Comparison of CT Pulmonary Angiography Quality at Low Tube Voltage (80 Kvp) With Standard Conditions (100 Kvp) Among the Patients with Suspected Pulmonary Embolism

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Abstract:
Background: Pulmonary embolism (PE) is a common and potentially devastating cardiovascular complication with a high mortality rate, worldwide. The diagnosis based solely on the presence of clinical features remains challenging due to heterogeneity of the nonspecific manifestations of the disease. CT pulmonary angiography (CTPA) is a fast, accurate and cost effective diagnostic test of PE, as the radiation exposure to the patient is the major disadvantage of this technique. Since voltage drop result in reduce radiation exposure, comparison of image quality at different tube voltages may provide an optimum and secure voltage for patients.

Aim: Comparison of CTPA quality at low tube voltage (80 kVp) with standard conditions (100 kVp) among the patients with suspected pulmonary embolism, referred to the Golestan Hospital, Ahvaz.

Materials and methods: In this triple-blind clinical trial, 92 patients with suspected PE already admitted to the Golestan Hospital, randomly divided into two equal groups and CTPA was performed at 2 different dose protocols: group A (80 kVp) and group B (100 kVp). The groups were then compared based on the image quality scores reported by two radiologists, along with the image quality parameters (SNR, and CNR) and the radiation dose (DLP).

Results: The overall image quality score of in-group A was higher than that in-group B (p = 0.002). Although group A was also superior (P < 0.0001) to group B with regard to image noise, but the signal-to-noise ratio (SNR) and the carrier-to-noise ratio (CNR) values were similar at different contrast levels for both groups. In addition, the radiation dose (DLP) was lower in-group A than in-group B.

Conclusion: The results indicated that a reduction in tube voltage from 100 kV to 80 kV in CTPA could both reduce the radiation dose and improve the diagnostic image quality.

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Introduction

Pulmonary embolism (PE) is a common and potentially devastating cardiovascular complication with a high mortality rate, as the prevalence ranges from 60 to 70 per 100,000 individuals, worldwide (1). The diagnosis based solely on the presence of clinical features remains challenging due to heterogeneity of the nonspecific manifestations of the disease (2). Yet, PE-related deaths (94%) are largely due to diagnostic errors (3) and therefore, evaluation of clinical signs have low sensitivity through the diagnosis of PE. Several new methods have been developed with the aim of improving diagnostic accuracy of PE patients in the future. Algorithm for the diagnosis of PE has undergone several fundamental changes in recent years. CT pulmonary angiography (CTPA) has become the first choice for diagnosing PE due to its low complication rate, as well as fast and sensitive
function (4). Diagnostic accuracy of PE on CTPA is greatly depend on the technology that is used, as currently multidetector CT applications have the ability to readily detect the PE with the sensitivity ranging from 84% of 94% and specificity ranging from 94% to 100% (5).

Nowadays, using radiological techniques have raised concerns about the increased cancer risks associated with radiation. It is estimated that approximately 1.5-2% of all malignancies may be secondary to medical imaging exposure (6). Moreover, multi-slice CT expose patients to more radiation than single-slice CT (7). Therefore, radiation dose reduction alongside the diagnostic quality maintenance of CTPA seem to be vital through the safety process improvement of this technique.

Several studies have shown that the voltage drop could result in a significant reduction of radiation dose, without compromising the image quality (8). Evaluation of image quality at low tube voltages have also been proposed to find an optimal protocol for detection of PE. Our aim is to compare the image quality of 80 with 100 kVp CTPA in patients with suspected PE.

Materials and methods
Study design. In this triple-blind clinical trial, 92 patients with suspected PE already admitted to the Golestan Hospital, randomly divided into two equal groups. Patients with one or more than one contraindication for CTPA, including renal failure, pregnancy, respiratory tract problems, hyperthyroidism and seizure were excluded from the study. All the patients signed a consent form and the research has been approved by the Research Ethics Committee of Ahvaz Jundishapur University of Medical Sciences.

CTPA was performed at two different dose protocols for patients with suspected PE: intervention group (group A) at 80 kVp and control group (group B) at 100 kVp. The main variables that were focused in each group are the measurable pulmonary artery pressure in different lung segments, the resonance assessment of the pulmonary arteries, image noise and the image quality score. Patients were assigned into two groups with different voltages by a block randomization. Using a triple-blind design, the doctor had no voltage information regarding to reported image. All the images were numbered by a fellow researcher, who did not interfere with the image production, reporting and the data analysis. Finally, the analysis specialist was also unaware of all image sources.

CT angiography protocol. All CTPA examinations were performed on a computed tomography scanner (Somatom Sensation, Siemens, Germany). The tube voltage of 80 kVp and 100 kVp were set to intervention and control groups, respectively. Visipaque contrast agent was injected into the cubital vein at 4cc/s. Imaging protocols were assessed for parallel beams of 16×0.75 mm, slice thickness of 5mm, rotation time of 0.42 s, pitch 1.2 and reconstruction of 2.0 mm.

Quantitative assessment of image quality. The signal intensity (RI) of the main pulmonary artery (MPA) was measured in order to assess the obstruction of central pulmonary arteries. Image noise measurements were then done at three homogeneous area with no mobility or artifacts. In addition, the image quality assessment indexes, including the signal-to-noise ratio (SNR) and the contrast-to-noise ratio (CNR) were evaluated in different lung segments by the following formulas:

CNR= average signal- average signal of right ventricular/noise
SNR= signal/noise

Qualitative assessment of image quality. Images were then scored from 1 to 5:
Score 1. Very poor image quality with no diagnostic information
Score 2. Low image quality with reduced diagnostic reliability
Score 3. Medium picture quality with sufficient diagnostic reliability
Score 4. Good image quality with representation of anatomical structures
Score 5. High picture quality with low ability to differentiate anatomical structure differences

Radiation dose estimation. The dose length product (DLP) values of all the patients were measured and recorded in order to estimate the amount of radiation dose.

Statistical analysis. Statistical analyses were performed using SPSS 19.0. The results were considered significant with a P-value of less than 0.05. Kolmogorov-Smirnov test was used to assess the normal distribution of multiple variables at 80 and 100 kVp. The comparison between the images quality, radiation dose, patient characteristics and the scan parameters at 80 and 100 kVp was
performed through the t-student test. Finally, Wilcoxon test was used to assess the differences of contrast volume and dose with the qualitative assessment of image quality at 80 and 100 kVp.

**Results**

Comparison of individual parameters for each group are summarized in Table 1. The results indicate that there is no statistically significant difference between the groups (Table 1). Image quality scores showed that the intervention group (80kVp) had higher images quality than the control group which is statistically significant (p = 0.002). However, the evaluation of SNR and CNR indexes at different voltage levels did not show significant differences between the two groups. The mean ± SD of image noise were 69.45 ± 32 and 42.3 ± 9.1 in the intervention and control groups, which is statistically significant. The DLP value was significantly lower in group A than in group B (51.43 ± 37.4 vs 140.78 ± 84.4) (Table 2).

**Table 1. Demographic characteristics of participants.**

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Group 1, Voltage 80 n=46</th>
<th>Group 1, Voltage 100 n=46</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>48.1</td>
<td>46.6</td>
<td>NS</td>
</tr>
<tr>
<td>Sex</td>
<td>Male</td>
<td>19</td>
<td>27</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>21</td>
<td>25</td>
</tr>
<tr>
<td>BMI</td>
<td>26.5</td>
<td>26.4</td>
<td>NS</td>
</tr>
</tbody>
</table>

**Table 2. Image quality of low voltage (80 kVp) in comparison with high voltage(100 kVp).**

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Group 1, Voltage 80 n=46</th>
<th>Group 1, Voltage 100 n=46</th>
<th>p Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>DLP</td>
<td>51.43±37.4</td>
<td>140.78±84.4</td>
<td>p&lt;0.0001</td>
</tr>
<tr>
<td>SNR</td>
<td>SNR 1</td>
<td>0.75</td>
<td>0.71</td>
</tr>
<tr>
<td></td>
<td>SNR 2</td>
<td>-0.014</td>
<td>-0.20</td>
</tr>
<tr>
<td></td>
<td>SNR 3</td>
<td>0.86</td>
<td>0.55</td>
</tr>
<tr>
<td></td>
<td>SNR 4</td>
<td>0.73</td>
<td>0.43</td>
</tr>
<tr>
<td>CNR</td>
<td>CNR 1</td>
<td>8.74±5.3</td>
<td>9.73±6.54</td>
</tr>
<tr>
<td></td>
<td>CNR 2</td>
<td>7.97±4.8</td>
<td>8.8±6.8</td>
</tr>
<tr>
<td></td>
<td>CNR 3</td>
<td>8.85±5.4</td>
<td>9.57±5.9</td>
</tr>
<tr>
<td></td>
<td>CNR 4</td>
<td>8.72±5.8</td>
<td>9.4±5.8</td>
</tr>
<tr>
<td>Image quality</td>
<td>poor</td>
<td>0 (2.2%)</td>
<td>1 (2.2%)</td>
</tr>
<tr>
<td>score</td>
<td>fair</td>
<td>0 (4.3%)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Good</td>
<td>3 (6.5%)</td>
<td>14 (30.4%)</td>
</tr>
<tr>
<td></td>
<td>Excellent</td>
<td>43 (93.5%)</td>
<td>29 (63%)</td>
</tr>
</tbody>
</table>

**Discussion**

Nowadays, CTPA has become the first choice assay for diagnosis of patients with suspected PE. More recently, the wide popularity and acceptance of this technique has created concerns about the serious effects of CTPA radiation on exposure cases especially girls, who constitute approximately half of the patient population. Therefore, various studies have explored solutions for radiation dose reduction alongside the diagnostic quality maintenance of CTPA. In general, voltage reduction is one of the well-studied methods in this regard (8-10). Our
findings have showed that not only the voltage drop has not lead to a loss of image quality or diagnostic accuracy of PE, but the overall image quality score of in group A is higher than that in group B. Although Gill et al. (11) have observed a lower image quality score among the patients receiving CTPA of low voltage, but could not found a significant difference in comparison to high voltage group. It appears that our findings are in parallel with results obtained from the other investigations (12-14), in which the noise of the CTPA increased among the low tube voltage cases, while the SNR and CNR values were similar at different contrast levels for both groups. However, Qi et al. demonstrated that the SNR and CNR, as well as image quality scores have a significant increase among the low voltage group (70 kVp), compared to patients receiving CT of high voltage (120 kVp) (15). This result might be due to differences in value of evaluated voltages. These findings can cause to make assumptions that the value voltage variations are associated with the extensive changes of mentioned factors. However, more studies are needed in this field to come to a definite conclusion.

Study results also suggested a relationship between the radiation dose and voltage value, as the DLP values were significantly lower in studied individuals with low tube voltage, compared to high voltage group. Yilmaz et al. were also showed the significant differences of DLP value between the three studied groups at different tube voltage settings (80, 100 and 120 kVp) (16). Other studies have also reached similar results (11, 13).

In general, our results showed that the voltage drop could result in a significant reduction of radiation dose and provide images with high diagnostic quality. The limitations of the study are small sample size and the lack of investigation at conventional voltage ranges, while the analysis of two matched groups of patients’ outcome is considered as the strengths of our study.

References


