Ventilation/Perfusion SPECT versus multidetector CT of pulmonary arteries, CTA

M. Bajc, Lund (SE) and B. Jonson, Lund (SE)

Introduction

Pulmonary embolism is an acute ailment, which should be treated as soon as possible in order to avoid deterioration and potentially death. Diagnosis cannot be set on the basis of clinical observations. Imaging tests are therefore essential for proper diagnosis and treatment. The imaging tests used for this purpose are:

1. Conventional pulmonary angiography (PA), previously regarded as the gold standard
2. Ventilation and Perfusion scintigraphy was for a long time the principal diagnostic method of choice. Occasionally, perfusion-only lung scanning is performed.
3. CTPA is now frequently cited as the primary diagnostic method for PE diagnosis.

As PA has been shown to have limited sensitivity and specificity, PA does not deserve the status as gold standard. PA is invasive and difficult to perform. PA has become rarely used apart from in very special cases in centres with highly qualified angiographers.

Ventilation/Perfusion scintigraphy can be performed with planar technique and with single photon emission tomography, V/P_{SPECT}. Compared to planar technique, V/P_{SPECT} has been shown to have higher sensitivity and specificity and yields much lower numbers of non-diagnostic studies. V/P_{SPECT} is as easy and fast to perform as planar studies. The advantages of V/P_{SPECT} over planar technique has led to that V/P_{SPECT} is recommended in EANM guidelines. This presentation will therefore focus on V/P_{SPECT}.

Bronchopulmonary segments have a conical shape, with its apex pointing towards lung hilus and its along the pleural surface. Thrombi occuluding pulmonary arteries therefore lead to lobar, segmental or subsegmental wedge shape perfusion defects with its base along the lung periphery. Ventilation is not affected. This leads to a pattern of preserved ventilation and absent perfusion known as V/P mismatch, Fig. 1. Areas with mismatch due to PE are commonly multiple, partly because emboli fragment in the right heart.

A normal pulmonary perfusion pattern excludes PE. PE can be a single event or a recurring process giving rise to multiple emboli over short or long periods of time. Apart from PE, V/P mismatch is rarely caused by other disorders such as congenital pulmonary vascular abnormalities, vasculitis and lung cancer.

Ventilation is studied after inhalation of a radioactive aerosol of liquid or solid particles. The particles become deposited in the periphery of the lung in proportion to regional ventilation. The liquid aerosol used is ^{99m}Tc-diethylen-tetraamino-pentaacetate, ^{99m}Tc-DTPA. The droplets should be less than 2 micron so that they reach the lung periphery. Technegas® is an aerosol of solid graphite particles. The average diameter of <0.2 micron implies that it reaches the lung periphery even in patients with obstructive lung disease.

Perfusion scintigraphy is based on i.v. injection of radio-labelled particles causing microembolization within the pulmonary circulation in proportion to perfusion. The particles are macro aggregates of human albumin (MAA), labelled with ^{99m}Tc, 15-100 microns in diameter.

Fig 1 shows a sagittal slice of left lung in a patient with PE. The perfusion defect is wedge shaped. Ventilation is preserved. The abnormality is highlighted in the V/P

V/P_{SPECT} can be performed in less than one hour when ventilation is studied immediately before perfusion using a large field-of-view dual head gamma camera. With optimal combination of activities and acquisition times used for ventilation and perfusion, collimators and image matrices one can used very low isotope doses, i.e. 25-30 MBq for ventilation studies and 100-120 MBq for perfusion studies and still obtain images of adequate quality with a total time under the camera of only 20 minutes [1]. The image acquisition procedure is quite practical for the staff. Radiation doses are very low using the recommended low doses of isotopes. Effective dose for V/P_{SPECT} is 1.8-2 mSv and absorbed dose to breast is 0.8 mGy [2].

Pregnancy, particularly during the first trimester, poses unique circumstances in relation to radiation hazards. In pregnant women, the interpretation of lung perfusion scintigraphy is usually straightforward because of low frequency of co-morbid pulmonary disorders. Therefore, to minimize radiation, a one to two day protocol is suggested. Perfusion-only scans should be performed on day 1, using a reduced dose of ^{99m}Tc-MAA. In most cases PE can be excluded on the basis of a normal perfusion pattern. When the perfusion pattern is abnormal but not diagnostic of PE, subcutaneous low molecular heparin can be given until a ventilation study is performed on day 2, using an activity deposited in the lung of 20-30 MBq. After the first trimester the standard 1 day protocol or the one to two day protocol can be used. During the first trimester the recommended dose for perfusion study (50 MBq) gives a fetal absorbed dose of 0.1-0.2 mGy. The absorbed dose to the female breast is 0.25 mGy.

Tomographic images are obtained with iterative reconstruction and they are presented in frontal, sagittal and transversal projections as well as in rotating 3-D images. Standard software can be used.

V/P_{SPECT} has no contraindications. It can be performed in 99 % of eligible cases. The diagnostic performance of V/P_{SPECT} is superior with high sensitivity, specificity and 1% of non-diagnostic tests [3].

Multidetector row spiral CT scanning or multislice CT (CTA) is a technological evolution of spiral CT which uses CT scanners equipped with an array of multiple X-ray detectors that can simultaneously image multiple sections of the patient during a rapid volumetric image acquisition. Currently used CTA machines have usually 16 detectors. To highlight the pulmonary arteries a bolus of i.v. iodine contrast is used. Subsequent images are obtained during the injection of contrast (via a vein in the anticubital fossa). Computed tomographic pulmonary angiographic results are categorized as positive for PE if an intraluminal filling defect is seen within a pulmonary arterial vessel and are considered negative if no filling defect is observed. Scans are considered technically inadequate because of motion artefact and if main or lobar pulmonary vessels are not opacified.

The best study of CTA in PE diagnosis is the PIOPED II study [4]. In this study sensitivity for PE was 83 %. The authors concluded: “The false negative rate of 17 % for CTA indicates the need for additional information to rule out PE”. The positive predictive value for a PE observed within a lobar pulmonary artery was 97 % but fell to 68 and 25 % in segmental and subsegmental pulmonary vessels, respectively. Obviously, CTA has not few false negative and false positive results. In PIOPED II CTA could not be performed in 50 % of eligible cases because of various contraindications, notably kidney failure, critical illness, recent myocardial infarction, ventilator support and allergy to the contrast agent. 6 % of performed CTA studies were of insufficient quality for conclusive interpretation.

In the literature, estimations of radiation dose from CTA vary within wide limits. According to ICRP the average effective dose for 4-16-detector CTA is 5.4 mSv . Notably, this information was based on computed rather than measured dose data. Hurwitz et al. reported for current adult PE protocol with 64-detector CTA a measured effective dose of 19.9±1.38 mSv [5]. These authors point out that real measured doses are about 50 % higher than those computed. The absorbed dose to the breasts was 35-42 mGy. Absorbed radiation dose to the breast for a single slice CT was 20-50 mGy and 30-50 % greater with a 4-slice CT. In a very recent study Hurwitz et al. studied radiation dose saving regimes. Dose saving protocols are promising but are still not validated with respect to diagnosis of PE.

V/P_{SPECT} and CTA. Based upon data from ICRP reports, the effective dose for V/P_{SPECT} with the recommended protocol is about 35-40 % of the dose from CTA. The dose to the female breast for V/P_{SPECT} is only 4 % of the dose from CTA with full dose saving means according to Hurwitz [5]. This may have particular importance in pregnant women with profilerating breast tissue. During the first trimester of pregnancy the fetal dose of CTA is greater than or equivalent to that of V/P_{SPECT} . The advantage of V/P_{SPECT} increases after the 1st trimester.

Recent studies show that CTA is often technically suboptimal during pregnancy. In pregnant women, contrast opacification within pulmonary arteries is very often insufficient for diagnosis, probably because of increased cardiac output and plasma volume.

Chronic PE has often an insidious onset. Due to progression prognosis is poor without treatment. Recently it has been shown that CTA is of very limited value for the diagnosis of chronic thromboembolic pulmonary disease. CTA had a sensitivity of 51% while the sensitivity of V/P scintigraphy was 96-97%. The authors concluded that “ventilation/perfusion scintigraphy, which is widely available and easy to perform, has a higher sensitivity than CTA as well as very good specificity in detecting chronic pulmonary thromboembolic disease as a potential curable cause of pulmonary hypertension”.

Comparison between V/P_{SPECT} and CTA

CTA is in general much more available than V/P_{SPECT}

V/P_{SPECT} carries no risk associated with contrast injection.

V/P_{SPECT} give much lower radiation burden.

V/P_{SPECT} yields lower rate of non-diagnostic reports.

V/P_{SPECT} has higher sensitivity at similar specificity.

V/P_{SPECT} allows better estimation of PE extension based upon functional impact of PE.

V/P_{SPECT} is the preferred diagnostic method for PE in pregnancy.

V/P_{SPECT} is the preferred diagnostic method for chronic PE.

Conclusion

It is a challenge for the discipline Nuclear Medicine to make V/P_{SPECT} available to highest extent possible. Only so can we meet the requirements with respect to Good Medical Practise.

References

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