Pulmonary Embolism - radiation doses of new generation low dose CTPA v/s V-Q scan

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Learning Objectives

1. To recognize the major reductions in radiation doses with new generation Multi Detector Computed Tomography (MDCT) scanners in CT Pulmonary Angiography (CTPA).
2. To understand the resulting modifications to the diagnostic algorithm for suspected PE. (See Fig. 1)
**Fig. 1:** Diagnostic Imaging pathway for Suspected Pulmonary Embolism

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Background

- Pulmonary embolism (PE) can mimic any cardio-pulmonary disease such as pneumonia, pericardial effusion, abscess and malignancy. But the incidence of PE is only around 4% among patients with cardio-pulmonary symptoms. Most institutions advocate Computed Tomography-Pulmonary Angiography (CTPA) as the choice of investigation for acute pulmonary embolism, but in the young, particularly females with sensitive breast tissue, Ventilation-Perfusion Scintigraphy (V-Q scan) is often advocated as the first choice following the preliminary chest radiography and lab investigations for reasons of lower radiation exposure.

- Clinical decision rules like the Wells Criteria and Revised Geneva Criteria have been well validated and the available literature supports the use of either to increase the diagnostic yield of imaging in suspected acute pulmonary embolism.

- Although CTPA has been shown to have higher diagnostic yield and accuracy than V-Q scan, having a higher radiation dose compared to V-Q scan has been a limiting factor in advocating it to young females with sensitive breast tissue.

- The initial Prospective Investigation of Pulmonary Embolism Diagnosis (PIOPED) study reported around 70% of ventilation-perfusion scans were nondiagnostic in the study but the recent PIOPED II study reports similar diagnostic accuracies for V-Q scans and CTPA. Citing the large difference (avg. 70-fold) in radiation doses between conventional CTPA and V-Q scans, many authors have suggested V-Q scans to be the imaging modality of choice especially when the initial chest radiograph is normal. But, it is of interest to note that the comparisons used in the PIOPED II study were from 120 kVp MDCT settings with high tube currents.

- Are the differences in radiation doses so profound as have been claimed between V-Q scans and CTPAs? With more new generation low dose CT scanners and protocols being employed, What is the current comparison?
• Catheter Pulmonary Angiography is the historical gold standard for diagnosing Pulmonary Embolism. More than 40 years ago, perfusion lung scanning was introduced and owing to its non-invasive nature compared to catheter angiography, readily replaced the latter during the 1980s and 1990s as the modality of choice.[2]

• Early 1990s saw the emergence of Helical CT which enabled visualizing pulmonary arterial trees though limited to those located centrally, and by the early 2000s CTPA had overtaken V-Q scans as the preferred choice of investigation for suspected acute pulmonary embolism in many centres. However, the large difference in the effective radiation dose to the body, especially to female breast tissue which is highly radiation-sensitive, meant V-Q scanning would remain as the first choice in this group of patients.

• Early Single-slice Helical CT scanners have largely been replaced by 16-64 slice (or higher) Multi-Detector CT scanners (MDCT) in many of the secondary and tertiary referral centres. MDCTs increased the accuracy of CTPAs in detecting sub-segmental emboli but at the same time due to overlap of imaging, increased the overall radiation doses.

• Technological advancements in CT have been progressing at an impressive rate and ways to reduce the effective tissue doses to various organs during these procedures using tube current and energy modulations, iterative reconstruction techniques, organ-specific protocols and breast shielding have all been shown to be effective. [7,8,12,13,14,15,16]

• The average estimated effective dose to the body in general is around 1.3 mSv for a V-Q scan and around 4-5 mSv for CTPA. The absorbed dose for breast tissue however is around 10-70 mGy for CTPA and <1.5 mGy for a V-Q scan. [9,10,11]

• New generation MDCTs (64 slice) with low tube energies (80kVp, 100kVp and 120 kVp) have been shown to reduce the effective radiation doses by ≥ 70% compared to 140kVp tube energy without compromising the image quality and diagnostic yield. The sensitivity, specificity and likelihood ratios of a CTPA with 80 kVp setting is similar to that of higher settings. [1,3,4,5,9] (See Fig. 2 - Fig. 6)

• Recent studies using a 64 slice MDCT reported phantom absorbed doses of 1.4-2.3 mGy & 1.1-1.6 mGy for breast skin & parenchyma respectively with 80 kVp, 3.5-6.0 mGy & 4.6-5.8 mGy with 100 kVp and 14.5-17.0 mGy & 8.5-13.6 mGy with 120 kVp settings depicting major reductions in radiation doses by lowering tube energies to 80 kVp and 100 kVp. [6,7,8] (See Fig. 7)
<table>
<thead>
<tr>
<th>Tissue Type</th>
<th>80 kVp</th>
<th>100 kVp</th>
<th>120 kVp</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breast Skin</td>
<td>1.4-2.3 mGy</td>
<td>3.5-6.0 mGy</td>
<td>14.5-17.0 mGy</td>
</tr>
<tr>
<td>Breast Parenchyma</td>
<td>1.1-1.6 mGy</td>
<td>4.6-5.8 mGy</td>
<td>8.5-13.6 mGy</td>
</tr>
</tbody>
</table>

Phantom study absorbed dose results on a 64 slice MDCT with low tube voltage settings [6]

- Compared to previously reported breast absorbed doses of 10-70 mGy using standard tube energy (140 kVp), 2.3mGy using 80 kVp protocol reflects a radiation reduction in excess of 75%.
- Combined with bismuth shielding and iterative reconstruction, this reduction in radiation exposure at low tube energies may be further magnified and be will in-line with that of a standard V-Q scan.
Fig. 2: 80 kVp CTPA

**Fig. 3: 100 kVp CTPA**

**Fig. 4:** 80 and 120 kVp CTPA comparison

**Fig. 5:** 80 and 120 kVp CTPA comparison

Fig. 6: 80 and 120 kVp CTPA comparison

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Fig. 7: Phantom study on radiation doses during CTPA

Conclusion

By reducing tube energy levels in new generation MDCTs, it has been successfully shown by a number of studies that major reductions in radiation doses can be achieved without compromising image quality and with the added advantage of reduced volume of contrast required. Maintaining the ability to diagnose many other abnormalities detected by CT and avoiding the significant number of non-diagnostic studies with V-Q scans are important additional advantages of CTPA. Thus, CTPA can be the preferred choice of investigation for acute PE even in young women so long as no contraindications exist for injecting contrast material and new generation MDCTs with dose modulation technologies are available. Further research involving all the available dose reduction techniques in CTPA while evaluating the image quality, diagnostic yield and effective radiation to specific organs would be highly beneficial in directing future imaging guidelines in pulmonary embolism.

A revised diagnostic algorithm for PE is also presented.

A limitation of these findings would be a lack of quality studies on radiation doses in patients with high BMI. V-Q scan may still have a significant role in these patients especially young women with high BMI.
Fig. 1: Diagnostic Imaging pathway for Suspected Pulmonary Embolism

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