The diagnostic management of suspected pulmonary embolism
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Diagnosing pulmonary embolism in pregnancy:
Rationalising fetal radiation exposure in radiological procedures

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In pregnancy, the diagnosis of pulmonary embolism (PE) is problematic. There is doubt as to whether objective diagnostic tests are needed and confusion as to what objective test is the safest with respect to fetal radiation exposure. A recent study has reported a very low (1·8%) prevalence of high-probability ventilation-perfusion (VQ) lung scans in pregnant women suspected of PE. From this study it is apparent that the clinical diagnosis of PE is inaccurate and therefore objective diagnostic tests are mandatory, in order to avoid treatment of women that do not have PE.

Currently, helical computerised tomography (CT) and VQ scintigraphy are the most common diagnostic tests used in non-pregnant patients with suspected PE. Physicians are reluctant to perform helical CT in pregnant women because of potential adverse effects of radiation exposure to the fetus. VQ scintigraphy has been assumed to be associated with less radiation exposure than helical CT. To compare the relative amounts of radiation exposure to the fetus, we calculated fetal radiation exposure when single- and multi-detector row helical CT and VQ scintigraphy were performed using our local hospital protocols. Further, we compared our data with data of the literature.

Since there are no established methods for calculating fetal radiation exposure in diagnostic radiological procedures, we used a pragmatic approach. The amount of radiation absorbed by the fetus was assumed to be equal to that absorbed by the uterus of a non-pregnant woman. Assessment of the uterus dose was achieved by measurement of the computed tomography dose index and the application of organ dose conversion factors. The following CT protocols were used for fetal dose assessment: 120kV, 250 mAs, slice thickness 3 mm and pitch factor 1·7 for single-detector row helical CT (Philips AVE) and 120 kV, 85 mAs, slice thickness 16 × 0·5 mm and pitch factor 1·4 for multi-detector row helical CT (Toshiba Aquilion 16). The scanned range extends from the dorsal lung sinus to the top of the lung. Since fetal radiation exposure was calculated, physical measures (eg. abdominal shielding with lead) to reduce radiation exposure were not taken into account.

For the perfusion scintigraphy protocol we used 40 MBq of Technetium-labelled albumin aggregates. In our institution, ventilation scintigraphy is performed with Krypton-81m, which is inhaled for two minutes per image. The Rubidium-Krypton generator generates 450-750 MBq per minute. Our calculated data of CT radiation exposure were compared with doses in nuclear medicine and doses calculated by the International Commission on Radiological Protection (ICRP) and the National Radiological Protection Board (NRPB) of the UK. The calculated dose of radiation absorbed by the fetus for a single-detector row helical CT was 0·026 mSv. An even lower dose (0·013 mSv) was calculated for the multi-detector row helical CT. In comparison, the calculated dose of fetal radiation with perfusion scintigraphy was 0·11-0·20 mSv. In comparison with doses given by the ICRP and NRPB (table 1), our calculated doses of helical CT were low.

Our study suggests that performing a helical CT according to our local protocol, whether single- or multi-detector row, exposes the fetus to less radiation than perfusion
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scintigraphy. Our findings are clearly contradictory to the general idea that helical CT is more hazardous to the fetus than perfusion scintigraphy.

Table 1
Radiation dose to the fetus by radiological examination

<table>
<thead>
<tr>
<th>Examination</th>
<th>LUMC (mSv)</th>
<th>ICRP (mSv)</th>
<th>NRPB (mSv)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single-detector row helical CT</td>
<td>0.026</td>
<td>0.06</td>
<td>0.06</td>
</tr>
<tr>
<td>Multi-detector row helical CT</td>
<td>0.013</td>
<td>n.d.</td>
<td>n.d.</td>
</tr>
<tr>
<td>Perfusion scintigraphy (99mTc MAA, 200 MBq)</td>
<td>n.a.</td>
<td>0.0-0.6</td>
<td>0.2-0.4</td>
</tr>
<tr>
<td>Perfusion scintigraphy (99mTc MAA, 40 MBq)</td>
<td>0-0.20</td>
<td>n.d.</td>
<td>n.d.</td>
</tr>
<tr>
<td>Ventilation scintigraphy (99mTc aerosol)</td>
<td>n.a.</td>
<td>0.1-0.3</td>
<td>0.3-1.2</td>
</tr>
<tr>
<td>Ventilation scintigraphy (81mKr, 600 MBq)</td>
<td>0.0001</td>
<td>n.d.</td>
<td>n.d.</td>
</tr>
</tbody>
</table>

n.a. = not applicable, n.d. = not determined
LUMC = University Medical Centre Leiden
ICRP = International Commission on Radiological Protection
NRPB = National Radiological Protection Board

Regarding the generalizability of our data, it is apparent that our calculated fetal radiation dose for CT is well within the range of that found by others. It has been documented that radiation exposure to the patient for a given radiological procedure can vary considerably between different institutions and even within the same institution. There are several factors that affect radiation dose from CT, e.g. (beam energy, tube-current time product, pitch, collimation, patient size and dose reduction options). Each institution should therefore carefully scrutinize its protocol for performing helical CT and define the optimal balance between minimal patient radiation exposure and maximal diagnostic CT image quality.

Calculating patient radiation exposure with a computerized model beholds accepting certain assumptions, which possibly differ from an exact measurement. An exact measurement is however, impossible to perform, both in helical CT as well as in scintigraphy. Due to lack of more appropriate measurements it is commonly assumed that radiation dose to the uterus is a good approximation of the radiation dose to the fetus in early pregnancy. This period of early pregnancy is the most important period, since the fetus is considered to be most vulnerable to radiation effects in the period of organogenesis (in the 3rd until the 15th week). The main issue following in-utero exposure at typical diagnostic levels is induction of malignancies. The number of excess malignancy cases up to age 15 years following irradiation in utero is considered to be 1 in 16000 per mSv.5

We conclude that when a clinical suspicion of pulmonary embolism is raised in a pregnant patient, only objective diagnostic testing can rule out the disease. Our calculation of fetal radiation dose in helical CT justifies performing this objective diagnostic method as a first line test in pregnancy. It is hoped that increased awareness of the risks and benefits of imaging in pregnant patients suspected of pulmonary embolism will result in a more rational management to this patient group.
Chapter 9

Reference List