Ultra-low dose contrast CT pulmonary angiography in oncology patients using a high-pitch helical dual-source technology

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PURPOSE
We aimed to determine if the image quality and vascular enhancement are preserved in computed tomography pulmonary angiography (CTPA) studies performed with ultra-low contrast and optimized radiation dose using high-pitch helical mode of a second generation dual source scanner.

METHODS
We retrospectively evaluated oncology patients who had CTPA on a 128-slice dual-source scanner, with a high-pitch helical mode (3.0), following injection of 30 mL of Ioversal at 4 mL/s with body mass index (BMI) dependent tube potential (80–120 kVp) and current (130–150 mAs). Attenuation, noise, and signal-to-noise ratio (SNR) were measured in multiple pulmonary arteries. Three independent readers graded the images on a 5-point Likert scale for central vascular enhancement (CVE), peripheral vascular enhancement (PVE), and overall quality.

RESULTS
There were 50 males and 101 females in our study. BMI ranged from 13 to 38 kg/m² (22.8±4.4 kg/m²). Pulmonary embolism was present in 29 patients (18.9%). Contrast enhancement and SNR were excellent in all the pulmonary arteries (395.3±131.1 and 18.3±5.7, respectively). Image quality was considered excellent by all the readers, with average reader scores near the highest possible score of 5.0 (CVE, 4.83±0.48; PVE, 4.68±0.65; noise/quality, 4.78±0.47). The average radiation dose length product (DLP) was 161±60 mGy.cm.

CONCLUSION
Using a helical high-pitch acquisition technique, CTPA images of excellent diagnostic quality, including visualization of peripheral segmental/sub-segmental branches can be obtained using an ultra-low dose of iodinated contrast and low radiation dose.

O ncology patients are at a higher risk (up to 6 times) of developing pulmonary embolism (PE) and deep venous thrombosis (DVT) (1). Cancer accounts for 20% of new thromboembolic events (2). This risk of PE is higher in specific cancers (brain, ovary, stomach, pancreas) (3), particularly in advanced stages, more common in the first few months of diagnosis and during active chemo- or radiotherapy (4). Computed tomography pulmonary angiography (CTPA) is the primary imaging modality utilized in the diagnosis of PE due to its high accuracy, wide availability and rapid turnaround time. The PIOPED II study identified sensitivity of 83%, specificity of 96%, negative predictive value of 95% and positive predictive value of 86% in the diagnosis of PE (5), with only <10% of studies being positive for PE in CTPA (6). Some disadvantages of CT include the use of ionizing radiation and iodinated contrast media. Although there is no direct epidemiologic data, a linear no-threshold theory model predicts higher cancer risks with radiation, directly proportional to the dose (7). CT radiation dose can be minimized by using strategies such as low tube current (mAs), automatic tube current modulation, low tube voltage (kVp), automatic tube potential selection, and iterative reconstruction algorithms (8).

Contrast-induced nephropathy (CIN) is an important disadvantage of using iodinated contrast (9). Oncology patients are vulnerable to CIN due to higher prevalence of renal insufficiency, nephrotoxicity of some chemotherapy agents and dehydration due to old age,

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cachexia, nausea, and vomiting (10). Recent literature also suggests that iodinated contrast agents amplify DNA radiation damage in CT (11–13). Although recent studies have shown overall lower prevalence and incidence of CIN (14–16), the potentially reduced renal capacity of cancer patients suggest that it would be worthwhile to use low doses of contrast media, especially since they require frequent CT examinations. Several techniques are currently available for decreasing the contrast dose for CTPA. Scanning at a lower tube potential (i.e. <120 kVp) facilitates low contrast dose due to higher attenuation of iodine at lower energies. CTPAs done at 70 and 80 kVp with low contrast dose have shown good image quality (17–23), with additional benefit of low radiation dose (23, 24). Sub-millisievert doses are now possible (23), with the use of iterative reconstruction algorithms that minimize noise (25–29). The tube potential can now be automatically selected based on patient size, with corresponding increases in tube current to maintain image quality (28, 29). With dual-energy scanners the patient can be scanned at normal tube potentials, but virtual monoenergetic images (VMI) reconstructed at low energies (50–70 keV) enhance the contrast attenuation, allowing the use of low contrast dose (30–33). Alterations in contrast injection protocol, such as injecting at an exponentially decelerating rate (34) also allows the use of a low contrast dose, but this may involve complex calculations, which are too complicated for routine patient care (35).

Another novel technology involves the use of a high-pitch helical (Flash) mode in a second or third-generation dual source scanner. For multislice CT, pitch is defined as the table distance travelled in one 360° rotation divided by total thickness of all the simultaneously acquired slices. Normal helical CT is done at a pitch of <1.5, since values higher than this will result in gaps in data. However, with dual-source CT, pitch of up to 3.4 can be achieved, since the gaps in data are filled using data sampled from a second detector which is offset by 95 degrees. The entire chest can be scanned under 1 second, with no motion artifacts. Since the contrast enhancement is required only for a short period of time, a low dose of contrast can be used. The radiation dose is also lower due to lower overlapping sections for imaging volumes (36). There has been only limited evaluation of this technique in PE (37, 38) and there has been no previous study in an oncology patient population.

The purpose of our study was to determine if the image quality and vascular enhancement are preserved in CTPA studies performed with ultra-low contrast and optimized radiation dose using high-pitch helical mode of a second generation dual source scanner.

Methods

This is an IRB-approved (IRB protocol # 02-13-08) HIPAA compliant single center retrospective study. Informed consent was waived by IRB since this was a retrospective study.

Study population

The study population comprised of all adult oncology patients who were scanned using an ultra-low contrast dose CT pulmonary angiography protocol described below. Exclusion criteria included age <18 years, history of severe allergy to contrast media, and severe renal dysfunction (eGFR <30 mL/min) not on dialysis.

Scanning technique

All the patients were scanned on a 128-slice dual-source Siemens Definition Flash scanner (Siemens Healthcare). Images were acquired in a high-pitch helical mode, with a pitch of 3.0, gantry rotation time of 0.28 seconds, and collimation of 64 × 2 × 0.6 mm. Scanning parameters were dependent on BMI, with kVp of 80 to 120 and mAs of 130–150 as listed in Table 1. The tube current was chosen based on initial experience with the scanner to produce diagnostic quality image sets. Scanning was acquired following the administration of 30 mL of Ioversol (Optiray 350, Mallinckrodt) at 4 mL/s. A bolus-trigger technique was used by placing a ROI in the main pulmonary artery, monitoring scans every second after contrast administration and triggering acquisition of the scan 5 seconds after a threshold of 150 HU was reached in the main pulmonary artery. All scans were obtained in caudo-cranial direction at expiration.

Image reconstruction and analysis

Axial CT images were reconstructed at 1 mm thickness at 0.5 mm increments with filtered-back projection algorithm. Medium to soft convolution kernel (B26f) was used. Coronal and sagittal reconstructions at 2 × 1 mm were also obtained. Images were reviewed in the PACS (Sectra, Sectra AB) at a window level of 60 HU and width of 360 HU. Quantitative and qualitative image analysis was performed. ROIs were placed in eleven locations in the pulmonary arterial tree, namely main pulmonary artery, right pulmonary artery, left pulmonary artery, right upper lobar artery right interlobar pulmonary artery, left upper lobar artery, left lower lobar artery, right upper lobe anterior segmental artery, right lower lobe medial segmental artery, left upper lobe anterior segment and left lower lobe medial segmental artery. The ROIs were sized to occupy two thirds of the artery of interest (Fig. 1). The mean attenuation (signal) and standard deviation (noise) were measured at these ROIs. The signal-to-noise ratio was calculated using the formula, SNR= mean attenuation of pulmonary artery/noise. Averaged values were also obtained for all segmental branches, lobar branches and the entire pulmonary tree.

Qualitative analysis of the images was performed by three independent reviewers with 20, 16, 10 years' experience in radiology (Readers 1 through 3, respectively), who were blinded to the results of one another. The images were graded using a 5-point Likert scale for central vascular enhancement (CVE), peripheral vascular enhance-

Main points

- Oncology patients are at a higher risk of developing pulmonary embolism (PE) and deep venous thrombosis (DVT).

- High quality CT pulmonary angiography (CTPA) studies can be obtained in oncology patients with ultra-low dose of intravenous contrast using high-pitch dual source acquisition.

- This technique is able to obtain good quality in central as well as peripheral pulmonary vessels.

Table 1. Scan technique of the patients in the study group

BMI (kg/m²)	kVp	mAs
>35	120	150
30–35	100	150
25–30	100	130
<25	80	130

BMI, body mass index; kVp, peak tube kilovoltage (tube potential); mAs, milliampere-second (tube current).
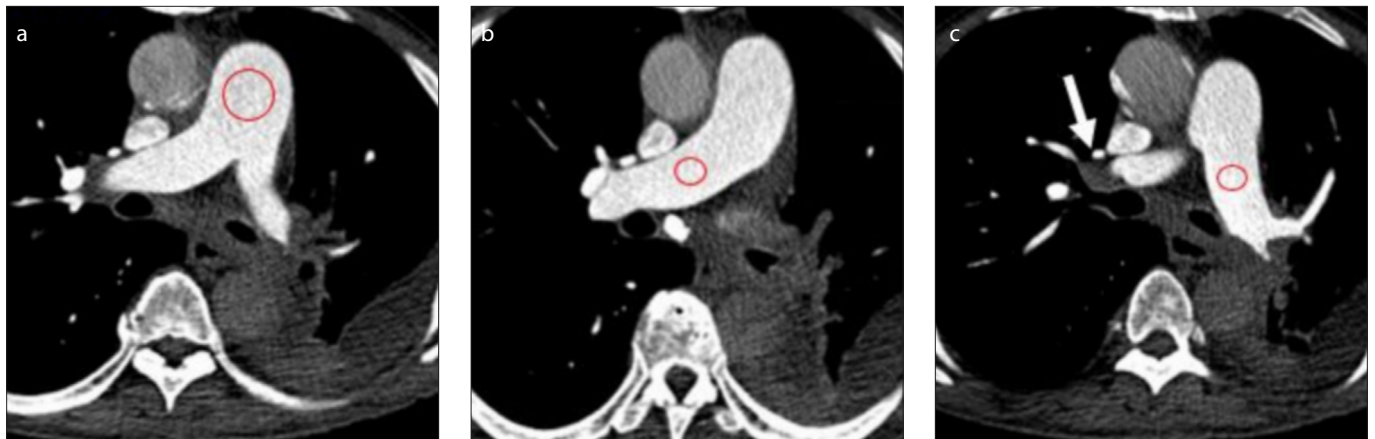
Figure 1. a–c. Quantitative analysis of the attenuation and noise in the pulmonary arteries. ROIs *(red)* are placed in the **(a)** main pulmonary artery, **(b)** right pulmonary artery, and **(c)** left pulmonary artery (LPA). The attenuation and standard deviation (noise) were calculated in these ROIs.

	Central vascular enhancement	Peripheral vascular enhancement	Image noise and overall image quality
Table 2. Qualitative scoring in the evaluation of CTPA studies			
1	None	No opacification of segmental/subsegmental arteries	Major noise, no diagnosis possible
2	Slight, low confidence in making diagnosis	<25% of segmental/subsegmental arteries are opacified	Major noise, diagnosis of PE possible, but with low confidence
3	Moderate, sufficient for diagnosis	25%–50% of segmental/subsegmental arteries are opacified	Moderate, but sufficient for PE diagnosis
4	Good	50%–75% of segmental/subsegmental arteries are opacified	Minor, diagnosis not influenced
5	Excellent	>75% of segmental/subsegmental arteries are opacified	No noise; excellent image quality
CTPA, computed tomography pulmonary angiography; PE, pulmonary embolism.			

ment (PVE), and image noise (1, least; 5, best) as shown in Table 2 (39). The entire lungs including all lobes and segmental and subsegmental branches were visually evaluated to generate these scores. Average scores of subjective image quality were compared to results previously in the literature. The presence of artifacts was also noted.

The presence of pulmonary emboli was noted by one chest radiologist with 16 years' experience (PR), who was blinded to patient history and clinical findings. PE was defined as an occlusive/nonocclusive filling defect or nonvisualization of segmental/subsegmental branches (37). Artifacts were carefully excluded. The number and location of PE was noted.

Radiation dose metrics were also noted. The dose length product (DLP) was noted and the effective radiation dose in milliseiverts was obtained by multiplying the DLP with conversion factor of 0.014 mSv/mGy*cm (40). Radiation dose was compared to previous published results in the literature to determine if potential dose differences exist.

Statistical analysis

Statistical analysis was performed using SPSS (Version 11.5, SPSS Inc) and MedCalc (Version 18.5 MedCalc Software). The normality of distribution of the data was evaluated using Shapiro-Wilk test (41, 42). The differences in image quality as determined by the 3 blinded readers was evaluated using the Friedman test, which is the nonparametric equivalent of repeated measures ANOVA. The intraclass correlation coefficient (ICC) was measured using ICC (3,1) type (43) to evaluate the degree of consistency among the qualitative measurements of central vascular enhancement, peripheral vascular enhancement, and noise. Student's t-test (for independent samples) and the chi-square test for the difference between two proportions (44–47) were used to compare study values with previously published data (5, 40, 48–53), using sample size, means, and standard deviation. The robustness due to sample size was a factor in selecting parametric methods, when the normal distribution could not be assessed for external data (54–56). A P value < 0.05 was considered statistically significant.

Results

There were 151 patients in the study, 50 males (33%), 101 females (67%), with age range of 20–93 years (mean±SD, 62.4±14.6 years). BMI ranged from 13 to 38 kg/m^2 (22.8±4.4 kg/m^2). The most common cancers were lung (n=42, 27%), breast, (n=28, 18%), hematological (n=19, 13%), and head and neck (n=13, 9%). The distribution of different cancers is shown in Table 3. In terms of scanning parameters, 120 kVp was used in 140 patients, 100 kVp in 10 patients, and 80 kVp in 1 patient. The average scan time was 0.64±0.8 seconds.

Contrast enhancement was excellent in all the pulmonary arteries. Previous studies have shown that the minimum attenuation required for the diagnosis of acute embolism is 93 HU and for chronic embolism is 211 HU (40, 48, 57). The attenuation values in our study were: 372±129 HU for main pulmonary artery, 367±128 HU for left pulmonary artery, 368±124 HU for right pulmonary artery, 390.0±137.9 HU for lobar artery, 420.1±136.7 HU for segmental artery, 395.3±131.1 HU for all pulmonary
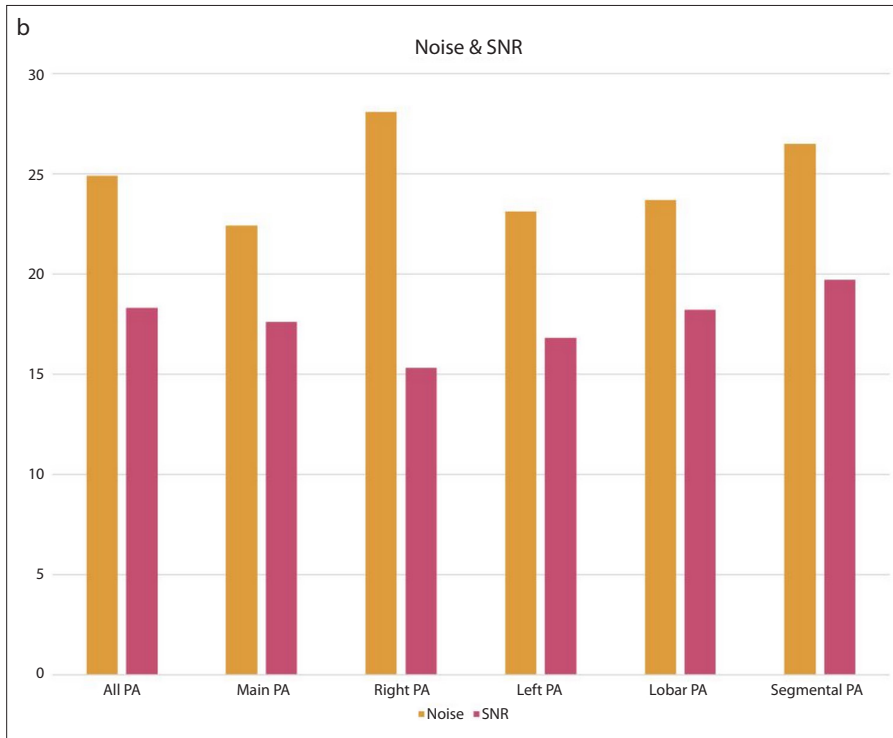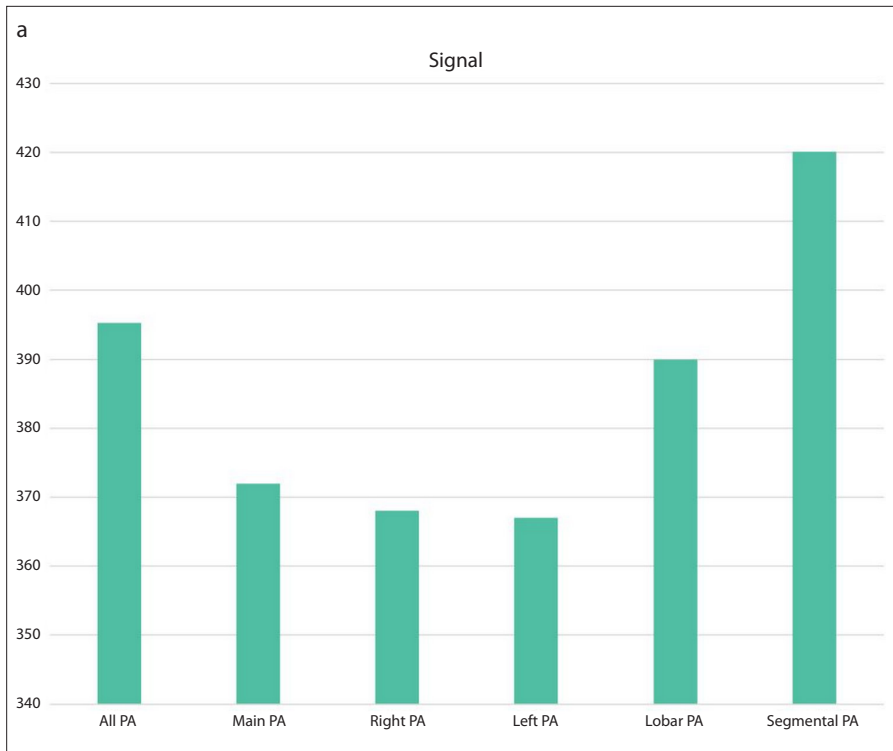
Signal

b

Noise & SNR

Noise ■ SNR

Figure 2. a, b. Charts showing the attenuation **(a)**, noise and signal-to-noise ratio (SNR) **(b)** at different pulmonary artery (PA) levels. Attenuation and noise are measured in Hounsfield units and SNR is a ratio. Note that the attenuation and SNR are excellent at all PA levels.

arteries. SNR was also good in all the pulmonary arteries, with 17.6±7.0 for main pulmonary artery, 16.8±6.4 for left pulmonary artery, 15.3±6.3 for right pulmonary artery, 18.2±6.9 for lobar artery, 19.7±6.5 for segmental artery, and 18.3±5.7 for all pulmonary arteries (Figs. 2, 3, Table 4). The mean attenuation values from this study (395.3 HU), were compared to the results of published studies from Zordo et al. (49)

Table 3. Frequencies of different neoplasms in our study	
Neoplasm	n (%)
Lung	42 (27)
Breast	28 (18)
Hematological	19 (13)
Head and neck	13 (9)
Melanoma	1 (0.5)
Genitourinary- male	5 (3)
Genitourinary-female	16 (10)
Gastrointestinal	15 (9)
Hepatobiliary	4 (3)
Pancreas	4 (3)
Sarcoma	3 (2)
Unspecified	1 (0.5)

and Yilmaz et al. (50). The mean attenuation values were higher than 5 of 8 study groups in the literature and were not found to be significantly different ($P > 0.05$) for 5 of 8 CT scan parameters in the literature (Table 5). Specifically, the mean attenuation value from our study was higher than the 120 kVp group of Yilmaz et al. (309.5 HU, $P = 0.11$), while the attenuation value from our study is significantly higher than that of single source 120 kVp (313 HU, $P = 0.001$) and DSCT 120 kVp groups of Zordo et al. (342 HU, $P = 0.040$) (49, 50) (Table 5).

Similarly, the proportion of suboptimal studies using the ULDCT procedure were not significantly different than those provided in the literature. Suboptimal studies, i.e., studies with attenuation <210 HU in the main pulmonary artery, were seen in 10 of our patients (6%), which is similar to the rate of 6.1% reported in literature (51) ($P = 0.997$, χ^2 difference in proportion test). This is also significantly lower than the 11%, which has been established as a guideline by some societies such as the Royal College of Radiology (52).

Image quality was considered excellent by all the readers. The average reader scores were near the highest possible score of 5.0 (CVE, 4.83±0.48; PVE, 4,68±0.65; noise/quality, 4.78±0.47). The scores for Reader 1 were: CVE 4.8±0.5, PVE 4.6±0.7, noise 4.7±0.5; for Reader 2, CVE 4.9±0.5; PVE 4.7±0.6, noise 4.8±0.4; for Reader 3, CVE 4.9±0.4, PVE 4.7±0.6, noise 4.8±0.4. The overall correla-

Table 4. Attenuation, noise and signal-to-noise ratio at different pulmonary arterial levels

Vessel	Signal			Noise			SNR		
	Mean±SD	Median	IQR	Mean±SD	Median	IQR	Mean±SD	Median	IQR
Main pulmonary artery	372±129	350	158.5	22.4±7.1	21	8	17.6±7.0	16.3	7.9
Right pulmonary artery	368±124	342	135.5	28.1±29.6	24	9	15.3±6.3	14.0	6.8
Left pulmonary artery	367±128	338	143.5	23.1±7.0	22	6.5	16.8±6.4	15.8	8.7
Lobar artery, averaged	390.0±137.9	363	147	23.7±6.6	22	7.3	18.2±6.9	16.7	9.6
Right upper lobe	398.9±145.8	372	151	22.8±10.0	20	11	20.0±10.1	17	12.6
Right interlobar	370.8±129.8	344	136.5	25.1±8.1	23	8	15.6±5.7	14.6	8.23
Left upper lobe	394.4±145.7	371	154.5	22.7±9.2	22	8	19.4±10.0	16.7	10.4
Left lower lobe	395.8±141.5	366	148.5	24.2±8.2	23	9	17.9±8.3	15.8	9.1
Segmental artery, averaged	420.1±136.7	399	136.4	26.5±9.4	24.5	10.5	19.7±6.5	19.1	7.4
RUL, anterior seg.	425.9±145.5	407	147	25.9± 15.9	22	18.8	20.7±11.0	18.6	12.8
RLL, medial seg.	406.8±138.8	387	137	24.9±13.0	21	14	20.1±12.4	17.3	11.3
LUL, anterior seg.	428.6±148.7	400	176	27.5±17.0	23	17	19.9±12.2	17.2	12.4
LLL, medial seg.	419.53±147.4	398	139	27.5±13.6	25	15	18.1±9.5	15.6	10.5
Average all pulmonary arteries	395.3±131.1	376.7	133.9	24.9±6.7	23.7	6.8	18.3±5.7	17.	6.9

SD, standard deviation; IQR, interquartile range; SNR, signal-to-noise ratio; RUL, right upper lobe; seg., segment; RLL, right lower lobe; LUL, left upper lobe; LLL, left lower lobe.

Table 5. Comparison of the mean attenuation values in our study compared with studies in the literature

Value	Our study ULDCT	Zordo et al. (49) DSCT 100 kV	Zordo et al. (49) DSCT 120 kV	Zordo et al. (49) DECT 100/140 kV	Zordo et al. (49) SCT 100 kV	Zordo et al. (49) SCT 120 kV	Yilmaz et al. (50) 120 kV	Yilmaz et al. (50) 100 kV	Yilmaz et al. (50) 80 kV
Mean (HU)	395.3	424.0	342.0	348.0	401.0	313.0	309.5	381.7	477.3
SD (HU)	131.1	110.0	121.0	106.0	159.0	62.0	79.1	124.0	193.3
Comparison		ULDCT vs. DSCT 100 kV	ULDCT vs. DSCT 120 kV	ULDCT vs. DECT 100/140 kV	ULDCT vs. SCT 100 kV	ULDCT vs. SCT 120 kV	ULDCT vs. 120 kV	ULDCT vs. 100 kV	ULDCT vs. 80 kV
t-value		1.11	-2.06	-1.86	0.20	-3.36	1.11	0.38	3.73
P		0.26	0.040*	0.070	0.83	0.001*	0.11	0.71	<0.001*

ULDCT, ultra-low dose CT (our study); DSCT, dual-source CT; kV, kilovoltage; DECT, dual-energy CT; SCT, single-source CT.
*P < 0.05.

tion between the readers was evaluated as excellent. Specifically, the ICC between the readers was 0.85 for CVE (95% CI, 0.80–0.89), 0.90 for PVE, (95% CI, 0.87–0.93), and 0.80 for noise (95% CI, 0.75–0.86). For CVE, Reader 1 scored significantly differently than Readers 2 and 3 (P < 0.001). The readers did not score significantly differently for PVE (P = 0.21, Friedman test). For perceived noise, Readers 1 and 2 scored it significantly differently than did Reader 3 (P = 0.032). Our mean score of image quality (4.8) was also comparable to other studies in the lit-

erature including the study by Yilmaz et al. (50) on a dual-source normal pitch protocol, where the mean score for the 120 kVp group was 4.8 (P = 0.77) and for 100 kVp group was 4.7 (P = 0.42).

Only 3 studies were considered non-diagnostic. Motion artifacts were seen in 5 patients and interruption of contrast column was not seen in any patient. Our nondiagnostic rate of 1.98% is significantly lower than the PIOPED study (5) (6.2%, P = 0.038) and comparable to Lou et al. (53) (4%, P = 0.22).

Pulmonary embolism was present in 29 patients (19%). There were 19 clots in the central pulmonary vasculature and 43 clots in the peripheral pulmonary vasculature (Fig. 4).

The average DLP was 161±60 mGy.cm, which corresponds to an effective radiation dose of 2.3±0.8 mSv (Table 5). This is comparable to literature doses of 2.2 to 7.0 mSv (P = 0.18) for single source and lower than the reported 3.2 to 4.7 mSv for dual energy CT (P < 0.001) (40, 48). The average radiation dose in our study is lower than the 120 kVp group used in a dual-source regular pitch scanner

Figure 3. a–c. Axial standard (**a**), axial MIP (**b**) and coronal MIP (**c**) CT images of a normal study in a patient with lung cancer. Body mass index (BMI) was 32 kg/m^2. The study was performed with 30 mL of intravenous contrast, at 100 kvp, 150 mAs and pitch of 3.2. Note the excellent contrast attenuation in all the pulmonary arteries, both central and peripheral.

Figure 4. a–c. Axial standard (**a**), coronal standard (**b**) and coronal MIP (**c**) CT images in a CTPA study performed with 30 mL of intravenous contrast shows a nonocclusive pulmonary embolism *(arrow)* in the right interlobar pulmonary artery extending to a segmental branch. The patient had a BMI of 29 kg/m^2, and hence 100 kVp, 130 mAs and pitch of 3.2 were used.

Table 6. Ultra-low dose contrast CTPA protocol and radiation dose evaluation

Parameter	Protocol
Acquisition mode	Dual source, high pitch
Detector collimation (mm)	64 × 2 × 0.6
Pitch	3.2
Gantry rotation time (ms)	280
Tube voltage (kVp)	80–120
Reference tube current time product (mAs eff)	130–150
Contrast medium volume (mL)	30
Mean DLP (mGy.cm)	161±60
Estimated effective radiation dose (mSv)	2.3±0.8
DLP, dose-length product.	

by Yilmaz et al. (50) (4.7 mSv, $P < 0.001$) and comparable to the 100 kVp group in that study (2.5 msV, $P = 0.18$). Our radiation dose was lower than the normal pitch 120 kVp group in the study by Zordo et al. (49) (mean 4.52, $P < 0.001$) as well as high pitch 120 kVp group (mean 4.1 mSv, $P < 0.001$) and normal pitch 100 kVp group (2.8, $P = 0.016$) (49).

Discussion

Our study demonstrates the feasibility of obtaining high quality CTPA studies in oncology patients using a protocol with ultra-low dose of intravenous contrast media (Table 6). To our knowledge, this is the first study to demonstrate low contrast CTPA using high-pitch dual-source acquisition in a large oncology patient cohort.

Dual-source CT scanners have two x-ray tube/detector units, which can be operated in three modes, namely dual-energy, single-energy with standard pitch and single-energy with high-pitch, all of which can be done either with or without electrocardiography (ECG)-gating. In the dual-energy mode, the two tubes are operated at different energies, which allows generation of additional images, including iodine perfusion maps (58) and VMI, which can enhance contrast signal in suboptimal enhanced studies (31, 32). In the conventional single-energy, standard pitch mode, both tubes are operated at the same energy (36). Lower contrast (i.e., 40 mL) and radiation doses (50%) can be achieved by using lower tube potential (e.g., 70 kVp) (29). In the single-energy high-pitch mode, both x-ray tubes are operated at the same tube poten-

tial, but at high pitch values of up to 3.4. Although a high-pitch mode generally results in suboptimal angiographic studies due to gaps in data, the presence of second tube in dual-source CT fills the gaps, maintaining image quality.

Radiation dose is lower (up to 35%) in high-pitch mode than conventional CTA at 100 kVp due to rapid scanning and lower imaging volume (49, 59). With appropriate timing, an ultra-low contrast dose study can be performed since contrast is required to be present in pulmonary arterial system only for a short period. There have been few previous CTPA studies used with this mode (37, 38, 60), but none in an oncology patient population. One study used 40 mL of contrast, 70 kVp and iterative reconstruction (IR) algorithm to lower radiation dose by 80% and preserve image quality as compared to standard-pitch, 60 mL contrast study (38). Another study with 30 mL of contrast at 80 kVp and IR showed similar results with half the radiation dose of a 100 kVp standard pitch scanner with 60 mL of contrast (37). However, in both these studies, the BMI, height and weight were not reported. The low kVp techniques would not be suitable for large patients, since it is not possible to generate a higher tube current-time product (mAs) to maintain image quality in these patients because only a single x-ray tube is collecting data in gaps, short acquisition time and poor performance of automatic tube current modulation (29). The third generation of these scanners have higher x-ray tube power and IR algorithms, but reconstruction is limited to central 33 cm of field-of-view.

In our study, we utilized BMI-dependent tube potential and the image quality was excellent in all the patients. We did not use 70 kVp, since we believed the image quality would not be appropriate for diagnosing PE. We were able to obtain good quality in the peripheral vessels as well, indicating our ability to detect small peripheral pulmonary emboli. The high-pitch mode has higher temporal resolution and lower motion not only in pulmonary arteries, but also in other cardiovascular structures, including heart and coronary arteries as well as the lungs, thus improving the image quality and ability to evaluate adjoining structures (61). This scan mode can also be performed with ECG-gating, which further decreases motion artifacts with lower radiation dose than conventional CTA (62).

Overall, our results for subjective image quality, proportion of suboptimal studies and mean attenuation values were not significantly different than those previously published in the literature in non-oncology patients using various scanning modes and regimens (49–53).

Our study has several limitations. This is a single-center retrospective study, with no control group of patients scanned at standard-pitch mode. However, we wanted to demonstrate that the image quality of our protocol is sufficient to make a diagnosis of PE. Based on previously published contrast attenuation cutoff required for demonstrate emboli (48, 49), we suggest that the image quality of our scans is high. We have also compared our results with the previously published data in the literature. We did not use an IR in our protocol due to nonavailability in our institution, which would have facilitated even further radiation dose reduction. We were able to achieve such low radiation doses without IR algorithm due to optimal timing of the low contrast bolus, which was needed to be present in the pulmonary circulation only for a short period of time. Due to absence of control group, we could not directly estimate the radiation dose savings, but we used data from the literature (59, 63) to suggest reduced radiation dose. Although motion artifacts were low and cardiovascular structures including coronary arteries were seen better with this technology, we did not evaluate these advantages in our study, since it was not our focus.

In conclusion, high quality CTPA with excellent diagnostic quality is feasible in oncology patients with a low dose of iodinated contrast media and radiation dose using a high-pitch helical acquisition mode in a second generation dual-source scanner. The quality was good even for visualization of small, peripheral segmental/subsegmental branches, which makes it suitable for detection of small peripheral emboli. This technique is useful in oncology patients who require repeated scans by reducing toxicities associated with administration of iodinated contrast. There is also potential for further reduction of contrast and radiation dose.

Conflict of interest disclosure

Dr Robert Gilkeson- Research Consultant, Riverain Technologies, LLC Research support, Koninklijke Philips NV Research support, Siemens AG Research support, General Electric Company; Leslie Ciancibello- Consultant and Speakers' bureau, Siemens Healthineers.

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