nevertheless, LUS seems to be more comfortable than EBUS, and not only in acute PE.

D-Dimer-testing is often regarded as necessary in the diagnostic algorithm for diagnosing PE. Nevertheless, in the multicentre study, 8% of PE-patients did not reveal elevated D-Dimer. Among other reasons, this may be dependent on clot-burden and the time-lag between acute onset and diagnosis. Therefore, D-Dimer is essential in extensive PE, but may fail in small peripheral PE.

Differential diagnosis of pulmonary embolism

In general, pneumonia, compression and obstructive atelectasis as well as lung carcinoma are the most important differential diagnoses. The sonomorphological criteria for these disorders are defined in table III.

Summary

Peripheral pulmonary embolism may be detected by LUS in about 70-94% of cases. Lesions have to reach the visceral pleura in order to be detected. For immediate diagnosis, those intercostal spaces where the thoracic pain is localized should be investigated first. Typical sonographic findings of peripheral PE are: multiple (mean 2.3-2.6 lesions per patient) wedge shaped, hypoechoic, pleural-based lesions, which are mostly well-demarcated. PE is accompanied by a basal and/or localized pleural effusion in about 50-60% of patients. The sensitivity, specificity and accuracy of LUS for diagnosing pulmonary embolism are 70%-94%, 70%-95% and 84-91%, respectively. However, inconspicuous LUS may not exclude PE, because strictly central localized PE are not detectable by LUS.
### Table III

<table>
<thead>
<tr>
<th>Pulmonary embolism</th>
<th>Pneumonia</th>
<th>Lung carcinoma</th>
<th>Compressive atelectasis</th>
<th>Obstructive atelectasis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Echogenicity</td>
<td>Hypoechoic</td>
<td>Hypoechoic</td>
<td>Moderately echoic</td>
<td>Hypoechoic, comparable to that of the liver</td>
</tr>
</tbody>
</table>

**Echotexture**

- Mostly homogeneous
- Non-homogeneous
- Mostly homogeneous
- Mostly non-homogeneous
- Homogeneous

**Shape**

- Triangular > round
- Polygonal
- Round or polycyclic
- Concave, like a jelly bag cap
- Variable shape that remains unchanged during respiration and after thoracocentesis

**Border**

- Well-demarcated, sharp margins
- Serrated margins
- Infiltrating growth possible
- Sharp and smooth
- Sharp

**Air bronchogram**

- None
- Typical feature
- None
- Often, especially visible during inspiration
- None

**Characteristic features**

- A single central echo may occasionally be present
- Fluid bronchogram may be present
- Tissue necrosis may occur
- Associated with large effusion; reduced size following thoracocentesis
- Relatively large size in comparison to the extent of effusion; fluid bronchogram may often be present

**Vascularity**

- **CDS**
  - No flow signals; “vascular sign” possible
  - Enhanced, tree-like
  - Detectable
  - Enhanced, tree-like
  - Enhanced (early) absent (late)

- **SCA**
  - BA possible
  - PA and BA
  - ICA, TN possible
  - PA
  - PA and BA

- **CES**
  - No detectability or delayed TE, reduced EE
  - Short TE, marked EE
  - Delayed TE, variable EE
  - Short TE, marked EE
  - Short TE, marked EE (early)

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**REFERENCES**


