CT Pulmonary Angiography versus Ventilation-Perfusion Scintigraphy in Pregnancy: Implications from a UK Survey of Doctors’ Knowledge of Radiation Exposure

Ashley M. Groves, MB, BS
Stuart J. Yates, MSc
Thida Win, MB, BS
Irfan Kayani, MB, BS
Ferdia A. Gallagher, MB, BS
Rizwan Syed, MB, BS
Jamshed Bomanji, MB, BS, PhD
Peter J. Ell, MD

Purpose: To prospectively investigate the fetal dosimetry knowledge of health care professionals involved in the management of pulmonary embolism.

Materials and Methods: One hundred sixty-one health care professionals consented to participate in this study, which had ethical board approval. The individuals surveyed were from 14 hospitals (seven university and seven community hospitals) in the United Kingdom, and 68 trainees were included. These health care professionals included 102 radiologists, 13 nuclear physicians, seven dual-accredited radiologist-nuclear medicine physicians, 16 medical physicists, and 23 pulmonologists. The interview included eight questions. Two questions asked which examination—computed tomographic (CT) pulmonary angiography or ventilation-perfusion (V/Q) scintigraphy—gave (a) the larger radiation exposure (effective dose) to an adult and (b) the larger fetal dose. Two questions assessed the magnitude of the dose differences between these two tests. Four questions asked for an estimate of the dose to both adult and fetus from CT pulmonary angiography and scintigraphy. Subgroup analysis was performed by using the Fisher exact test.

Results: Of the 161 professionals surveyed, 93 (58%) appreciated correctly that V/Q scintigraphy delivers a higher fetal dose than does CT pulmonary angiography. Three of 161 professionals were able to answer all eight questions correctly. In terms of the knowledge that V/Q scintigraphy has a higher fetal dose than does CT, there was no statistically significant difference in correct answers between specialties (P > .05), between university and community hospitals (P = .13), or between attending physicians and residents (P = .52).

Conclusion: This survey reveals that there is a lack of knowledge of fetal dosimetry in the imaging of pregnant women suspected of having pulmonary embolism.

© RSNA, 2006
Currently, the American Academy of Family Physicians and the American College of Emergency Physicians share a common set of guidelines for recommending ventilation-perfusion (V/Q) scintigraphy or computed tomographic (CT) pulmonary angiography in the diagnosis of suspected pulmonary embolism (PE) (1). In Europe, the British Thoracic Society guidelines recommend the use of CT pulmonary angiography rather than V/Q scintigraphy as the initial investigation method of choice in nonmassive PE (2). Although it is recognized that chest pain and PE are common in pregnancy (2), there are no formal imaging strategies for pregnant patients in either set of guidelines. Interestingly, on its Web site, the Royal College of Obstetricians and Gynecologists has guidelines for the management of PE in pregnancy and recommends the initial use of perfusion-only scintigraphy. It is unclear as to the role dosimetry played in the formulation of the three sets of guidelines. However, there is strong scientific evidence that the fetal dose from V/Q scintigraphy (640–800 μGy) is considerably higher than that from CT pulmonary angiography (3–131 μGy; Table 1) (3–5). CT pulmonary angiography and V/Q scintigraphy expose patients to ionizing radiation, and the fetus is particularly at risk from this (6). The International Commission on Radiological Protection (ICRP) has made recommendations requiring ionizing radiation exposures to patients to be minimized, especially during pregnancy (7,8). The ICRP recommendations precipitated the European Medical Exposure Directive (9). Subsequent legislation places legal responsibilities on referring as well as imaging doctors, with the aim of protecting patients from unnecessary exposures, especially during pregnancy. Despite recommendations by the ICRP and legal obligation in European countries, an audit from one of our institutions revealed that one pregnant patient underwent V/Q scanning every 6 weeks. It is therefore important that pulmonologists and internists who are likely to be advising obstetricians and family practitioners are informed regarding the radiation burden of V/Q scintigraphy and CT pulmonary angiography. Clinicians may, in turn, obtain advice from radiologists, nuclear physicians, and medical physicists.

Despite increasing emphasis on recognizing and communicating risks from imaging exposures (10), there is convincing evidence from both North America (11) and Europe (12) that there are deficiencies in this important aspect of medical practice. Given these deficiencies and the ICRP guidelines, the purpose of our study was to prospectively investigate the fetal dosimetry knowledge of health care professionals who are involved in the management of PE.

Materials and Methods

Participants

Over a period of 1 month, 164 health care professionals (including 68 trainees) in radiology, medical physics, nuclear medicine, and pulmonology were surveyed. Three of these individuals declined participation. One hundred sixty-one (98.2%) individuals consented to participate after the study was explained to them (Table 2). Our study received ethical board clearance. The survey incorporated trainees and included seven university hospitals and seven community hospitals from two regions in the United Kingdom. An attempt was made to interview all the radiologists, medical physicists, and chest and nuclear medicine physicians who were present at the time of the hospital visit. However, radiologists who did not practice general radiology, such as dedicated neuroradiologists and interventional radiologists, as well as medical physicists in unrelated practice (eg, magnetic resonance imaging physicists), were not surveyed. In total, it is estimated that the total population of health care professionals who met the criteria for inclusion was 201, of whom responses were obtained from 161 (80.1%).

Survey

The survey was performed by means of direct interview (in person) by one of five surveyors (A.M.G., S.J.Y., T.W., I.K., and F.A.G.) so as to enable the surveyor to clarify questions regarding V/Q and CT protocols used, including definition of the scintigraphic agents (ie, diethylenetriaminepentaacetic acid aerosol). Although the interviewers were not dedicated professional surveyors, each had previous exposure to this form of data collection.

The interview covered eight questions (Table 3). Two questions asked which examination—CT pulmonary angiography or V/Q scintigraphy—gave (a) the larger radiation exposure (effective dose) to an adult and (b) the larger fetal dose. Two questions assessed the magnitude of the dose differences between these two tests. Four questions asked for an estimate of the dose to both adult and fetus from CT pulmonary angiography and scintigraphy. Answers to dosimetry questions were accepted...
in units of millisieverts (or milligrays for fetal dose), as well as in terms of equivalent number of chest radiographs or years of background radiation. Because quoted dosimetry values vary, answers were accepted if they were in the range of reference values (3–5,13), with 10% latitude. The age of the health care professional was not recorded, in an attempt to reassure the interviewee with respect to anonymity.

In addition, the medical surveyor who was assigned to a particular institution asked one senior attending radiologist or nuclear physician (director or deputy) from each imaging department a further single question regarding the presence or absence of a formal protocol in the imaging of pregnant patients suspected of having PE.

### Statistical Analysis

With respect to correctly answering the specific question, “Does V/Q scintigraphy or CT pulmonary angiography deliver a higher fetal radiation exposure?” (Table 3), the Fisher exact test was performed (Graph Pad, 2005; Graph Pad, San Diego, Calif) to investigate statistically significant differences between subgroups. This included differences between each specialty and the rest of the study group as a whole (eg, pulmonologists vs the rest of the study group), between fully qualified health care professionals and trainees, and between health care professionals working at university hospitals and those employed at community hospitals. P values of less than .05 were considered to indicate a statistically significant difference.

### Results

#### Correct Responses

Ninety-three (58%) of 161 health care professionals correctly answered that V/Q scintigraphy has a higher fetal dose than does CT pulmonary angiography (Table 4). Three (2%) of 161 individuals answered all eight questions correctly (one radiology trainee, one nuclear medicine physician, and one medical physicist). The question with the highest correct response rate (84%) was the question that asked whether CT or V/Q scintigraphy had the higher adult exposure. The least-well–answered question...
(7%) was the question that asked about the CT fetal radiation dose.

Fetal Dose Responses

In terms of the knowledge that V/Q scintigraphy has a higher fetal dose than does CT pulmonary angiography, there was no statistically significant difference between individual specialties and the surveyed group as a whole (Table 5). Dual-accredited combined nuclear medicine–radiology specialists had the highest correct response rate (71%, P = .70), while nuclear medicine physicians had the lowest correct response rate (46%, P = .40).

University versus Community Hospitals

There was no statistically significant difference between university and community hospitals (P = .13) or between attending physicians–qualified medical physicists and residents–trainee physicists (P = .52) (Table 6).

Formal Protocol

No hospital had an in-house, agreed-on, formal protocol for imaging of PE in pregnancy.

Discussion

This study showed that only slightly more than one-half of specialists (in related fields) knew that V/Q scintigraphy exposes the fetus to a higher radiation dose than does CT pulmonary angiography. Moreover, depending on the trimester of pregnancy (Table 7), the V/Q fetal dose can be over 200 times greater than the CT pulmonary angiography dose: The CT fetal dose ranges from 3 to 131 μGy (3), while scintigraphy dose is in the region of 700–800 μGy (with use of technetium aerosol) (4). Although the overall fetal doses might be considered small, current theories in radiation biology imply that the greater the radiation exposure, the greater the risk (7). Therefore small doses are relevant. Since some guidelines prefer CT pulmonary angiography for investigating PE (2), a view that has recently received increasing scientific support (14,15), the fetal dosimetry differences between the two techniques would appear to make the use of V/Q scintigraphy during pregnancy difficult to justify.

The majority of those surveyed in this study were radiologists, which in part reflects the general abundance of this specialty compared with nuclear medicine and pulmonology specialists in the United Kingdom. Nonetheless, there was a lack of variation in knowledge between specialties and other subgroups. As part of their training, radiology and nuclear medicine trainees are often taught detailed dosimetry, but they performed no better in this survey than their senior colleagues. This may suggest that educational methods with respect to dosimetry teaching may need to be reviewed. Although our survey included data from only a single country, in a survey of imaging practice in North America (16), nearly half of the hospitals surveyed performed V/Q studies in preference to CT in pregnant patients suspected of having PE. This may suggest a similar deficiency in fetal dosimetry knowledge. However, dosimetry appeared to have been a minor concern in that study, since it was quoted as a factor that influenced practice in only 5% of respondents (16).

There are other scintigraphic agents and protocols available that alter the precise fetal dosimetry (Table 8). Agents such as krypton (krypton 81m) gas for ventilation will reduce the fetal exposure, but even if one was to perform a half-dose perfusion study in isolation, this still only reduces the scintigraphic dose to 140–250 μGy (5). The lower end of this dose range is achieved only very early in pregnancy, however,
at which time the CT dose is particularly low (3–20 μGy) (3) because the uterus is at maximum distance from the chest (Table 7). Therefore, the half-dose perfusion examination still delivers a considerably higher radiation dose to the fetus, and such reduced administered activity may result in a less-diagnostic study.

There are a number of important dosimetry issues that could counterbalance the arguments against V/Q scintigraphy. It needs to be appreciated that although the fetal CT dosimetry values that were quoted in this article were calculated by using exposure factors that are typical in our institutions, these exposure factors may not be universal, and higher exposures might be encountered. However, even if the CT exposure were doubled, the CT pulmonary angiography fetal dose would still remain many magnitudes smaller than that from lung scintigraphy (Table 9).

Another consideration is maternal dosimetry. The mother’s radiation dose is higher from CT (2.2–60 mSv) (13) than from scintigraphy (1.4 mSv) (3). This is a stronger issue toward the end of pregnancy, when the fetal dose at CT is closer to that at scintigraphy (Table 7).

Moreover, there has been concern regarding the increased breast cancer risk to the mother from CT pulmonary angiography (18), but it should be appreciated that this increased risk is taken in to account within the calculation of the mother’s CT pulmonary angiography dose. However, the ICRP is revising the tissue-weighting factors, and, thus, CT pulmonary angiography dosimetry quoted in the future may rise. Nevertheless, the law in many countries gives legal preference to the mother over the fetus and therefore, as has recently been argued (10), patients should be better informed of the radiation implications so that they can be more involved in imaging decision making.

There are other factors unrelated to dosimetry that may also favor scintigraphy over CT pulmonary angiography.

In summary, the results of our survey suggest a lack of knowledge regarding fetal dosimetry in investigating pregnant patients suspected of having PE. The findings suggest that health care professionals need further education regarding dosimetry, and, in turn, patients should benefit if the risks of radiation are better communicated. There are arguments that might be forwarded for the use of lung scintigraphy over CT pulmonary angiography in pregnancy, including availability of techniques, concerns regarding CT intravenous contrast medium, the higher maternal exposure, and patient preference. Nevertheless, given present PE imaging guidelines, recent meta-analyses favoring CT pulmonary angiography (14,15), fetal dosimetry, and ICRP recommendations, as well as the legal obligations in some countries, it is becoming increasingly difficult to justify the use of V/Q scanning in pregnancy over CT pulmonary angiography.

Acknowledgment: We thank Linda Sharples, PhD, Medical Research Council Senior Statistician, for her advice.

References


| Table 8 |

| V/Q Scintigraphy Fetal Dosimetry with Alternative Ventilation Agents |
|-------------------------|----------|-------------|
| Agent                  | Activity (MBq) | Fetal Dose (μGy) |
| Technetium 99m gas     | 40        | 350–570     |
| Krypton 81m            | 6000      | 281–502     |
| Xenon 133              | 400       | 380–508     |

Source.—References 3 and 4.

Note.—Half-dose perfusion-only scintigraphy (50 MBq 99mTc macroaggregates) would expose the fetus to 140–250 μGy. Whatever combination of agents is used (including half-dose perfusion-only scintigraphy), fetal exposure remains much greater compared with that at CT pulmonary angiography. It should be noted that in our survey the interviewer clarified that these alternative agents were not being considered.

| Table 9 |

| Fetal Dosimetry at Different CT Pulmonary Angiography Exposures (X-ray Tube Currents) |
|-------------------------|--------------------|----------------|
| Exposure (mAs) *         | Fetal Dose (μGy)   |
| 100 *                    | 3.3–130.8          |
| 110                      | 3.6–143.9          |
| 150                      | 5.0–196.2          |
| 200                      | 6.6–261.6          |

Note.—At twice the CT pulmonary angiography exposure as quoted in this article, the fetal dose remains smaller compared with that at scintigraphy.

* The tube voltage is maintained at 120 kV.
† The exposure quoted by Winer-Muram et al (3).