Original Article

Diagnosis efficiency for pulmonary embolism using magnetic resonance imaging method: a meta-analysis

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Received November 5, 2014; Accepted January 10, 2015; Epub August 15, 2015; Published August 30, 2015

Abstract: PE (Pulmonary embolism, PE) is a common disease, usually caused by blockage of pulmonary artery and its branches due to exogenous or endogenous embolic obstruction. PE always be misdiagnosed in clinical. The aim of this study is to calculate the sensitivity and specificity of magnetic resonance imaging (MRI) in assessing the resectability of PE. In this study, a meta-analysis of the reported sensitivity and specificity of each study with 95% confidence intervals (CI) was performed. Five studies were included in the meta-analysis. The results indicated that the quality assessment scores ranged from 11 to 13, with a mean study quality score of 12. The sensitivity and specificity values including 95% CI at the patient level were calculated. The sensitivities ranged from 78% to 100%, and the specificity ranged from 99% to 100%. The pooled sensitivity value including 95% CI was 0.83 (0.78-0.88), and with inconsistency (I²) of 62.8%. The pooled specificity value including 95% CI was 0.99 (0.98-1.00), with inconsistency (I²) of 0.0%. Pooled positive likelihood ratio (PLR) (95% CI) was 70.22 (29.04-169.76), and the pooled negative likelihood ratio (NLR) (95% CI) was 0.19 (0.14-0.25). The overall diagnostic odds ratio (DOR) (95% CI) was 448.98 (163.47-1233.18). The summary receiver operating characteristic (SROC) data illustrated that the area under the curve (AUC) was 0.9852. In conclusion, the MRI method may be acts as a potential and assistant method for the PE diagnosis.

Keywords: Pulmonary embolism, magnetic resonance imaging, diagnosis, meta-analysis

Introduction

PE (Pulmonary embolism, PE) is a common disease, usually caused by blockage of pulmonary artery and its branches due to exogenous or endogenous embolic obstruction [1]. The PE could also result in pulmonary circulation disorders and blood flow interruption in lung tissue, and leading to lung tissue necrosis pathological changes, which is also called pulmonary infarction [2].

PE misdiagnosis often appears clinically. In recent years, CT (computed tomography) technology has been very mature one for the diagnosis of pulmonary embolism with good sensitivity and specificity [3]. Meanwhile, Magnetic Resonance Imaging (MRI) is also commonly used in the diagnosis of pulmonary embolism [4-6]. Compared to CT, MRI has the advantage that there is no ionizing radiation, nor the use of iodinated contrast media, which has small hazard to the patient’s health [7]. This meta-analysis aims to investigate the diagnostic validity of MRI in PE.

Methods

Search strategy

We searched PUBMED, EMBASE and Springer for relevant citations. The search was completed in June 2014 and covered published literature since January 1990 (Figure 1). The terms in the search were “Pulmonary Embolism” AND (“MR imaging” OR “MR” OR “MRI” OR “Magnetic Resonance Imaging” OR “Magnetic Resonance”). The reference lists of known previous reviews and of all of the primary studies included were examined to identify cited articles not found by the electronic searches (Figure 1). There were no restrictions regarding publication language.

Eligibility criteria

Titles and abstracts identified by the electronic search were analyzed by two independent
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Methodological quality was assessed independently by the same reviewers based on the Quality Assessment of Studies of Diagnostic Accuracy included on Systematic Reviews (QUADAS) guidelines [8]. Disagreement was resolved by consensus (Table 1). This evidence-based tool was developed specifically to assess the quality of diagnostic accuracy studies and includes 14 quality items. The 14 items, phrased as questions, are scored as “yes,” “no,” or “unclear.” The quality assessment score can range from 0 to 14, where 14 is the maximum attainable score (Table 1). A more detailed description of each item, together with a guide on how to score each item, is provided by Whiting et al. in 2003 [8]. Additionally, we noted whether the study design was prospective or retrospective.

Statistical analysis

This meta-analysis was performed with MetaDisc (1.4.0.0) statistical softwares [9]. Primary outcomes of this meta-analysis were summary receiver operating characteristic (SROC) curve, sensitivity (sensitivity, Sen), specificity (specificity, Spe), positive likelihood ratio (positive likelihood ratios, PLR), negative likelihood likelihood ratio (negative likelihood ratios, NLR), diagnostic tests odds ratio (diagnostic odds ratio, DOR) and their 95% confidence intervals (confidence intervals, CI).

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Figure 1. Flow chart of the study selection procedure.
### Table 1. Quality assessment of the included articles

<table>
<thead>
<tr>
<th>QUADAS list item</th>
<th>Reference number of the included studies</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Did the spectrum of patients represent the patients who will receive the test in practice?</td>
<td>+ + + + + + + +</td>
</tr>
<tr>
<td>2. Were selection criteria clearly described?</td>
<td>+ + + + + + + +</td>
</tr>
<tr>
<td>3. Is the reference standard likely to correctly classify the target condition?</td>
<td>+ + + + + + + +</td>
</tr>
<tr>
<td>4. Is the period between the reference standard and index test short enough to be reasonably sure that the target condition did not change between the 2 tests?</td>
<td>+ + + + + + + +</td>
</tr>
<tr>
<td>5. Did the entire sample or a random selection of the sample receive verification using a reference standard of diagnosis?</td>
<td>+ + + + + + + +</td>
</tr>
<tr>
<td>6. Did patients receive the same reference standard regardless of index test result?</td>
<td>+ + + + + + + +</td>
</tr>
<tr>
<td>7. Was the reference standard independent of the index test (i.e., index test did not form part of the reference standard)?</td>
<td>+ + + + + + + +</td>
</tr>
<tr>
<td>8. Was execution of the index test described in sufficient detail to permit replication of the test?</td>
<td>+ + + + + + + +</td>
</tr>
<tr>
<td>9. Was execution of the reference standard described in sufficient detail to permit its replication?</td>
<td>+ + + + + + + +</td>
</tr>
<tr>
<td>10. Were index test results interpreted without knowledge of results of the reference standard?</td>
<td>+ - + 0 0 0</td>
</tr>
<tr>
<td>11. Were reference standard results interpreted without knowledge of results of the index test?</td>
<td>- + 0 0 +</td>
</tr>
<tr>
<td>12. Were the same clinical data available when test results were interpreted as would be available when the test is used in practice?</td>
<td>+ 0 0 0 0</td>
</tr>
<tr>
<td>13. Were uninterruptable/intermediate test results reported?</td>
<td>+ + - + - +</td>
</tr>
<tr>
<td>14. Were withdrawals from the study explained?</td>
<td>+ + + + + +</td>
</tr>
</tbody>
</table>

**QUADAS:** Quality Assessment of Diagnostic Accuracy Studies. +: YES; -: NO; 0: not clear.
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Literature search

The literature search identified 1542 articles (Figure 1). After screening of the titles and abstracts, 1231 items was remained because the duplication. Among the 1231 items, 1214 items were excluded because one or more inclusion criteria were not fulfilled. The remaining 17 articles were evaluated by reading the full text. Of these, 12 were excluded (the reasons are given in Figure 1). The remaining 5 studies were included in the meta-analysis [7, 13-16]. The study characteristics are shown in Table 2.

Quality assessment

The quality assessment scores of this study ranged from 11 to 13, with a mean study quality score of 12 (Table 2). All of the studies with the higher quality.

MRI detection for sensitivity and specificity

The results showed that all of the MRI detection with the relative higher sensitivity and specificity (Figure 2). The sensitivity and specificity values including 95% CI at the patient level were calculated. The sensitivities ranged from 78% to 100%, and the specificity ranged from 99% to 100%. The pooled sensitivity value including 95% CI was 0.83 (0.78-0.88). The specificity value including 95% CI was 0.99 (0.98-1.00) (Figure 2A). The pooled specificity value including 95% CI was 0.99 (0.98-1.00) (Figure 2B). The sensitivity and specificity values including 95% CI at the patient level were calculated. The sensitivities ranged from 78% to 100%, and the specificity ranged from 99% to 100%. The pooled sensitivity value including 95% CI was 0.83 (0.78-0.88), and the specificity value including 95% CI was 0.99 (0.98-1.00) (Figure 2A). The pooled specificity value including 95% CI was 0.99 (0.98-1.00) (Figure 2B).

Table 2. Characteristics of each included study

<table>
<thead>
<tr>
<th>id</th>
<th>Author reference</th>
<th>year</th>
<th>Country</th>
<th>Magnetic field intensity</th>
<th>MRI scan sequence</th>
<th>n</th>
<th>M/F</th>
<th>Age</th>
<th>TP</th>
<th>TN</th>
<th>FP</th>
<th>FN</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Kluge [5]</td>
<td>2006</td>
<td>Germany</td>
<td>1.5T</td>
<td>3-D FLASH</td>
<td>65</td>
<td>34/31</td>
<td>60.9±15.7</td>
<td>15</td>
<td>43</td>
<td>0</td>
<td>4</td>
</tr>
<tr>
<td>2</td>
<td>Revel [12]</td>
<td>2012</td>
<td>French</td>
<td>1.5T</td>
<td>3-D FSPGR/SSFP/GRE</td>
<td>274</td>
<td>127/147</td>
<td>59.8±19.0</td>
<td>87</td>
<td>170</td>
<td>1</td>
<td>16</td>
</tr>
<tr>
<td>3</td>
<td>Zhang [14]</td>
<td>2013</td>
<td>China</td>
<td>3 T</td>
<td>3-D FLASH</td>
<td>27</td>
<td>18/9</td>
<td>38.9±14.4</td>
<td>24</td>
<td>3</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>4</td>
<td>Stein [13]</td>
<td>2010</td>
<td>USA</td>
<td>1.5T/3T</td>
<td>NA</td>
<td>279</td>
<td>NA</td>
<td>≤18</td>
<td>59</td>
<td>201</td>
<td>2</td>
<td>17</td>
</tr>
<tr>
<td>5</td>
<td>Pleszewski [11]</td>
<td>2006</td>
<td>Canada</td>
<td>1.5T</td>
<td>3-D SEGP</td>
<td>34</td>
<td>20/28</td>
<td>22.8±4</td>
<td>9</td>
<td>23</td>
<td>0</td>
<td>2</td>
</tr>
</tbody>
</table>

3-D: 3-dimensional; FLASH: fast low-angle shot gradient-echo sequence; FSPGR: fast spoiled gradient echo; SSFP: Steady-state-free precession; GRE: gradient recalled echo; SEGP: spoiled echo gradient pulse; NA: Not available.

Figure 2. Sensitivity and specificity of MRI detection for the diagnosis of PE. A. The sensitivity of MRI detection for the diagnosis of PE. B. The specificity of MRI detection for the diagnosis of PE. PE: Pulmonary embolism; CI: confidential interval; MRI: Magnetic Resonance Imaging.
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CI was 0.99 (0.98-1.00), \( Q = 1.21 \), df =4 \( (P=0.8762) \), inconsistency \( (I^2) = 0.0\% \) (Figure 2B).

**Pooled PLR and NLR**

Our results indicated that the pooled positive likelihood ratio (PLR) (95% CI) =70.22 (29.04 to 169.76), \( Q = 3.49 \), df =4 \( (P=0.4802) \), inconsistency \( (I^2) = 0.0\% \) (Figure 3A). The pooled negative likelihood ratio (NLR) (95% CI) =0.19 (0.14 to 0.25), \( Q = 3.86 \), df =4 \( (P=0.4258) \), inconsistency \( (I^2) = 0.0\% \) (Figure 3B).

**DOR and SROC curves**

Overall diagnostic odds ratio (DOR) and summary receiver operating characteristic (SROC) curves for the diagnostic performance of MRI detection was drew. The DOR (95% CI) =448.98 (163.47 to 1233.18), \( Q = 1.01 \), df =4 \( (P=0.9077) \), inconsistency \( (I^2) = 0.0\% \) (Figure 4A). The SROC data illustrated that the AUC was 0.9852 (Figure 4B).

**Discussion**

Clinically, the diagnosis of PE always be performed by using the CT method. However, the CT may cause some side-effects compared with the MRI method [19]. The method acts as a diagnostic tool depends on the sensitivity and the specificity for the disease [20]. The present meta-analysis study involves the studies of Magnetic Resonance Imaging (MRI) for diagnosis of PE. By analyzing the data in these studies, we found that MRI is a highly accurate diagnostic efficiency with a pooled sensitivity of 83% and a pooled specificity of 99%.

Furthermore, the positive likelihood ratios (PLR), negative likelihood ratios (NLR), diagnostic odds ratio (DOR) and 95% confidence intervals (CI, 29.04 to 169.76) were also higher enough for the method applies as a diagnostic tool in clinical. For the area under the curve analysis, the AUC level was also close to 1, which suggests that MRI method with a better diagnostic efficiency.

The MRI method has been used in the assistant diagnosis for many other diseases. Nael et al. [21] used the six-minute magnetic resonance imaging protocol to evaluate the acute ischemic stroke, which results in significant reduction in scan time rivaling that of the multimodal computed tomographic protocol. Puskas et al. [22] indicated that the diffusion-weighted magnetic resonance imaging with conventional sequences is a useful and promising functional imaging modality in the early diagnosis of myeloma multiple. Thompson et al. [23] also found that the MRI plays a useful role in the diagnosis and management of the prostate cancer, and appears to be of value in planning dosimetry in men undergoing radiotherapy, and in guiding selection for and monitoring on active surveillance. Filippi et al. [24] also analyzed the application and exploring the insights of the magnetic resonance imaging for some other diseases, and pointed out that all of the conventional and non-conventional MRI techniques will be benefit from the use of high-field MRI systems (3.0T or more).
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Figure 4. Overall DOR and SROC curves for the diagnostic performance of MRI detection in PE. A. Overall DOR curves for the diagnostic performance of MRI detection. B. SROC curves for the diagnostic performance of MRI detection. DOR: diagnostic odds ratio; SROC: summary receiver operating characteristic; AUC: area under the curve.

Though the MRI has been used in many diseases, there are also some disadvantages as the followings: (1) The samples are relatively small, which may affect the statistical efficiency for the diagnosis; (2) Though there are not the threshold effect and no-threshold effects, the heterogeneity may exist among the researches; (3) This study only included the published studies, the un-published documents may be omitted, which may also cause the false positive and amplify the diagnostic efficiency of MRI.

In conclusion, the data of this meta-analysis suggests that the MRI method for PE diagnosis with a higher sensitivity and specificity, and also with lower misdiagnosis rate and missed diagnosis rate. The MRI method may be acts as a potential and assistant method for the PE diagnosis.
Disclosure of conflict of interest

None.

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References


