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Brief Communication

SPECT ventilation perfusion scanning with the addition of low-dose CT for the investigation of suspected pulmonary embolism

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Abstract

Single-photon emission computed tomography (SPECT) ventilation perfusion (V/Q) scanning with low-dose computed tomography (LDCT) is an emerging imaging technique for investigation of suspected pulmonary embolism (PE). We aimed to estimate diagnostic utility of the combined technique using results from all patients referred in 2009 compared with final diagnosis and 6-month follow-up status. PE was diagnosed in 28 of 106 patients (26%), including in 2 of 80 (2%) with negative SPECT V/Q and LDCT. The estimated negative predictive value of SPECT V/Q for PE was 97%. LDCT was abnormal in 43 (41%) patients, including 41 patients who had negative SPECT V/Q. In 29 (27%) patients, LDCT provided information on alternative pathologies that accounted for presenting symptoms, and the combined technique had a diagnostic yield of 52%.

Acute pulmonary embolism (PE) is common[1,2] and frequently fatal if untreated.[3] Diagnosis is challenging even when PE is suspected, with debate about the best approach for accuracy and efficiency. Single-photon emission computed tomography (SPECT) ventilation perfusion (V/Q) scanning is a modality that is increasingly used for the diagnosis of PE. The technique represents a transition from planar to cross-sectional imaging, with data acquired tomographically and analysed as a three-dimensional dataset. SPECT V/Q overcomes the superimposition of lung with normal perfusion, which can mask PE and studies demonstrate enhanced sensitivity, specificity and marked reduction in the non-diagnostic rate compared with planar V/Q.[4,5] SPECT V/Q is now available at many public and private facilities throughout Australasia, although accuracy data on its performance are still emerging.[6] The addition of low-dose computed tomography (LDCT) in the same sitting for anatomical correlation is an even newer technique now being used; however, the benefit of LDCT remains to be quantified.

We report the outcomes of SPECT V/Q scans done for suspected PE at a 600-bed tertiary institution in terms of sensitivity and specificity, and describe the incremental benefit of the addition of LDCT to the diagnostic yield.

We reviewed all SPECT V/Q with LDCT scans done on patients referred to the Department of Nuclear Medicine, Sir Charles Gairdner Hospital in 2009 for suspected PE. Demographic and clinical information were obtained from review of case notes. We recorded presenting symptoms, smoking status, comorbidities, vital signs (including initial room air oxygen saturation, SpO_2), Wells score, and final clinical diagnosis given by the attending physician. Six-month follow-up status was ascertained either from case notes or by telephone contact. Serum creatinine levels were obtained from an online pathology results system.

SPECT V/Q and LDCT were reported by two experienced nuclear medicine physicians blinded to clinical data and classified by consensus as positive or negative for PE using predefined criteria (PE diagnosed in the presence of >50% perfusion mismatch in an anatomical segment or ≥2 regions of perfusion mismatch regardless of size). Abnormalities detected by LDCT were categorised into likely pathologies and correlated to SPECT V/Q findings to suggest alternative diagnoses in those negative for PE.

To estimate the sensitivity and specificity of SPECT V/Q, a composite reference standard for PE was used. The reference diagnosis was PE if the final physician diagnosis was PE and there were no alternative diagnoses at 6

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months; and not PE if the final physician diagnosis was not PE and there was no occurrence of venous thromboembolism (VTE) at 6 months. The study was approved by the local human research ethics committee.

There were 122 scans performed in 2009, with 106 patients having clinical and follow-up data available (Table 1). Fifteen patients were referred from other institutions and were excluded from analysis as clinical data was unavailable.

In 122 scans, SPECT V/Q was classified as positive for PE in 28 (23%), negative in 93 (76%) and equivocal in 1 (1%). The patient with the equivocal result (excluded from analysis) received a diagnosis of gastritis, had no LDCT abnormalities and was stable at 6 months. In the 106 patients analysed, SPECT V/Q was classified as positive for PE in 26 (25%) and negative in 80 (75%). Four of the 80 patients with negative scans had CTPA due to ongoing high clinical suspicion for PE. In two, CTPA was negative for PE and were classified as SPECT V/Q true negatives. In two, CTPA was positive for PE and were classified as false negatives; the CTPA appearances in these two were thought to represent chronic PE. During 6 months follow-up, there were no other diagnoses of VTE in those with negative scans, and no alternative diagnoses made in those with positive scans. There were 12 deaths (11%) in the follow-up period – 6 from malignancy, 1 each from PE, acute coronary syndrome, sepsis, heart failure, chronic obstructive pulmonary disease (COPD) and acute respiratory distress syndrome (ARDS). One death from PE and one from malignancy occurred in those with positive SPECT V/Q scans, and all other deaths occurred in those with negative scans.

Table 1 Population characteristics for all patients and for patients classified as positive and negative for pulmonary embolism (PE)

Characteristics	Total, $n = 106$	PE positive, $n = 28$	PE negative, $n = 78$
Age (years)	51 ± 22	51 ± 20	52 ± 23
Male gender	27 (25)	10 (36)	17 (22)
Admission status			
Emergency department	63 (59)	14 (50)	49 (63)
Inpatient	28 (26)	5 (18)	23 (31)
Outpatient clinic	14 (13)	9 (32)	5 (6)
Presenting symptoms			
Chest pain	62 (58)	12 (43)	50 (64)
Dyspnoea	57 (53)	17 (61)	40 (51)
DVT symptoms	13 (12)	5 (18)	8 (10)
Cough	11 (10)	1 (4)	10 (13)
Haemoptysis	4 (4)	1 (4)	3 (4)
Smoking status			
Current smoker	17 (16)	6 (21)	11 (14)
Ex-smoker	17 (16)	3 (11)	14 (18)
Non-smoker	43 (40)	12 (43)	31 (40)
Unknown	29 (27)	9 (32)	20 (26)
Comorbidities			
Asthma	11 (10)	6 (21)	5 (6)
COPD	5 (5)	1 (4)	4 (5)
Ischaemic heart disease	15 (14)	2 (7)	13 (17)
Malignancy	15 (14)	4 (14)	11 (14)
Previous VTE	26 (24)	13 (46)	13 (17)
Thrombophilia	8 (7)	2 (7)	6 (8)
Diabetes	17 (16)	4 (14)	13 (17)
Hypertension	29 (27)	7 (25)	22 (28)
Renal impairment			
Creatinine >120 mmol/mL	28 (26)	5 (18)	23 (29)
Creatinine >200 mmol/mL	9 (8)	1 (4)	8 (10)
Vital signs and miscellaneous			
Pulse (bpm)	88 ± 18	86 ± 17	88 ± 18
Systolic blood pressure (mmHg)	139 ± 24	132 ± 26	141 ± 23
Diastolic blood pressure (mmHg)	79 ± 13	80 ± 15	79 ± 13
SpO_2 (% on room air)	95 ± 5	95 ± 4	95 ± 5

Values are given as number (%) or mean ± SD. COPD, chronic obstructive pulmonary disease; DVT, deep vein thrombosis; SpO_2, oxygen saturation; VTE, venous thromboembolism.

The prevalence of PE by traditional Wells criteria[7] was 3% (1/30), 23% (13/56) and 50% (5/10) in the low, moderate and high probability groups, respectively. The prevalence of PE by modified Wells criteria[8] was 11% (6/55) and 32% (13/41) in the PE unlikely and PE likely groups, respectively.

The results of this study demonstrate that our initial experience with SPECT V/Q for suspected PE was one of reasonably high accuracy, similar to other studies of

LDCT demonstrated pulmonary abnormalities in 43 (41%) patients and was normal in 63 (59%). In the 26 patients with a positive SPECT V/Q, the LDCT was abnormal in two (8%) patients, both consistent with small pulmonary infarctions. In the 80 patients with a negative SPECT V/Q, 41 (51%) had LDCT abnormalities – 14 of atelectasis or consolidation, 11 of pulmonary oedema, 9 of emphysema, 3 of pleural effusions, 2 of incidental nodules, and 2 of elevated hemidiaphragm. In 29 (36%), LDCT abnormalities contributed to final clinical diagnoses – 10 of left ventricular dysfunction, 10 of pneumonia, 8 of infective exacerbation of COPD and 1 of ARDS. Along with the 26 patients with a positive scan for PE, this provided a total of 55 patients with diagnostic information from SPECT V/Q with LDCT, for an overall diagnostic yield of 52%.

Using the composite reference standard for PE, 28 (26%) patients were classified as positive, and 78 (74%) were classified as negative. Based on the reference standard, the estimated sensitivity, specificity and negative predictive value (95% CI) of SPECT V/Q for the diagnosis of PE was 93% (83–100%), 100% (93–100%) and 97% (93–100%), respectively. There were 26 true positive, 78 true negative, and 2 false negative results.

Table 2 Accuracy studies of SPECT V/Q for pulmonary embolism

Study	Year	*n*	Reference standard	Follow-up	Sensitivity	Specificity
Ling	2010	107	Consensus, SPECT	6 months	93%	100%
Gutte *et al*.[9]	2009	81	Consensus, SPECT, CTPA	6 months	97%	88%
Miles *et al*.[10]	2009	100	Consensus, SPECT, CTPA	3 months	83%	98%
Bajc *et al*.[4]	2008	1785	Consensus, SPECT	6 months	99%	98%
Bajc[11]	2004	53	Consensus, SPECT, CTPA	n/a	100%	93–95%
Reinartz *et al*.[12]	2004	83	Consensus, SPECT, CTPA	5 months	97%	91%
Collart *et al*.[13]	2002	66	Consensus	n/a	80%	96%
Reinartz *et al*.[14]	2001	103	Not stated	n/a	89–96%	96–100%
Lemb *et al*.[15]	2001	85	SPECT follow-up	22 months	96%	97%
Palla *et al*.[16]	1988	180	Selective conventional angiography	n/a	90%	64%

CTPA, computed tomography pulmonary angiogram; SPECT, single-photon emission computed tomography; V/Q, ventilation perfusion.

SPECT V/Q performance (Table 2). Also, we found that the addition of LDCT added useful information by identifying alternative causes for the presenting symptoms, and contributed to the overall diagnostic yield.

To date, SPECT V/Q has not been evaluated against an independent objective gold standard for the diagnosis of PE,[5] and investigations on the accuracy of the SPECT V/Q have necessarily relied on composite reference standards that include the imaging study itself (Table 2). This study utilised a similar composite reference standard, with a longer follow-up period than many previous investigations. Studies on planar V/Q have shown that false positive results can occur with a variety of pathologies, including vasculitis, pulmonary fibrosis and neoplasia.[17,18] With such reference standards, the true false positive rate is unknown, although the likelihood of this being low in this study is supported by the lack of alternative findings on LDCT and the absence of alternative diagnoses during the 6-month follow-up. The false negative rate in this study is very low, and the results are supported by the 6-month follow-up status that did not reveal any subsequent diagnoses of PE or VTE. This is similar to findings in other larger studies,[19,20] suggesting that SPECT V/Q has excellent negative predictive value. Nonetheless, caution should be taken when accepting these estimates given the lack of an independent reference standard and the inevitable confounding influence of SPECT V/Q results on the reference standard in use, particularly with regards to the false positive rate as the true specificity is almost certainly lower than 100%.

The benefit to diagnostic yield with the addition of LDCT has not been quantified. Gutte and colleagues[9] investigated the accuracy of SPECT V/Q with LDCT for the detection of PE compared with CTPA, and found that the addition of LDCT increased the specificity of SPECT V/Q while maintaining its sensitivity. This was due to the ability of LDCT to visualise abnormalities such as atelectasis, emphysema and consolidation that may explain SPECT V/Q defects. Several patients were allocated a false positive diagnosis of PE with SPECT V/Q alone due to the presence of interlobar fissures and paraseptal emphysema that were detected on LDCT.

In this study, we demonstrate that the addition of LDCT increases the diagnostic yield of the test by providing alternative diagnoses, which correlated to the final clinical diagnosis provided for each case. Findings on LDCT were correlated to characteristic defects on SPECT V/Q to provide alternative diagnoses in 29 (27%) patients. These include consolidation on LDCT with appropriately matched or reverse mismatched defects on V/Q in those with pneumonia,[21] and pulmonary oedema on LDCT with preferential perfusion redistribution to the upper zones in left ventricular dysfunction.[22] In patients where emphysematous changes are shown, heterogeneous ventilation defects on V/Q is indicative of COPD. In these instances, LDCT enables detection of structural inflammatory changes such as opacity or infiltrates, that when correlated to matched or reverse mismatched V/Q abnormalities is highly suggestive of infective exacerbation of COPD.[23] However, it is important to note that diagnoses are often made based on other clinical data (e.g. history, examination, echocardiography and spirometry), and these results primarily reflect the contribution of useful information from LDCT.

Wells criteria have been used extensively in determining the likelihood of PE.[7,8] Encouragingly, the prevalence of PE by traditional Wells criteria in this study are very close to pooled data from previous reports, including PIOPED II.[24]

SPECT V/Q has several advantages over CTPA that make it an attractive first-line investigation for suspected PE. This includes non-nephrotoxic radioisotopes, lower total radiation dose (institutional average 1.5mSv for SPECT V/Q with 150MBq technetium-labelled albumin, 0.9mSv for spiral LDCT at110kVp 20mA and 4.0–12.0 mSv for CTPA depending on software and equipment),

and considerably lower breast radiation dose.[25] Only very low volumes of intravenous radioisotope are required during the perfusion phase, allowing utilisation of small bore intravenous cannulae (23–25 gauge) in patients with difficult venous access. SPECT V/Q, however, is not without limitations. In particular, after hours availability is limited in many institutions,[5] and a 30 min acquisition time[26] means that CTPA remains the preferred investigation in unstable patients.

A final point of note is that patients in this study do not represent consecutive patients with suspected PE, but are referred in consultation with nuclear medicines physicians and selected mainly based on factors that make SPECT V/Q preferable over CTPA. This represents a selection bias and care should be taken when applying these results to a more general population.

In conclusion, the initial experience with SPECT V/Q at our institution has been one of high sensitivity and good negative predictive value for PE. The addition of LDCT increases the diagnostic yield of the test by providing information on alternative pathologies that account for presenting symptoms. SPECT V/Q is a useful diagnostic test for suspected PE with significantly higher diagnostic yield compared with planar V/Q, making it a viable first-line alternative to CTPA. In the setting of renal impairment, radiocontrast allergy and in younger females, SPECT V/Q should be considered the investigation of choice.

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Healthcare burden of in-hospital gout

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Abstract

The disease burden of inpatient gout has not been reported. Using a discharge diagnosis database and individual case record review, 77 patients who developed acute gout complicating a hospital admission for another reason were identified between January 2001 and April 2010 at The Townsville Hospital. A control group of 28 301 cases with identical principal diagnoses were similarly ascertained, along with a subgroup of 231 cases matched for age, gender and ethnicity. Patients with an admission complicated by acute gout stayed 6 days longer in hospital than matched control patients (9 days vs 3 days, $P = 0.0005$) with the same principal diagnoses and demographics. Patients with an attack of gout were more likely to be older, male or indigenous. Early diagnosis and appropriate treatment may help to reduce the healthcare costs of this overlooked disease.

In Western countries, gout is the most common inflammatory arthritis. In the United Kingdom and United States, the prevalence of gout is 1–2%.[1] The prevalence of gout is higher in men and increases with age, with a prevalence approaching 7% in men over the age of 65.[2] Other risk factors associated with gout include dietary excess, alcohol, diuretics, low-dose aspirin and renal disease.[3] It is associated with significant burden on patient quality of life, the health system and the economy.[4]

Acute gout in hospitalised patients presents a distinct clinical problem. First, gout is particularly prevalent in hospitals because the disease processes that lead to hospitalisation, such as acute renal failure,[5] and treatments administered in hospital, such as diuretics and surgical procedures, all can precipitate gout. Second, diagnosing gout in hospital may be problematic, as there may be a number of reasons for acute pain and a gout diagnosis may be overlooked. Third, contraindications to colchicine and non-steroidal anti-inflammatory drugs,[6] such as heart failure, renal impairment and elevated gastrointestinal bleeding risk, are common in inpatients.

A major undersupply of acute hospital beds in Australia has focused efforts on reducing inpatient length of stays.[7] Acute gout might be expected to prolong inpatient length of stay; however, the additional bed use resulting from inpatient gout is yet to be reported. To measure this, a retrospective case-control study was performed where cases and controls were matched for principal diagnosis (not gout), and with cases having a recorded episode of inpatient gout while controls did not. Demographical details were also collected.

The Townsville Hospital discharge diagnosis database was interrogated for patient admissions that were coded under the International Classification of Diseases (10th revision) with a secondary diagnosis of gout (M10) and a

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