EM Advances

Familiarity with radiation exposure dose from diagnostic imaging for acute pulmonary embolism and current patterns of practice

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ABSTRACT

Objective: To assess the current level of knowledge and practice patterns of emergency physicians regarding radiation exposure from diagnostic imaging modalities for investigating acute pulmonary embolism (PE).

Methods: An online survey was sent to adult emergency physicians working at two academic tertiary care adult emergency departments (EDs) to determine imaging choices for investigating PE in various patient populations and to assess their current knowledge of radiation doses and risks. A retrospective chart review was performed for all adult patients who underwent computed tomographic pulmonary angiography (CTPA) and/or ventilation-perfusion (V/Q) scanning in the same EDs.

Results: The survey response rate was 72.1% (31 of 43 physicians). For patients < 30 years old, 83.9% of physicians chose V/Q scanning as their test of choice, regardless of gender. Although only a third of respondents knew the estimated radiation dose of a V/Q scan (37.5%) and a CTPA (32%), the majority were aware that V/Q scans involved less ionizing radiation than CTPAs. In the retrospective review, 663 charts were reviewed, including 201 CTPAs and 462 V/Q scans. V/Q scanning was the preferred modality in female patients (75.9% v. CTPA 24.1% [OR 2.1; 95% CI 1.5–2.9]) and in patients < 30 years old (87.9% v. CTPA 12.1% [OR 4.8; 95% CI 2.4–9.4]).

Conclusions: Although surveyed physicians possessed limited knowledge of radiation doses of CTPA and V/Q scans, they preferentially used the lower radiation V/Q scans in younger patients, particularly females, in both the survey vignettes and in clinical practice. This may reflect efforts to reduce radiation exposures at our institution.

RÉSUMÉ

Objectif: L'étude visait à évaluer le degré de connaissances des urgentologues et leur pratique en ce qui concerne l'exposition au rayonnement émis par les différents types d'imagerie diagnostique, dans le contexte de l'embolie pulmonaire (EP) aiguë.

Méthodes: Un questionnaire d'enquête en ligne a été envoyé à des urgentologues travaillant dans deux services d'urgence (SU) universitaires, de soins tertiaires, pour adultes, visant à déterminer le type choisi d'imagerie pour confirmer la présence d'une EP dans différents groupes de patients, et à évaluer leur degré de connaissances sur les doses de rayonnement et leurs risques. Nous avons procédé à un examen rétrospectif des dossiers médicaux de tous les adultes ayant subi une angiographie pulmonaire par tomodensitométrie (APTDM) et/ou une scintigraphie de ventilation et de perfusion (VA/Q) dans ces mêmes SU.

Résultats: Le taux de réponse a atteint 72.1% (31 médecins sur 43). Chez les patients de moins de 30 ans, 83.9% des médecins ont choisi la scintigraphie de VA/Q comme examen de première intention, indépendamment du sexe. Un tiers seulement des répondants connaissait la dose estimée de rayonnement de la scintigraphie de VA/Q (37.5%) et de l'APTDM (32%), mais la majorité savait que la scintigraphie de VA/Q émettait moins de rayonnement ionisant que l'APTDM. L'examen rétrospectif a permis d'analyser 663 dossiers: 201 faisaient mention d'une APTDM et 462, d'une scintigraphie de VA/Q. Ce dernier examen s'est révélé la technique préférée d'imagerie chez les femmes (75.9% contre 24.1% pour l'APTDM [risque relatif approché (RRA): 2.1; IC à 95%: 1.5–2.9]) et chez les patients de moins de 30 ans (87.9% contre 12.1% pour l'APTDM [RRA: 4.8; IC à 95%: 2.4–9.4]).

Conclusions: Les médecins qui ont répondu au questionnaire d'enquête avaient peu de connaissances sur les doses de rayonnement émises par l'APTDM et par la scintigraphie de VA/Q; ils ont néanmoins préféré la scintigraphie de VA/Q, dont la dose de rayonnement est faible, à l'APTDM chez les jeunes patients, notamment de sexe féminin, et ce, tant dans les scénarios décrits dans l'enquête qu'en pratique

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clinique. Les résultats peuvent témoigner des efforts faits dans notre établissement afin de diminuer l'exposition au rayonnement.

Keywords: computed tomographic pulmonary angiography, diagnostic imaging tests, pulmonary embolism, radiation exposure, ventilation-perfusion scan

There is growing concern in the public and medical community over the biologic effects of ionizing radiation from diagnostic imaging, especially in young adults and women.[1–5] Young patients are at greatest risk due to the higher proportion of actively dividing cells and longer period of time to accumulate and express radiation-induced malignancies.[6] Young females are particularly susceptible due to the radiosensitivity of breast tissue.[7–9] In 2007, the American College of Radiology stated that "the rapid growth of computed tomography (CT) and certain nuclear medicine studies...may result in an increased incidence of radiation-related cancers in the not too distant future" and that physicians should consider radiation exposure when selecting imaging tests for patients.[3]

Radiation exposure to patients can be reduced by substituting CT with nonionizing imaging investigations such as ultrasonography (US). This has been suggested for the investigation of appendicitis and urolithiasis.[10,11] When nonionizing imaging modalities are not feasible, the next best option is a test that minimizes radiation exposure.

Chest pain and dyspnea are common emergency department (ED) complaints. In patients in whom acute pulmonary embolism (PE) is suspected, both computed tomographic pulmonary angiography (CTPA) and ventilation-perfusion (V/Q) scanning are useful diagnostic tests.[12–14] However, the dose of ionizing radiation from a CTPA has been reported to be at least five times greater than that of a V/Q scan, particularly to breast tissue.[8,9,15] Currently, it is unknown if emergency physicians consider radiation exposure when choosing diagnostic imaging for acute PE.

The primary objective of this study was to assess the current level of knowledge of emergency physicians regarding radiation exposure from diagnostic imaging tests for investigating acute PE. The secondary objective was to determine if physicians chose the test with less ionizing radiation in more radiosensitive populations, both in theoretical patients (assessed by a survey) and in actual practice (assessed by a retrospective chart review).

METHODS

Survey design and setting

All emergency physicians working in the two academic tertiary care EDs that are affiliated with Western University (combined annual census 140,000) in London, Ontario, were invited to complete an online survey consisting of 3 baseline demographic questions and 22 questions divided into two sections (Appendix). The first section contained 11 clinical vignettes of patients with varying ages, genders, and comorbidities; the scenarios involved healthy 25-year-old, healthy 45-year-old, healthy 60-year-old, and 60-year-old patients with recent head and abdominal CT scans and a 60-year-old patient with breast cancer and chronic obstructive pulmonary disease (COPD). Participants were asked to select which imaging modality they would choose to investigate for PE for each scenario. To avoid influencing their decision, participants were not informed of the study intent.

After submitting answers to the first section, participants were asked 11 questions regarding their knowledge of radiation doses and risks from common environmental and medical sources. The survey was designed such that participants were required to answer questions in sequence and not permitted to revise previous answers. Survey questions were created by the investigators based on a review of the relevant literature, as well as consultation with emergency medicine residents, physicians, and a clinical epidemiologist. Prior to distribution, the questionnaire was peer reviewed by three emergency physicians unrelated to the study and tested for ease of comprehension. Participation was voluntary and anonymous. Approval for this research study was obtained from the Health Sciences Ethics Board at Western University.

Retrospective review design and setting

A retrospective electronic medical record review was conducted for all adult (≥ 18 years old) patients who had a V/Q scan or a CTPA ordered by an emergency physician for suspected PE over a 1-year period (April 1, 2009, to March 31, 2010). Patients were excluded if they were pregnant, they were undergoing a follow-up study for a PE diagnosed within 90 days, their test was ordered for an indication other than PE, they did not show up for the test, they had a history of chronic PE or deep vein thrombosis (DVT) or a previous diagnosis of PE or DVT within 90 days, or they had imaging ordered by consulting services. All duplicate studies were excluded.

A trained abstractor reviewed the electronic medical records and recorded imaging results, as well as any results from follow-up imaging studies (CTPA, V/Q scanning, or venous US) that had been performed within 90 days of the original investigation using a standardized data collection tool. The following information was also documented: patient age and gender; documented pulmonary, cancer, or thromboembolic comorbidities; calculated glomerular filtration rate (GFR); intravenous contrast allergies; and the number of CT and nuclear medicine scans accumulated over the last 10 years. We considered a positive CTPA to be any test where the final radiology report confirmed a pulmonary vascular filling defect consistent with PE and a negative CTPA to be any test where no vascular filling defect was interpreted. We considered a positive V/Q scan to be any test where the final radiology report read positive or high probability for PE (as per Prospective Investigation of Pulmonary Embolism Diagnosis [PIOPED] criteria) and a negative V/Q scan to be any test reported as normal or negative for PE.[16] Nondiagnostic VQ scans included indeterminate, very low probability, low probability, or intermediate scans and were considered negative if immediate follow-up imaging (e.g., venous US or CTPA) was negative for DVT or PE or if no follow-up imaging was ordered and the patient did not have a DVT or PE diagnosed within 3 months of the original study by medical record review. We considered a false negative CTPA and V/Q scan to be when the initial radiology interpretation was negative for PE but follow-up imaging within 3 months of the original study diagnosed either DVT or PE.

Data analysis

Data were entered directly into a study-specific Microsoft *Excel* database (Microsoft Corporation, Redmond, WA). Standard descriptive statistics were summarized using means and standard deviations (SDs), and differences in proportions were assessed by the Pearson χ^2 statistic. Univariable analysis was used to assess the association between V/Q scans, age, and gender. The results are reported as odds ratios (ORs) with 95% confidence intervals (CIs). All data analyses were performed using *SPSS* 19.0 (IBM Corporation, Armonk, NY).

RESULTS

Physician survey

Of the 43 emergency physicians invited to participate, 31 (72%) completed the online survey. The majority (71%) of respondents were male. Years of emergency medicine practice varied from < 5 years (33%), 5 to 15 years (33%), and > 15 years (33%).

Physicians preferentially chose V/Q scanning for younger patients or if the patients had a history of multiple recent CT scans (Table 1). In contrast, the number of CTPAs chosen increased with advancing

Table 1. Diagnostic imaging tests chosen by surveyed physicians to investigate pulmonary embolism

	Imaging test chosen		
Clinical vignette	V/Q scanning	CTPA	CTPA and CTV
Healthy 25-year-old female	26	5	0
Healthy 25-year-old male	26	5	0
Healthy 45-year-old female	22	7	0
Healthy 60-year-old female	16	15	0
Healthy 60-year-old male, head CT and abdominal CT performed within last year	26	4	0
60-year-old female with breast cancer	10	20	1
60-year-old male with COPD	2	28	1

COPD = chronic obstructive pulmonary disease; CT = computed tomography; CTPA = computed tomographic pulmonary angiography; CTV = computed tomographic venography; V/Q = ventilation-perfusion.

age and comorbidities. The gender of patients did not appear to influence imaging test choices.

When asked if they inform patients about the risks of receiving radiation from diagnostic imaging tests, 58% of respondents stated that they inform all patients and 35% only patients deemed to be "high risk" (including pregnant patients and females of childbearing age). One respondent reported informing patients that there are radiation risks, but the degree of risk is unknown, and another reported never informing patients of these risks.

When asked to determine the approximate radiation dose of a CTPA and a V/Q scan expressed in mSv, radiation-absorbed dose (rad), or equivalent number of posteroanterior (PA) chest x-rays, 8 of 25 (32%) and 9 of 24 (38%) respondents chose the correct dose for CTPA and V/Q scanning, respectively (Table 2). These doses were the effective doses determined from a literature search and reported effective doses at our institution.[6,15,17] Respondents knew that the radiation dose from a V/Q scan is less than that from a CTPA. Only 3 of 26 (11%) respondents were aware that, at the present time, there are no generally accepted limits for cumulative lifetime radiation dose that a patient can safely receive from diagnostic imaging.

Retrospective review

There were 703 CTPAs and V/Q scans ordered from the two EDs over the 1-year study period. Of these, 40 were excluded (Figure 1), leaving 201 CTPAs and 462 V/Q scans included in this study. The mean (SD) age of all patients was 53.4 (20.3) years, and the majority (60.6%) of patients were female. Patients with poor renal function (estimated GFR < 60 mL/min), intravenous contrast allergies, asthma, malignancy, previous DVT, and previous PE were more likely to have a V/Q scan (Table 3).

Overall, the preferred imaging test was V/Q scanning (69.7%). When imaging tests were stratified according to age and gender, females and patients < 50 years old were more likely to get V/Q scanning (Table 4). In particular, 91.9% of females < 30 years old received V/Q scanning compared to 76% of males in the same age category (OR 3.6; 95% CI 1.1–12). The frequency of CTPAs increased with age and comorbidity in both the survey and the retrospective review.

The overall incidence of venous thromboembolism (VTE) during the study was 13.9% (92 of 663) (see Figure 1). Of these, 79 were diagnosed on the initial diagnostic test (32 on a CTPA and 47 on a V/Q scan) and 13 were diagnosed on follow-up studies (2 on a V/Q scan, 2 on a CTPA, and 9 on a venous sonogram) (Table 5). The most common alternative diagnosis for patients' symptoms seen on CTPAs that were read as negative for PE was consolidation. Other alternative diagnoses provided by CTPA are listed in Table 6. Alternative diagnoses not seen on a chest x-ray were found in only 1 of 12 (8.3%) CTPAs ordered in patients < 30 years old (pancreatitis) compared to 28 of 68 (41.2%) CTPAs ordered in patients ≥ 70 years old.

Patients < 30 years old had a higher incidence of diagnostic V/Q scan results (53 of 87 or 60.9% were normal or high probability), a lower prevalence of comorbidities (9 of 99 or 9.1%), and a higher prevalence of normal chest x-rays (84 of 89 or 94.3%). In contrast, patients ≥ 70 years old had a higher incidence of nondiagnostic V/Q scan results (79 of 103 or 76.7% were very low, low, or intermediate probability or indeterminate scans), a higher prevalence of comorbidities (104 of 171 or 60.8%), and a lower prevalence of normal chest x-rays (101 of 168 or 60.11%) (Figure 2). The incidence of positive studies for VTE remained relatively stable (8.1–12.6%) until age 70, when the incidence increased dramatically (22.8%).

Table 2. Estimated radiation doses (expressed as equivalent number of posterior anterior chest x-rays) of CTPA and V/Q scans chosen by surveyed physicians

	Equivalent number of PA chest x-rays					
	20	40	100	200	1,000	Not sure
CTPA	2	0	8	**8**	3	4
V/Q	5	**9**	3	2	0	5

CTPA = computed tomography pulmonary angiogram; PA = posteroanterior; V/Q = ventilation-perfusion.
The correct dose is indicated by boldface.

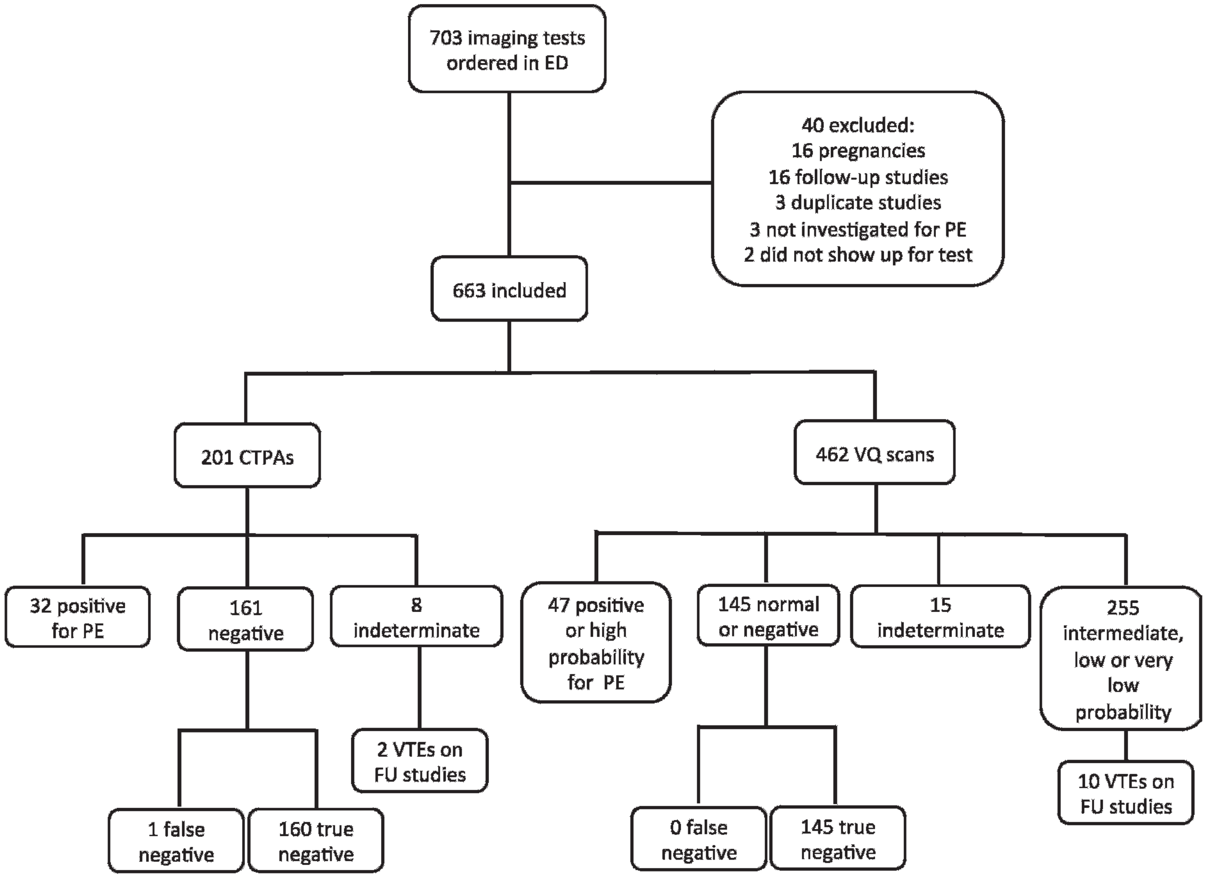

Figure 1. Flow diagram of patients enrolled in the retrospective review. VTE (venous thromboembolism) includes deep vein thrombosis and pulmonary embolism (PE). Follow-up imaging included venous ultrasonography of extremities, computed tomographic pulmonary angiography (CTPA), or ventilation-perfusion scanning (VQ). ED = emergency department; FU = follow-up.

Table 3. Demographics of patients included in the retrospective review

	V/Q scan (*n* = 462)	CTPA (*n* = 201)	Δ (95% CI)
Mean age, yr (SD)	51 (20.6)	60 (18.0)	
Female, *n* (%)	305 (75.9)	97 (24.1)	51.8% (45.5–57.3)
Male, *n* (%)	157 (60.1)	104 (39.8)	20.3% (11.8–28.4)
eGFR < 60 mL/min, *n* (%)	66 (72.5)	25 (27.5)	45.0% (31.0–56.5)
IV contrast allergy, *n* (%)	13 (81.2)	3 (18.8)	62.5% (28.2–79.7)
Comorbidity, *n* (%)			
Asthma	27 (61.4)	17 (38.6)	24.4% (2.8–43.0)
COPD	16 (41.0)	23 (59.0)	−18.0% (−37.7–4.1)
CHF	14 (41.2)	20 (58.8)	−17.6% (−38.6–5.8)
Restrictive lung disease	4 (33.3)	8 (66.7)	−33.3% (−60.9–5.7)
Malignancy	66 (57.4)	49 (42.6)	14.8% (1.9–27.0)
Previous DVT	37 (68.5)	17 (31.5)	39.2% (20.0–54.6)
Previous PE	42 (64.6)	23 (35.4)	29.2% (12.1–44.1)
Normal chest x-ray, *n* (%)	378/443 (85.3)	90/189 (47.6)	37.7% (29.8–45.3)

CHF = congestive heart failure; COPD = chronic obstructive pulmonary disease; CTPA = computed tomographic pulmonary angiogram; DVT = deep vein thrombosis; eGFR = estimated glomerular filtration rate; IV = intravenous; PE = pulmonary embolism; V/Q = ventilation-perfusion.

Table 4. Unadjusted estimates evaluating the association between the use of ventilation-perfusion scan, age, and gender

	n	Odds ratio	95% CI
Gender only			
Female	402	2.1	1.5–2.9
Age only			
18–30 yr	99	4.8	2.4–9.4
30–49 yr	211	2.1	1.3–3.2
50–69 yr	182	1.1	0.7–1.7
≥ 70 yr	171	Ref.	Ref.
Age and gender			
Age 18–30 yr	99		
Male	25	1.5	0.5–4.0
Female	74	5.3	2.1–13.3
Age 30–49 yr	211		
Male	84	0.9	0.5–1.7
Female	127	2.1	1.2–3.9
Age 50–69 yr	182		
Male	91	0.7	0.4–1.3
Female	91	0.8	0.5–1.4
Age ≥ 70 yr	171		
Male	61	0.4	0.2–0.7
Female	110	Ref.	Ref.

CI = confidence interval.

A retrospective review of the electronic medical records of patients included in this study revealed that, cumulatively, they had undergone 1,930 computed tomographic (CT) and nuclear medicine scans in the 10-year period prior to this study being conducted. This equates to a median (interquartile range) of 5 (3–7) ionizing radiation scans per person. Of all 663 patients reviewed, 223 (33.6%) patients had no documented previous scans, of which 65 patients were in the < 30 years old age group (65 of 99). Of the 440 patients who had at least one previous ionizing scan, 270 (61.3%) patients had 1 to 4 previous scans, 127 (28.9%) patients had 5 to 9 scans, and 43 (9.8%) patients had 10 or more scans. In the latter group, 9 patients were < 50 years old. The maximum number of scans documented per patient was 22 ($n = 2$). The most common comorbidities among patients who had undergone multiple scans were a history of cancer ($n = 25$), previous PE ($n = 13$), and pulmonary diseases such as COPD and interstitial lung disease ($n = 12$).

DISCUSSION

This study examined the current level of knowledge of the relative doses of radiation exposure from two common imaging modalities used by emergency physicians to diagnose acute PE. It also determined whether physicians chose the test with less ionizing radiation in more radiosensitive populations, both in theoretical patients and in actual practice.

Precise knowledge of estimated radiation doses was poor among survey respondents, but most physicians knew that V/Q scans exposed patients to less radiation than CTPAs. Physicians at our institution appeared to be cognizant of radiation exposure risks as they

Table 5. Follow-up test results for venous thromboembolism stratified by initial test results

	Results of initial diagnostic test	Results of follow-up tests			
		No FU	FU US positive*	FU CTPA positive*	FU V/Q high probability*
V/Q ($n = 462$)	High/positive ($n = 47$)	27	6/12	3/8	4/4
	Intermediate ($n = 40$)	0	2/33†	2/18†	0/1
	Low/very low ($n = 215$)	90	7/124	0/10	0/3
	Indeterminate ($n = 15$)	5	0/3	0/8	0/1
	Normal/negative ($n = 145$)	124	0/19	0/3	0/1
CTPA ($n = 201$)	Positive ($n = 32$)	24	1/7	0/1	1/2
	Subsegmental ($n = 5$)				
	Segmental ($n = 23$)				
	Massive ($n = 4$)				
	Indeterminate ($n = 8$)	3	0/4	0/1	2/4
	Negative ($n = 161$)	131	0/23	1/7	0/6

CTPA = computed tomographic pulmonary angiography, FU = follow-up; US = ultrasonography; V/Q = ventilation-perfusion scanning.
*For 36 patients, more than one follow-up test was performed.
†One patient had both follow-up positive CTPA and positive venous US.

Table 6. Alternative diagnoses seen on CTPA negative for pulmonary embolism

Diagnosis	*n*
No alternative diagnoses	83
Alternative diagnoses not seen on initial CXR	49
Consolidation	9
Pulmonary edema	7
Aspiration	6
Pericardial effusion	5
New nodule/tumour	4
Rib fractures	3
Inflammatory lung disease	3
Septic emboli	2
Empyema	2
Bronchiectasis	2
Pleural effusion	1
Pericarditis without effusion	1
Aortic pseudocoarctation	1
Splenic artery aneurysm	1
Foreign body	1
Pancreatitis	1

CTPA = computed tomographic pulmonary angiogram; CXR = chest x-ray.
One patient with a positive CTPA for pulmonary embolism also had pneumomediastinum, pericardial effusion, known lung mass, and consolidation seen on a CXR.

preferentially chose the lower ionizing radiation dose V/Q scan in younger patients (< 50 years old) in the survey. These results were validated by the retrospective chart review, where physicians selected V/Q scans for the majority of patients < 50 years old. In contrast to the survey results, where gender did not appear to be a decisive factor, in actual practice, physicians preferentially chose V/Q scans for females compared to males in similar age categories. This may

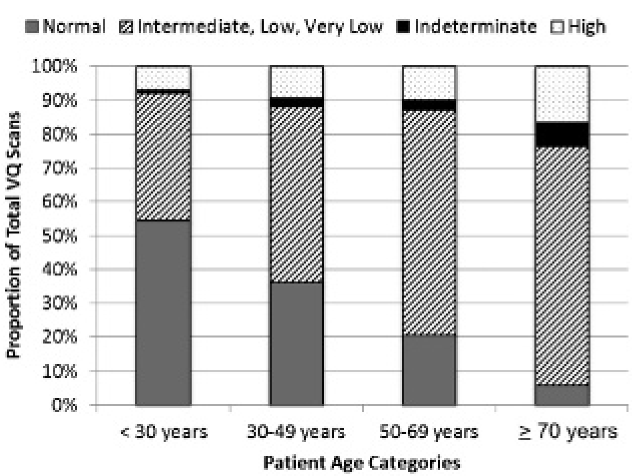

Figure 2. Ventilation-perfusion (VQ) scan results stratified by age.

reflect the influence of patient interaction that could not be reproduced in the clinical vignettes.

The literature suggests that there is good evidence of an increase in cancer risk from intermediate doses of radiation.[6] The Biological Effects of Ionizing Radiation VII report supports the current theory that this cancer risk can be extrapolated to the very low dose patients are exposed to from diagnostic imaging tests.[2] To date, there have been no prospective studies examining the effects of ionizing radiation from diagnostic imaging on the development of malignancies. Multiple cohort studies have estimated the detrimental effects of ionizing radiation from diagnostic imaging. However, the majority of the risk estimates for the development of solid cancers and leukemia have been derived from atomic bomb survivors in Hiroshima and Nagasaki.[18,19] A recent retrospective cohort study examined the effect of radiation exposure from CT scans in 178,604 children over a 20-year follow-up period and was the first study to directly correlate the cancer risk from medical imaging tests.[20] The study found that compared to people who had received doses < 5 mGy (< 5 mSv), the relative risk of leukemia for patients who received at least 30 mGy (30 mSv) was 3.18 (95% CI 1.46–6.94), and the relative risk for brain tumours for patients who received at least 50 mGy (50 mSv) was 3.32 (95% CI 1.84–6.42). This equated to a risk of one excess case of leukemia and one excess brain tumour per 10,000 head CT scans, 10 years after the first scan in children under 10 years old.[20] These risks have not yet been studied in young adults, but the increased risk of inducing malignancy from irradiating younger tissue appears certain.[20,21]

Despite the recent increased interest in radiation exposure in the literature, there appears to be a need to improve physicians' knowledge about radiation exposure from diagnostic imaging. A study by Lee and colleagues reported that 73% of emergency physicians significantly underestimated the radiation dose from a CT scan and that 91% of emergency physicians did not believe that CT scans increased the lifetime risk of cancer.[22] Another recent survey revealed that 77% of nonradiologists (20.3% of respondents were emergency physicians) underestimated the doses of common diagnostic imaging tests, and approximately one-third could not distinguish between ionizing (e.g., radioisotope scans) and nonionizing (e.g., magnetic resonance imaging) scans.[23]

Improving education will also provide physicians with the background knowledge needed to accurately

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inform patients of the risks prior to performing imaging studies. Only 3 to 13% of patients believe that exposure to ionizing radiation from diagnostic imaging tests increases their risk of cancer.[22,24] Nearly half (47%) of these patients stated they were informed of these risks, but only 22% of emergency physicians indicated that they provided their patients with this information.[22] This is in contrast to our study, in which 93% of physicians stated that they inform all high-risk patients of these risks and 58% inform all of their patients of these risks. However, the disclosure of these risks to patients in clinical practice was not examined, and the type and amount of information physicians actually provide to patients in a clinical setting are unknown.

The most effective way to reduce radiation exposure to patients is the judicious selection of imaging tests. The recent "Choosing Wisely" campaign initiated by the American Board of Internal Medicine and supported by the American College of Radiology and American College of Physicians favours reducing the number of imaging tests ordered to investigate for VTE.[25–27] In one particular study, up to one-third of imaging procedures performed on low-risk patients (1,205 of 4,113) were deemed unnecessary and could potentially have been avoided with proper use of D-dimer testing.[28]

In a recent study, investigators delivered educational seminars to physicians in the departments of emergency medicine, radiology, and nuclear medicine regarding radiation doses and the utility of V/Q and CTPA when investigating patients for PE.[29] After the seminars, the number of V/Q scans increased, whereas the number of CTPAs decreased, leading to a decreased radiation burden for their patients. This occurred without an increase in missed diagnoses of thromboembolic disease, as determined retrospectively by following patients for 90 days after their initial imaging test. Thus, increased use of V/Q scans in younger patients, particularly women, follows the "as low as reasonably achievable" (ALARA) principle for reducing radiation exposure to patients.[30,31]

Despite efforts to reduce radiation exposure, the use of V/Q scans has been declining since the introduction of CTPA. Between 2006 and 2009, the vast majority of scans ordered in the United States to investigate acute PE were CTPAs, even in teenage (< 20 year old) males (92%) and females (90%).[32] The advantages of CTPA include direct visualization of thrombus, simple positive or negative results, the provision of alternative explanations for symptoms, and improved accuracy compared to V/Q scans.[13]

The sensitivity and specificity of V/Q and CTPA scans vary depending on the study. A recent prospective trial that performed V/Q, chest x-ray, and CTPA in all patients presenting with suspected PE found that the sensitivity of VQ scans was highest using the Prospective Investigative Study of Acute Pulmonary Embolism Diagnosis (PISAPED) criteria (86.0%) compared to 64-slice CTPA (81.7%) and that the proportion of nondiagnostic scans was lower (0%) compared to the PIOPED II criteria (12.3%).[33,34] The specificity of CTPA is consistently higher than that of V/Q scanning, and the proportion of CTPAs positive for PE is higher than that for V/Q scans.[13,33] However, the clinical significance of subsegmental PE seen on CTPA is controversial because the mortality from PE remains unchanged despite an increase in the number of PEs diagnosed.[35] A recent systematic review and meta-analysis found that despite increased diagnoses of subsegmental PEs using multiple-detector CTPA compared to single-detector CTPA (9.4% v. 4.7%, respectively), improved detection did not lower the 3-month risk of thromboembolism in untreated patients with initial negative CTPAs (1.1% in multiple-detectors CTPAs and 0.9% in single-detector CTPAs).[36] Small studies involving patients with untreated subsegmental PEs were found to have no fatal recurrences in 1 to 3 months and no nonfatal recurrences of PE in 3 months.[37]

Studies examining investigation of PE often include adult patients of all ages. In our study, we found that the proportion of diagnostic V/Q scans was highest in patients < 30 years old. This correlated with a higher incidence of normal chest x-rays, fewer pulmonary or cancer comorbidities, and a lower frequency of alternative diagnoses provided by CTPA. These factors, combined with the reduced radiation exposure, make V/Q scanning a more appropriate test for younger radiosensitive populations. However, this needs to be examined prospectively in future studies. Low or nonionizing alternatives to V/Q scanning include single-photon emission computed tomography (SPECT), which is a three-dimensional nuclear medicine scan that shows comparable sensitivity and specificity to those of CTPA; pulmonary magnetic resonance angiography and venography; and the reduction of CTPA radiation dosages through technical (e.g., adjust voltage or current, limit *z*-axis coverage) or traditional (e.g., shielding) strategies, but further investigation is required.[13,38–41]

LIMITATIONS

This study has several limitations. First, the survey was distributed to physicians working in two Canadian tertiary care adult EDs, and as such, the results may not be generalizable to other settings. The applicability of these findings is limited to institutions that have access to V/Q scans. At our institution, it is standard practice to order V/Q scans for investigation of acute PE in ED patients with a normal chest x-ray. This may not be the usual practice in other EDs. V/Q scans are available daily from 0800–1600, with a technologist on call until midnight. In contrast, CT is available 24 hours a day.

In addition to radiation risk, other factors are involved when choosing an imaging study that were not investigated in this study, such as patient comorbidities (e.g., renal failure), contrast allergies, and institutional preferences. These issues could be addressed in a prospective study in which physicians would be asked to justify their reasons for choosing a particular diagnostic imaging test.

Lastly, this was a retrospective study, and patients were followed for 90 days after their initial imaging study by electronic medical record review. Although it is theoretically possible that we may have underestimated the incidence of missed PE in our sample as a consequence, this is unlikely because all centres that have CTPA and/or V/Q capability within 50 km of our hospitals share the same electronic medical record. Most patients were likely to return to one of these EDs for follow-up. The incidence of PE diagnosed on the initial CTPA (15.9%) and V/Q scan (10%) in our study compares favourably to that of the prospective study by Anderson and colleagues, conducted at four Canadian and one US tertiary care centre, in which the incidence of PE diagnosed with the initial CTPA was 17.7% and 11.7% with the initial V/Q scan.[12] The overall incidence of PE in that study was 17.2%, which was slightly higher than in our study (13.9%). However, no fatal cases of missed PE were identified in our retrospective review, and as discussed, the clinical significance of minor PEs, especially those found by CTPA, remains uncertain.[13,33]

CONCLUSIONS

The most effective method of reducing radiation exposure from diagnostic imaging is the judicious selection of patients who will undergo these investigations. This study demonstrated that although physicians at our institution had limited knowledge of actual radiation doses associated with CTPA and V/Q scans, they were aware that V/Q scans expose patients to less ionizing radiation. In practice, they preferentially chose the lower ionizing V/Q scan in radiosensitive populations. Further evidence-based education of physicians and medical trainees is needed to ensure informed decision making and accurate disclosure of radiation exposure risks to our patients.

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APPENDIX: SURVEY QUESTIONS DELIVERED TO ADULT EMERGENCY PHYSICIANS

Demographics

1. Gender
   - ○ Male
   - ○ Female
2. Years in practice
   - ○ < 5 years
   - ○ 5–10 years
   - ○ 10–15 years
   - ○ 15–20 years
   - ○ 20 years
3. Which guidelines do you follow for investigating venous thromboembolism?
   - ○ Published guidelines (e.g., British Thoracic Society)
   - ○ Local guidelines
   - ○ All of the above
   - ○ Neither

Clinical Vignettes

You are working the weekday daytime shift at a tertiary care emergency department where all of the listed investigations are available. What would be YOUR initial investigation of choice for the following patients presenting with pleuritic chest pain and shortness of breath. Assume a high pretest probability of PE (Wells score ≥ 4) or a positive D-dimer.

- ○ US venous Doppler ultrasonography
- ○ CT pulmonary angiography
- ○ CT pulmonary angiography with CT leg venography
- ○ Ventilation-perfusion scanning
- ○ Other

4. 25-year-old female. Otherwise healthy. Not pregnant. Chest x-ray is nondiagnostic.
5. 25-year-old female. Otherwise healthy. Pregnant < 20 weeks gestational age. Chest x-ray is nondiagnostic.
6. 25-year-old male. Otherwise healthy. Chest x-ray is nondiagnostic.
7. 45-year-old female. Otherwise healthy. Not pregnant. Chest x-ray is nondiagnostic.
8. 45-year-old female. Otherwise healthy. Previous V/Q scan 1 year ago, which was normal. Chest x-ray is nondiagnostic.
9. 45-year-old female. Otherwise healthy. Previous CTPA 1 year ago, which was normal. Chest x-ray is nondiagnostic.
10. 45-year-old male. Otherwise healthy. Previous head CT 1 year ago for fall, which was normal, and previous abdominal CT 2 months ago for diverticulitis. Chest x-ray is nondiagnostic.
11. 60-year-old male. Otherwise healthy. Chest x-ray is nondiagnostic.
12. 60-year-old female. History of left breast cancer treated with left total mastectomy and radiation therapy 5 years ago. Chest x-ray is nondiagnostic.
13. 60-year-old male. History of intracerebral hemorrhage 5 years ago. Chest x-ray is nondiagnostic.
14. 60-year-old male. History of COPD and smoker × 40 pack-years. Chest x-ray shows mild hyperinflation but is otherwise nondiagnostic.

Radiation Exposure Questions

15. Do you explain the radiation risks of diagnostic imaging tests to patients?
    - ○ Yes
    - ○ No
    - ○ Only to pregnant females and females of childbearing age
    - ○ All patients who you deem to be at high risk, including pregnant females and females of childbearing age
    - ○ Other
16. Do you possess knowledge regarding cancer risks associated with diagnostic imaging radiation?
    - ○ Yes
    - ○ No
17. What is the average background radiation dose per person, per year?
    - ○ 1 PA CXR (0.05 mSv or 0.005 rad)
    - ○ 2 PA CXRs (0.1 mSv or 0.01 rad)
    - ○ 40 PA CXRs (2 mSv or 0.2 rad)
    - ○ 100 PA CXRs (5mSv or 0.5 rad)
    - ○ 200 PA CXRs (10 mSv or 1 rad)
    - ○ Not sure
18. The North American population is exposed to radiation from various sources. Of these, medical radiation contributes to
    - ○ < 0.5%
    - ○ 1%
    - ○ 5%
    - ○ 10%
    - ○ 15%

- Not sure

19. What is the approximate radiation exposure during a round-trip commercial airline flight between New York and London, England (12- to 14-hour trip over 11,000 km total)?

- 1 PA CXR (0.05 mSv or 0.005 rad)
- 2 PA CXRs (0.1 mSv or 0.01 rad)
- 40 PA CXRs (2 mSv or 0.2 rad)
- 100 PA CXRs (5mSv or 0.5 rad)
- Not sure

20. What is the acceptable yearly maximum radiation dosage for radiation workers?

- 100 PA CXRs (5 mSv or 0.5 rad)
- 200 PA CXRs (10 mSv or 1 rad)
- 400 PA CXRs (20 mSv or 2 rad)
- 1,000 PA CXRs (50 mSv or 5 rad)
- No limit
- Not sure

21. What is the acceptable yearly maximum radiation dosage for diagnostic imaging in patients?

- 100 PA CXRs (5 mSv or 0.5 rad)
- 200 PA CXRs (10 mSv or 1 rad)
- 400 PA CXRs (20 mSv or 2 rad)
- 1,000 PA CXRs (50 mSv or 5 rad)
- No limit
- Not sure

22. What is the minimum in utero radiation dosage that has been associated with significant and quantifiable increase in the risk of childhood cancers?

- 2 PA CXRs (0.1 mSv or 0.01 rad)
- 20 PA CXRs (1 mSv or 0.1 rad)
- 100 PA CXRs (5 mSv or 0.5 rad)
- 200 PA CXRs (10 mSv or 1 rad)
- 300 PA CXRs (15 mSv or 1.5 rad)
- Not sure

23. What is the approximate radiation dosage of a CT pulmonary angiography?

- 20 PA CXRs (1 mSv or 0.1 rad)
- 40 PA CXRs (2 mSv or 0.2 rad)
- 100 PA CXRs (5 mSv or 0.5 rad)
- 200 PA CXRs (10 mSv or 1 rad)
- 1,000 PA CXRs (50 mSv or 5 rad)

24. What is the approximate radiation dosage of a ventilation-perfusion scan?

- 20 PA CXRs (1 mSv or 0.1 rad)
- 40 PA CXRs (2 mSv or 0.2 rad)
- 100 PA CXRs (5mSv or 0.5 rad)
- 200 PA CXRs (10 mSv or 1 rad)
- 1,000 PA CXRs (50 mSv or 5 rad)

25. The estimated lifetime risk of developing cancer after receiving 10 mSv of radiation (200 PA CXRs) is equivalent to

- 1 in 4.7 million (risk of contracting human immunodeficiency virus [HIV] from a single blood transfusion)
- 1 in 3.1 million (risk of contracting hepatitis C virus from a single blood transfusion)
- 1 in 82,000 (risk of contracting hepatitis B virus from a single blood transfusion)
- 1 in 40,000 (risk of anaphylactic reaction from a single blood transfusion)
- 1 in 5,000 (risk of transfusion-related acute lung injury)
- 1 in 1,000
- Not sure