A retrospective study of the value of indirect CT venography: a British perspective

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Objective: The aim of this study was to establish the value of indirect CT venography (CTV) in clinical practice within the UK.

Methods: 804 combined CT pulmonary angiogram and CTV studies were retrospectively reviewed. CTV was performed 180 s after the injection of contrast using an incremental technique with a 5-mm collimation and a 5-cm interspace between images extending from the iliac crests to the tibial plateaus.

Results: 12.9% of studies had isolated pulmonary emboli (PE), 3.0% had both a PE and deep vein thrombosis (DVT) and 1.1% had an isolated DVT. The proportion of positive cases diagnosed by CTV alone was 6.6%.

Conclusion: In a UK-based practice, the incidence and the proportion of isolated DVT diagnosed by CTV are lower than expected from published data. An analysis of possible causes for this is made within the paper.

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More than 250 000 cases of pulmonary embolism were identified in the UK between 1996 and 2006, yet the accurate diagnosis of this condition remains problematic [1]. Autopsy studies indicate that 88% of pulmonary emboli (PE) are unsuspected clinically prior to death. Although the majority of these PE are an incidental complication of an underlying comorbid condition, less than half of cases of fatal PE are correctly diagnosed ante-mortem [2, 3]. It is accepted that PE originate from distant sites of venous thrombosis and that both PE and deep vein thrombosis (DVT) are facets of the same disease process, with the majority of DVT arising within the lower limb veins. The evaluation of the presence of DVT is therefore considered part of the investigation of PE, and the presence of DVT in the absence of radiological evidence of PE can be accepted as surrogate evidence of venous thromboembolism (VTE). Lower limb indirect CT venography (CTV) may be added to CT pulmonary angiography (CTPA) to identify the presence of DVT, but this is at the expense of an increased examination time and an increased radiation dose, particularly to the reproductive organs. The prospective investigation of the PE diagnosis II study demonstrated the addition of CTV to CTPA increased the sensitivity for detection of PE from 83% to 90% [4]. Despite this, the routine addition of CTV to CTPA is not recognised in current British Thoracic Society guidelines, and it is not known how many centres in the UK have adopted this technique [5].

The aim of this study is to establish the incremental value of CTV in clinical practice within a British institution and ascertain whether factors such as image quality significantly influence the value of the examination. To our knowledge this is the first large British study of the value of CTV in the investigation of PE.

Methods and materials

CTPA examinations performed in a tertiary hospital between September 2009 and January 2010 were retrospectively identified using the radiology information system. CTV is routinely performed as part of the evaluation of acute VTE except when the presence of DVT has already been investigated, in the elective investigation of outpatients, during pregnancy and in the paediatric population. The gender, age and referral site of the patient were documented and the referral site was categorised as inpatient or outpatient. Emergency department referrals were categorised as outpatient. As this was an evaluation of our routine practice, no formal permission was required from our research and ethics department.

Patients were recruited from two hospitals and imaged on both 16- and 64-detector scanners, with the majority performed using 64-detector scanners. The CTPA technique involved administration of 100 ml of iodinated contrast (Ioversol 64%, 300 mg ml⁻¹; Tyco Healthcare, Mansfield, MA) at 3–4 ml s⁻¹ via a cannula within the arm using an automated injector. The patients were placed in the supine position and a helical scan of the thorax obtained at maximal inspiration in a caudocranial direction (160 mAs, 100 kV) with a 1-mm axial image reconstruction. Image acquisition was timed so that completion of the scanning of the thorax coincided with the end of the injection of the contrast bolus. Indirect CTV imaging commenced 180 s post-completion of the injection of intravenous contrast with a range extending from the iliac crests to the tibial plateaus. Non-contiguous axial scanning in a craniocaudal direction (200 mAs, 120 kV) with a 5-mm collimated slice and 5-cm intervals were obtained.

From the formal report, the results of the CTPA were recorded as positive, negative, equivocal or non-diagnostic. The result was considered non-diagnostic when the report clearly stated this or advised a repeat study. CTV

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Table 1. Study population demographics and results of CT pulmonary angiogram and CT venography

		Number of cases	Number of PE	Number of DVT	Number of isolated DVT
Gender	Male	331	70	22	5
	Female	473	58	11	4
Referral category	Outpatient	284	40	11	2
	Inpatient	520	88	22	7
Total		804	128	33	9

DVT, deep vein thrombosis; PE, pulmonary embolism.

Median age 67 years (range 17–96 years).

results were recorded as positive, negative, equivocal, non-diagnostic or not reported.

A separate retrospective evaluation of diagnostic quality of the CTV studies was made and the studies were categorised as either optimal or suboptimal quality. CTV studies were considered to be of optimal diagnostic quality if a minimum level of enhancement had been obtained and all anatomical levels of the pelvic and lower limb venous system had been visualised. An attenuation of ≥ 70 HU was considered to be of diagnostic quality [6]. The degree of contrast enhancement was measured within the most proximal vein below the level of the renal veins. The measurement was performed using a region of interest occupying $>50\%$ of the area of the vessel. Other causes of suboptimal studies, such as artefacts from metallic joint prostheses and poor positioning, were recorded. The site of any DVT was recorded as inferior vena cava (IVC), iliac vein, femoral vein, popliteal vein or a combination of these. Measurements were made by a consultant radiologist specialised in thoracic imaging with 5 years of experience and two senior thoracic radiology trainees.

The statistical significance of the incidence of DVT in different age and referral groups was calculated using the χ^2 test ($p < 0.05$). Fisher's exact test was used for the comparison of diagnostic and suboptimal studies ($p < 0.05$).

Results

A total of 911 CTPAs were performed within the study period. Examinations were excluded from further analysis if a CTV was not performed (105 studies) or the presence of a DVT was known prior to the study (2 studies). Of the 105 studies where CTV was not performed, 53 were outpatients undergoing elective investigation, 9 had recent investigations for the presence of DVT, 6 were pregnant and in the remainder no reason was stated. Within this excluded group the median age (61 years, range 21–93 years), gender distribution (46% male) and rate of positive CTPA (14.3%) did not significantly vary from the study group (Table 1).

Of the remaining 804 studies, 41% of patients were male and the median age was 67 years (range 17–96 years). Inpatients constituted 64.7% and outpatients 35.3% (Table 1). Of the 804 CTV studies, 19 (2.4%) were reported as equivocal or non-diagnostic and in 58 (7.2%) studies no comment was made on the presence or absence of DVT. Both of these were considered negative studies for the purposes of our analysis. A retrospective

review of these cases demonstrated two possible cases of DVT.

PE was identified in 128 (15.9%) studies, with an isolated PE identified in 104 (12.9%) and a PE and DVT present in 24 (3.0%). A DVT was identified in the absence of a PE in 9 (1.1%) studies. Therefore, the proportion of all patients correctly diagnosed by CTV alone was 9/137 (6.6%). No statistically significant difference was identified in the incidence of DVT in the different age, gender or referral groups.

Of the 33 DVTs detected, 2.8% involved the IVC, 30.6% the iliac veins, 61.1% the femoral veins and 47.2% the popliteal veins. 11% of DVTs were isolated to the iliac veins, 27% to the femoral veins, 25% to the popliteal veins and 37% affected more than 1 level. There were no DVTs isolated to the IVC.

The mean attenuation of the most proximal vein below the level of the renal veins was 89 (standard deviation=14.5). Previous studies suggest that >70 HU is an acceptable level of enhancement, and 47 studies (5.8%) fell below this level [6]. In 60 studies (7.4%), hip and/or knee prostheses obscured 1 or more level of the venous system. Poor patient positioning and motion artefacts made another 11 (1.4%) suboptimal. In total, 118 (14.6%) CTVs were deemed to be of suboptimal diagnostic quality. No DVTs were identified amongst the suboptimal studies, and the difference in incidence of DVT between the suboptimal and diagnostic studies was statistically significant ($p=0.03$). If the suboptimal studies are excluded from our analysis, 33 (4.8%) of the 688 diagnostic quality studies revealed a DVT, of which 12 (1.7%) had an isolated DVT.

Discussion

A number of studies assess the merits of CTV in the investigation of PE (Table 2). These demonstrate that 1.9–4.8% of patients have a DVT in the absence of PE (Table 2) [7–16]. Our finding of 1.1% is lower than expected. The incidence of PE within these studies ranges from 9% to 26% and the rate in our group of 15.9% is comparable. The incremental value of CTV can be judged by the proportion of positive cases correctly identified only with CTV. This has been reported as 10–27%. Our result of 6.5% is also lower than expected and indicates that CTV is of less value in our practice than suggested by previously published data (Table 2).

We analysed our methods in an attempt to identify a cause for the lower than expected detection of DVT. This may have been a reflection of the technique employed or the diagnostic quality of the studies. Using an interval scanning technique instead of contiguous imaging of the

Table 2. Summary table of the results of published studies investigating CT venography (CTV). The data from this study are included within the table

Author	Number of patients	Number of PE ± DVT (%)	CTV scanning technique (collimation/interspace)	Number of isolated DVT (%)	Proportion of patients with VTE diagnosed by CTV alone
Cham et al [7]	541	91 (17)	10 mm/10 mm	16 (3)	18%
Loud et al [8]	650	85 (13.0)	5–10 mm/50 mm	31 (4.8)	27%
Richman et al [9]	800	73 (9)	10 mm/20 mm	15 (2)	17%
Cham et al [10]	1590	243 (15)	10 mm/10 mm	48 (3)	16%
Revel et al [11]	178	47 (26.4)	5 mm/5 mm	5 (2.8)	9.6%
Ghaye et al [12]	Single detector CT 1100	219 (19.9)	5 mm/20 mm	37 (3.4)	14.4%
	Multidetector CT 308	53 (17.2)		20 (6.5)	27.4%
	Total 1408	272 (19.3)		57 (4.0)	17.3%
Rhee et al [13]	909				
Kalva et al [14]	2074	283 (13.6)	7.5 mm/7.5 mm	46 (2.2)	16.2%
Hunsaker et al [15]	829	124 (15)	10 mm/30 mm	28 (3.4)	18.4%
Stein et al [16]	1903	231 (12.1)		25 (1.9)	10.8%
Slater et al (current study)	804	128 (15.9)	5 mm/50 mm	9 (1.1)	6.6%

DVT, deep vein thrombosis; PE, pulmonary embolism; VTE, venous thromboembolism.

lower limbs may partly explain these findings. There is no consensus regarding the optimum technique for CTV and there is a balance to be struck between sensitivity for thrombosis and radiation dose. The incremental technique employed is based on that used by Loud et al [8] and has a reported sensitivity of 97% for the presence of DVT compared with sonovenography. A review of 12 CTV studies including both contiguous and sequential imaging concluded that there are no significant diagnostic differences between the techniques [17], and Goodman et al [18] showed 7.5 mm collimated slices at 15 mm intervals detected 89% of the DVTs seen on volume acquisitions acquired with a 7.5 mm collimation. However, Cham et al [10] found that 24% of DVTs measure <4 cm in length and estimated that a 5-cm interval technique could miss 40% of the DVTs measuring <4 cm in length [10].

An evaluation of the effect of suboptimal CTV studies was made to determine whether these contributed to the lower than expected benefit of CTV. A proportion of the studies (14.6%) were retrospectively considered to be of reduced diagnostic quality. No DVTs were identified in the suboptimal group and the incidence of DVT significantly differed from the diagnostic studies ($p=0.03$). If the suboptimal studies are excluded from our analysis, the overall incidence of DVT is slightly higher (4.9% *vs* 4.1%) and the incidence of isolated DVT rises from 1.1% to 1.7%. This still remains lower than those of previously published studies. Surprisingly the most common cause of a suboptimal study identified was the presence of metallic joint prostheses. This suggests that the presence of hip or knee prostheses is an indication for investigation with sonovenography rather than CTV. We concluded that studies in which all levels of the lower limb venous system are not visualised or in which the attenuation of the veins fails to reach 70 HU should be considered non-diagnostic, but this did not account for the reduced incidence of DVT.

A selection bias may have resulted from the initial exclusion of the 105 patients who did not undergo CTV

from the study group or from categorising 58 unreported cases as negative. The demographic features and the rate of positive CTPA in those who did not undergo CTV did not differ significantly, thus suggesting that these patients are representative of our study group. It therefore seems unlikely that this group contained a disproportionately high number of cases of DVT. A retrospective review of all 58 unreported CTVs demonstrated 2 possible DVTs. The inclusion of these cases would not have significantly increased our overall detection of DVT.

The benefits of CTV have to be interpreted in the light of the radiation dose and cost-effectiveness of the technique. The effective dose of the CTV technique used is calculated to be 1.48 mSv for males and 1.68 mSv for females. The additional lifetime risk of fatal cancer in males and females aged 20–29 years from this radiation dose is estimated to be $9.0\text{--}11.8 \times 10^{-5}$ [19]. The cost of adding CTV to CTPA in our department is estimated to be £79. In our practice, the cost of identifying a single case of isolated DVT is therefore estimated to be £7182. Despite the reduced benefit of CTV, the small additional radiation dose and increased cost are arguably still acceptable in view of the risk of missing a potentially fatal condition.

The patients in this study did not undergo the “gold standard” reference test of lower limb sonovenography, so we did not assess whether the reduced incidence of DVT reflected a limitation of the test and our reporting of the examination or a lower incidence of DVT. This is a limitation of our study, which was designed to assess the value of CTV in routine clinical practice. It is possible that the referral group for CTPA differs in the UK. For example, there may be a greater clinical emphasis on the detection of DVT and use of sonovenography as an initial investigation, which may identify DVT and prevent further investigation with combined CTPA/CTV. This requires further evaluation and we recommend that other centres in the UK consider reviewing the use of CTV to see if these findings are reflected in their practice.

Conclusion

PE is a difficult to diagnose and potentially fatal condition. Indirect CTV identified thromboembolic disease in an additional 1.1% of patients compared with CTPA alone. This indicates that the benefits of CTV in a UK setting may be lower than expected from previously published results. In order to accurately weigh the risk from underdiagnosing PE against the increased radiation dose and expense, we suggest that other UK centres consider reviewing their use of CTV to establish its true benefit.

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