CT Pulmonary Angiography versus Ventilation-Perfusion Scintigraphy in Pregnancy: Implications from a UK Survey of Doctors' Knowledge of Radiation Exposure[1]

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.

[1] From the Institute of Nuclear Medicine, University College London, Middlesex Hospital, Mortimer St, London W1T 3AA, United Kingdom (A.M.G., I.K., R.S., J.B., P.J.E.); East-Anglian Radiation Protection Service (S.J.Y.) and Department of Radiology (F.A.G.), Addenbrooke's Hospital, University of Cambridge Teaching Hospital Trust, Cambridge, United Kingdom; and Department of Chest Medicine, Lister Hospital, Cambridge, United Kingdom (T.W.). Received June 1, 2005; revision requested July 21; revision received August 9; accepted September 7; final version accepted October 31. **Address correspondence to** A.G. (e-mail: *drashleygroves@hotmail.com*).

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 referrers 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.

Advance in Knowledge

- Despite increasing emphasis on risks from radiation exposures, there is a deficiency in fetal dosimetry knowledge among health care professionals involved in the care of pregnant patients suspected of having pulmonary embolism.

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

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Abbreviations:
ICRP = International Commission on Radiological Protection
PE = pulmonary embolism
V/Q = ventilation-perfusion

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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

Table 1

Summary of V/Q Scintigraphy and CT Pulmonary Angiography Fetal Dosimetry Used in the Survey

Modality and Source	Fetal Dose (μGy)
CT pulmonary angiography/ Winer-Muram et al (3)	3–131
V/Q scintigraphy*	
ARSAC (4)†	800‡
Russell et al (5)	640–740§

Note.—Numbers in parentheses are reference numbers.

* Assuming a full dose of technetium 99m (^{99m}Tc)–based ventilation (aerosol) and perfusion agents.

† ARSAC = Administration of Radioactive Substances Advisory Committee.

‡ Uterine dose; since isotopes cross the placenta, there is potential for the uterine dose to underestimate the actual fetal exposure.

§ Calculated assuming administered activity as recommended by ARSAC (4).

Table 2

Composition of the Surveyed Population (*n* = 161)

Specialty	No. of Respondents
Radiology	102 (54)
Nuclear medicine	13 (3)
Dual nuclear medicine–radiology	7 (3)
Pulmonology	23 (8)
Medical physics	16 (0)

Note.—Data in parentheses are the numbers of trainees.

Table 3

Answers to the Questions Used in the Survey

Question	Correct Answer*
1. Does V/Q or CT have a higher adult radiation dose?	CT
2. What is the magnitude of the difference between the adult doses?	1.6–4.3
3. What is the CT adult radiation dose?	2.2–6.0 mSv
4. What is the V/Q adult radiation dose?	1.4 mSv
5. Does V/Q or CT have a higher fetal dose?	V/Q
6. What is the magnitude of the difference between the fetal doses?	5–267
7. What is the CT fetal dose?	3–131 μGy
8. What is the V/Q fetal dose?	640–800 μGy

Source.—References 3–5, 12.

* Accepted answers were the same with a 10% latitude on either side of the ranges.

Table 4

Number of Correct Responses to the Survey Questions

Question	No. of Correct Responses
1. Does V/Q or CT have a higher adult radiation dose?	135 (84)
2. What is the magnitude of the difference between the adult doses?	104 (65)
3. What is the CT adult radiation dose?	70 (43)
4. What is the V/Q adult radiation dose?	63 (39)
5. Does V/Q or CT have a higher fetal dose?	93 (58)
6. What is the magnitude of the difference between the fetal doses?	47 (29)
7. What is the CT fetal dose?	11 (7)
8. What is the V/Q fetal dose?	15 (9)
Correct responses to both questions 1 and 5	72 (45)

Note.—Data in parentheses are percentages.

Table 5

Number of Respondents Who Correctly Answered that V/Q Scintigraphy Gives a Higher Fetal Radiation Dose than Does CT Pulmonary Angiography

Specialty	No. of Correct Respondents*
Dual nuclear medicine–radiology	5/7 (71)
Medical physics	10/16 (62)
Radiology	61/102 (60)
Pulmonology	11/23 (48)
Nuclear medicine	6/13 (46)

* Data in parentheses are percentages. There was no statistically significant difference ($P > .05$) between individual specialties and the study group as a whole.

Table 6

Performances of the Different Subgroups in Regard to Fetal Dosimetry

Subgroup	No. of Respondents	No. of Correct Responses
Experience level		
Attending	93 (60)	57 (61)
Trainee	68 (40)	36 (53)
Hospital type		
University	58 (62)*	37 (64)
Community	35 (38)*	19 (54)

Note.—Data in parentheses are percentages. There was no statistically significant difference between the performance between attending physicians and trainees ($P = .52$) or between those employed by university and community hospitals ($P = .13$).

* Of 93 respondents (trainees were excluded).

(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 of 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,

Table 7

Summary of V/Q Scintigraphy and CT Pulmonary Angiography Fetal Dosimetry as It Changes with the Different Stages of Pregnancy

Parameter	Early Pregnancy	Mid Pregnancy	Late Pregnancy
V/Q dose (μGy)	740	680	640
CT dose (μGy)	3.3–20.2	7.9–76.7	51.3–130.8
V/Q-CT ratio	37–224	9–86	5–12

Source.—References 3–5.

Note.—Although the difference in fetal radiation exposure between the two techniques becomes smaller as pregnancy progresses, the V/Q fetal dose remains greater than CT pulmonary angiography dose by a factor of at least five.

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). Finally, the fetal dosimetry was calculated by using Monte Carlo techniques. This method is widespread and validated, but it has been shown to underestimate the exposures in some circumstances (17).

Another consideration is maternal dosimetry. The mother's radiation dose is higher from CT (2.2–6.0 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. There are potential fetal side effects from intravenously administered CT contrast medium. Although there is no evidence from animal studies to confirm that such contrast agents cause fetal harm (19), there have not been controlled studies performed in humans. Moreover, the dilution of intravenous contrast medium by means of the increased plasma volume associated with pregnancy may hamper CT pulmonary angiogram interpretation. Indeed, there are no published data comparing the diagnostic performance of CT pulmonary angiography with V/Q scintigraphy in pregnancy. Also, the availability or experience of CT pulmonary angiogram interpretation in the setting of PE may be limited in some hospitals.

Limitations of this study included selection bias (inherent to all surveys) with respect to the individuals and institutions chosen for survey. Data were obtained from only two regions of a single country, and thus the findings are not necessarily universal. Also, correct responses were accepted with an arbitrary 10% margin of error, and thus the results can be altered if other margins are chosen. However, half of the questions were qualitative and therefore not subject to such arbitrary margins.

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.

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 ^{99m}Tc 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).

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