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An audit of the adequacy of contrast enhancement in CT pulmonary angiograms in a South African tertiary academic hospital

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Declaration

I, Derik Basson declare that this research report is my own work. It is being submitted for the degree of Master of Medicine in Radiology at the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at this or any other University.



Derik Basson

Dedication

To my wonderful wife, Sunelle

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An audit of the adequacy of contrast enhancement in CT pulmonary angiograms in a South African tertiary academic hospital setting

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Background: Undiagnosed pulmonary embolism carries high mortality and morbidity. Computed tomography pulmonary angiogram (CTPA) is the diagnostic method of choice for accurate diagnosis. Inadequate contrast opacification is the second most common cause of indeterminate CTPAs.

Objectives: Audit the adequacy of CTPA contrast enhancement and determine whether inadequate enhancement is affected by the size and site of the intravenous cannula, flow rate, contrast volume, contrast leakage and day shift versus after hours services.

Method: Retrospective and prospective audits of the adequacy of contrast enhancement of CTPAs at the Charlotte Maxeke Johannesburg Academic Hospital were conducted using the Royal College of Radiologists guidelines (≤ 11% of studies with < 210 HU). Protocol variables were collected prospectively from questionnaires completed by radiographers performing the CTPAs. Adequate versus inadequate groups were analysed.

Results: A total of 63 (retrospective) and 130 (prospective) patients were included with inadequate contrast enhancement rates of 19% (12/63) and 20.8% (27/130), respectively. The majority of CTPAs were performed during the day 56.2% (73/130) with a 20G cannula 66.2% (86/130) in the forearm 33.8% (44/130) injecting 100 mL – 120 mL contrast 43.1% (56/130) at 3 mL/s 63.1% (82/130). The median flow rate (3 mL/s) and contrast volume (80 mL) were identical in both adequate and inadequate groups, while the remaining variables showed no statistical difference.

Conclusion: The rate of inadequately enhanced CTPAs in this study was high. The protocol variables did not have a significant influence on the rate of inadequate enhancement. Further research, particularly using flow rates > 4 mL/s, is required for protocol optimisation.

Keywords: contrast enhancement; audit; CT pulmonary angiogram; pulmonary embolism; flow rate.

Introduction

Accurate diagnosis of pulmonary embolism (PE) is imperative as untreated or undiagnosed PE carries a high mortality and morbidity.[1] Computed tomography pulmonary angiogram (CTPA) is the method of choice in the diagnosis of PE;[2,3] however, indeterminate studies have been estimated at 6.6%.[4] Inadequate contrast opacification has been cited as the second most common cause of indeterminate CTPA studies, the first being motion artefact, while less common causes include beam hardening artefact related to obesity and streak artefact.[4,5] The exact prevalence of PE in South Africa is not known; however, in 2016, 2124 deaths due to pulmonary vascular disease were reported, which included PE.[6]

The Royal College of Radiologists (RCR) recommend audits of CTPAs in order to limit indeterminate CTPAs due to inadequate enhancement. The RCR guideline (2013) advocates that a maximum of 11.0% of CTPAs can have inadequate contrast enhancement (< 210 Hounsfield units [HU]).[7] Several international audits have been performed, reporting a percentage of CTPA studies with inadequate contrast opacification varying between 1.5% and 18.0%.[8,9,10,11] Some had decreased inadequate rates following protocol changes, which were prompted by an audit.[9,11]

To the best of our knowledge, no such audit has been performed in South Africa. This audit primarily assessed the adequacy of contrast enhancement of CTPA examinations at a South African tertiary radiology department and secondarily assessed the influence of certain technical factors.

Materials and methods

A single-centre retrospective and prospective audits were performed at a large tertiary hospital in South Africa, which included routine in- and outpatient CTPA referrals from this hospital as well as from a network of referral hospitals and clinics.

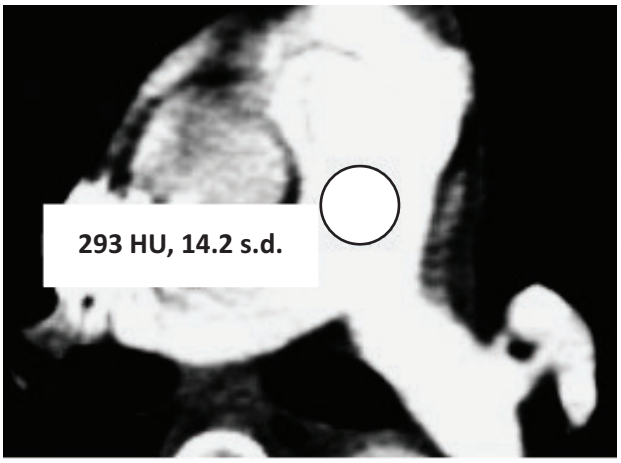
The retrospective audit was conducted using all consecutive CTPA studies for suspected PE in adult patients (18 years or older) from 01 December 2019 to 31 December 2019, while the prospective audit included all consecutive CTPA studies from 01 January 2020 to 31 March 2020. Informed consent was obtained from the patients for the prospective audit. Additionally, the prospective audit incorporated a questionnaire that was completed by the attending radiographer acquiring the scan, which included technical factors such as intravenous (IV) cannula size, location of the IV cannula, flow rate of the injector, volume of contrast, presence of contrast leakage and the time at which the scan was acquired. Data from the radiographer checklists were captured.

CT pulmonary angiograms were performed on either a Phillips 64 slice Brilliance, 128 slice Ingenuity or Siemens 64 slice Somatom CT scanner. Examinations were performed with the patient in the supine position with arms placed above the head and scans acquired in a cranio-caudal direction, from the lung apices to the mid-low liver. Patients were instructed to inspire and hold their breath, after which scanning was performed at full inspiration. A dose of 80 mL – 100 mL 350 mg iodine/mL of non-ionic iodinated intravenous contrast material (Omnipaque) was administered through the IV cannula, via a Guerbet Optivantage pump injector at a rate determined by the radiographer (preferably > 3 mL/s), depending on the IV-line size and position. Bolus tracking was used with a region of interest (ROI) centred within the main pulmonary artery (MPA), at the level of its bifurcation, with scanning to be initiated after a 6.2 s delay once a level of 110 HU was reached within the ROI.

All images were viewed on a Philips Enterprise PACS workstation. The contrast enhancement of every CTPA was assessed by placing a circular ROI within the MPA at its largest axial diameter on each study at a slice thickness of 1 mm. The ROI diameter was 50% of the vessel diameter. The HU obtained at this level was recorded as an average of three measurements (Figure 1). Hounsfield unit readings in the MPA were captured, and the HU was further categorised as adequate (≥ 210 HU) or inadequate (< 210 HU).

Statistical analysis

Descriptive statistics (frequencies and percentages) were calculated for categorical data, and medians and percentiles for numerical data. The Shapiro-Wilk test was used to investigate whether numerical variables followed a normal distribution. The Chi-Squared or Fisher's exact tests were used to compare frequencies of adequate versus inadequate HU values. The Mann–Whitney *U*-test was used to compare median values for the two independent groups: adequate HU versus inadequate HU. A significance level (α) of $p < 0.05$ was used. All data analysis was performed using SAS version 9.2.



HU, Hounsfield unit; s.d., standard deviation.

FIGURE 1: Contrast enhancement: Hounsfield unit measurement in the main pulmonary artery: 293 HU (adequate enhancement).

Ethical considerations

Ethics approval was provided by the Committee of Human Research of the Faculty of Health Sciences, University of the Witwatersrand (ethics clearance number M190454). Informed consent was obtained from the patients for the prospective audit. The identifying data of patients were anonymised and stored on a password-protected computer.

Results

A total of 63 (retrospective) and 149 patients (prospective) were included. Nineteen CTPAs from the prospective audit were excluded due to incomplete informed consent. Inadequate contrast enhancement was identified in 19% (12/63) of the retrospective and 20.8% (27/130) of the prospective cases.

The majority of CTPAs were performed with a 20 G IV cannula (86/130, 66.2%), mostly in the forearm (44/130, 33.8%), followed by the hand and antecubital fossa. The IV cannula sizes were not significantly different between the adequate and inadequate contrast enhancement groups ($p = 0.20$). Similarly, the IV cannula sites were not significantly different between the two groups ($p = 0.65$). (Table 1).

The majority of CTPAs were performed with 100 mL – 120 mL of contrast (56/130, 43.1%) (Figure 2) at 3 mL/s (82/130, 63.1%) (Figure 3). Both adequate and inadequate groups had a median flow rate of 3 mL/s, while both groups had a median contrast volume of 80 mL, with no significant

TABLE 1: CTPA technical factors.

Technical factors	Frequency (*n*=130)				*p*-value
	Adequate		Inadequate		
	n	%	*n*	%	
IV cannula size					0.20
Central venous catheter	7	5.4	0	0.0	
22 G	0	0.0	1	0.8	
20 G	67	51.5	19	14.6	
18 G	29	22.3	7	5.4	
IV cannula site					0.65
Subclavian vein	3	2.3	0	0.0	
Internal jugular vein	3	2.3	0	0.0	
Femoral vein	1	0.8	0	0.0	
Antecubital fossa	29	22.3	8	6.1	
Forearm	37	28.5	7	5.4	
Hand	30	23.1	12	9.2	
Flow rate					0.59
> 4ml/s	6	4.6	0	0.0	
< 4ml/s	97	74.6	27	20.8	
Time					0.21
Day shift	55	42.3	18	13.8	
Afterhours	48	36.9	9	7.0	
Contrast leakage					0.60
No	99	76.2	25	19.2	
Yes	4	3.1	2	1.5	

IV, intravenous.

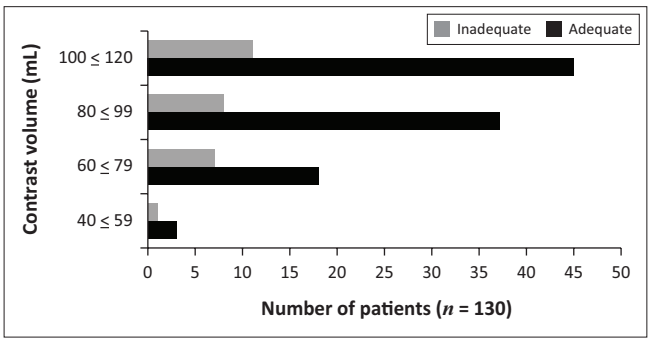


FIGURE 2: Frequency of adequate and inadequate contrast-enhanced CTPAs in the prospective group of patients for different contrast volumes.

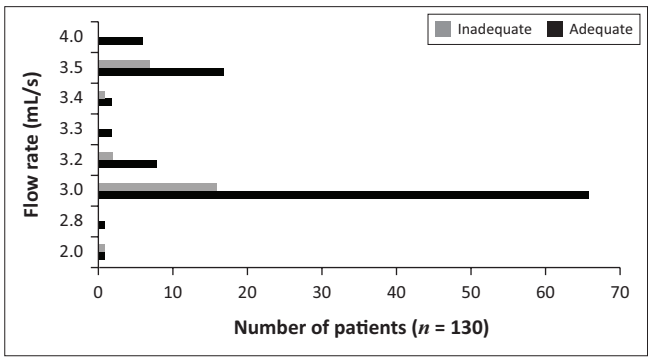


FIGURE 3: Frequency of adequate and inadequate contrast-enhanced CTPAs in the prospective group of patients for different flow rates.

differences (p = 0.94 and 0.55, respectively) (Table 2). One hundred and twenty-four studies were performed at < 4 mL/s compared to six studies at ≥ 4 mL/s (Table 1). The number of inadequate contrast opacified studies between flow rates of ≥ 4 mL/s and < 4 mL/s was not significantly different (p = 0.59) (Table 1).

The majority of the CTPAs were performed during the day (73/130, 56.2%). Additionally, the time of the scan acquisition, that is, day versus afterhour shifts and presence of contrast leakage made no significant difference to the rate of inadequate contrast enhancement (p = 0.21 and 0.60, respectively) (Table 1).

Discussion

This audit established that the rate of inadequate CTPAs was higher than the international guideline set by the RCR[7] and was also greater than international audits (1.5% – 18%).[8,9,10,11] The inadequate rate of 20.8% in the prospective audit compared closely to the 19.0% in the retrospective audit, which indicates that there was no radiographer bias in the prospective studies. This high rate of inadequate contrast enhancement is undesirable as it contributes to indeterminate studies and can lead to misdiagnosis, repeated examinations, increased radiation dose or unnecessary anticoagulation, all of which are detrimental to the patient.

The effect of the variables (position of IV cannula, size of IV cannula, flow rate, volume of contrast, time of study and presence of contrast leakage) on the rate of inadequate contrast enhancement was found to be non-significant. These findings provide some insights into what does not contribute to inadequate contrast opacification but have to be interpreted in light of the limitations subsequently discussed.

There were higher rates of inadequate contrast enhancement when IV cannulas were positioned in the hand (28.6%), compared to 21.6% in the antecubital fossa and 15.9% in the forearm; however, this small difference was not significant (p = 0.65). This is comparable to findings by Marshall et al.[12] (with a larger sample size of 1500) and Roggenland et al.[13] These two studies also found no significant difference between different IV cannula sizes, although, similar to our audit, they also had a limited frequency of 22 G IV cannulas. The RCR and American College of Radiology recommends a 20 G or a bigger IV cannula in the antecubital fossa or forearm, but there is no other literature supporting this practice for CTPAs.[7,12,14] They also do not stipulate recommendations for contrast volume. Contrast opacification is related to iodine flow rate, which is a function of iodine concentration and flow rate.[15] Our protocol utilised a concentration of 350 mg iodine/mL, which has been shown to be superior to lower concentrations.[16,17] It can, therefore, be postulated that IV cannula size should only impact contrast opacification when it restricts flow rate. The recommended minimum flow rate for general CT angiograms is 3 mL/s,[14] while a flow rate of 4 mL/s or higher has been recommended for CTPAs internationally.[13,18,19,20] Flow rates of 3 mL/s have been safely achieved with 22 G IV cannulae;[21] thus the use of 22 G cannulas can, in theory, still be sufficient. Power injectors have a predetermined pressure limit that can be exceeded in cases of access vein size and IV cannula size mismatch, and this will lead to an automatic decrease in the flow rate.[22] Therefore, the IV cannula size and access vein size should be considered as a continuum.

TABLE 2: Technical factors: Flow rate and contrast volume.

Technical factors	Frequency	Mean	Std Dev	Median	Lower Quartile	Upper quartile	Minimum	Maximum	*p*-value
Flow rate (mL/s)									0.94
Adequate	103	3.16	0.31	3	3	3.3	2	4	
Inadequate	27	3.12	0.32	3	3	3.5	2	3.5	
Contrast volume (mL/s)									0.55
Adequate	103	85.87	14.69	80	80	100	40	110	
Inadequate	27	84.37	16.69	80	70	100	53	120	

Std Dev, standard deviation.

This study only had six CTPAs with a flow rate of ≥ 4 mL/s, and although none of them had inadequate contrast opacification, we could not prove any significant difference in the rate of inadequately contrast-enhanced CTPAs between this and flow rates < 4 mL/s ($p = 0.59$). The significance is limited by the small number of CTPAs with flow rates ≥ 4 mL/s. Several international studies have achieved lower rates of inadequate contrast opacification, compared to ours, utilising flow rates higher than 4 mL/s. Lloyd et al.[11] achieved a 9% rate of inadequate contrast opacification (< 210 HU), utilising a flow rate of 4 mL/s, while Menon et al.[23] had < 2% inadequately opacified studies when using a flow rate of 5 mL/s. Similarly, Hendriks et al.[24] did not have inadequate CTPAs with a flow rate of ≥ 4.2 mL/s; however, they used a less strict cut-off of 180 HU. Ozawa et al.[25] achieved a significant decrease in inadequate contrast enhancement by increasing flow rate from 2 mL/s to 3 mL/s. Therefore, the high frequency of relatively low flow rates (< 4 mL/s) in this audit might be contributing to the high rate of inadequately opacified studies; however, this requires further investigation. Employing a saline chaser bolus may be helpful in addition to using a higher flow rate.

The contrast volume did not have any significant effect on the rate of inadequate contrast opacification. This is similar to the finding by Goble et al.[17] who found no significant difference in rates of inadequate contrast opacification between 100 mL and 75 mL (350 mg/mL) contrast volume when using a cut-off value of 250 HU. Another study by Chen et al.[16] found no significant difference in the rate of inadequately opacified studies between 75 mL and 60 mL (350 mg/mL) contrast volume, also using 250 HU as the cut-off. Individualised contrast volume protocols according to body weight can achieve a reduction in contrast volume while increasing pulmonary arterial enhancement.[24,26]

Other possible explanations for the high rate of inadequately opacified studies can include factors that were not evaluated in this audit such as cardiovascular status, body habitus, patient age, respiratory rate and IV cannula size to access site mismatch. Scanning at maximal inspiration, as utilised in our protocol, has shown inferior contrast enhancement compared to minimal inspiration and expiration.[27,28,29] Causes for this include transient interruption of contrast and dilution as inspiration causes negative intrathoracic pressure and increased venous return with unopacified blood entering the right heart. It has also been proposed that breath-holding after inspiration leads to a Valsalva effect, with subsequent diminished cardiac output and delayed pulmonary arterial contrast enhancement.[27,30]

A circulation adjusted protocol with scan initiation of 10 s after bolus triggering at 150 HU or a fixed scan delay of 19 s after injection was suggested as adequate.[31] The use of a multiphasic injection with an exponential decrease in injection rate as opposed to a uniphasic injection rate with a rapid decline results in more uniform and steady-state enhancement, which provides more room for error with regard to timing of scan acquisition.[17] These may be possible strategies to improve our CTPA scanning protocol which requires further investigation.

Limitations of the study

The small sample size limited the significance, especially the low number of CTPAs with high flow rates (≥ 4 mL/s) and a single CTPA with a 22 G IV cannula. As this was an audit, variables could not be controlled, which led to an unequal distribution within variables. This audit did not account for patient age, weight, cardiovascular status and respiratory motion, which have all been shown to affect contrast enhancement.[4,13]

The use of one reader limits reliability; however, the HU measurement in the MPA is an objective measurement that requires minimal expertise and the addition of the retrospective audit improved the reliability. The amount of contrast leakage was not quantified.

Recommendations

The CTPA protocol at this hospital should be assessed and adjusted to achieve a lower rate of inadequate contrast enhancement. This will lead to less indeterminate studies, less repeated studies and improved patient care. Alterations that have been advised and shown to be helpful include scanning at minimal inspiration or expiration,[27,28,29] changing timing after bolus tracking, use of a saline chaser and use of a test bolus.[7] Although this study found no significant difference in the effect of IV cannula size on the rate of inadequately opacified CTPAs, we do not have sufficient evidence to support the use of 22 G cannulas; therefore, the use of a 20 G or larger cannula is still preferred and is in line with current international recommendations. We suggest that CTPAs not be cancelled when IV access is peripheral to

the antecubital fossa if it can tolerate acceptable flow rates, as we did not find any significant difference in the rate of inadequately opacified studies with IV access distal to the antecubital fossa. We do not have enough evidence for an adequate minimum flow rate, but the limited findings of this audit together with international findings in favour of high flow rates (≥ 4 mL/s) warrant the investigation of higher flow rates in our setting. Further studies are still required to assess the minimum required flow rate for consistent adequate contrast opacification.

The use of protocols adjusting contrast volume according to body weight and using a multiphasic injection can be investigated. Following any changes to current practice, further audits should be performed to assess any subsequent improvement in the rate of inadequate opacification.

We recommend that similar audits be performed at other institutions to ensure that adequate contrast enhancement is achieved and local guidelines are established.

Conclusion

This audit proves that the rate of inadequately enhanced CTPAs at this hospital, according to the RCR recommendations, was high. Causes for inadequate contrast enhancement are multifactorial, and we could not prove any significant impact with regard to the size of IV cannula, position of IV cannula, volume of contrast, time of study acquisition and presence of contrast leakage on the rate of inadequately opacified CTPAs. Although evidence from this study is limited, the use of high flow rates (≥ 4 mL/s) should be explored in an attempt to reduce inadequate opacification.

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Competing interests

The authors declare that they have no financial or personal relationships that may have inappropriately influenced them in writing this article.

Authors' contributions

D.J.B. was the guarantor of the integrity of the entire study and responsible for the literature review, data analysis, result compilation and manuscript preparation. H.M. contributed to study concepts, design and manuscript editing.

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Data availability

Data that support the findings of this study are available upon request from the corresponding author D.J.B.

Disclaimer

The views and opinions expressed in this article are those of the authors and do not necessarily reflect the official policy or position of any affiliated agency of the authors.

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15th JULY 2019

POST GRADUATE OFFICE

RE: SUBMISSION ON THE CORRECTION OF MMed PROPOSAL- DR DERIK JACOBUS BASSON

I hereby certify that I have checked the corrections made by Dr Basson as per recommended by the accessor group (Radiation science) meeting for the protocol titled: "An audit of the adequacy of contrast enhancement in CTPAs in a South Africain tertiary academic hospital setting".

I am completely satisfied with the changes and support the submission.

Regards,

Prof. MDTH Vangu
MP0378593

Prof. Vangu Mboyo Di Tamba Willy
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An audit of the adequacy of contrast enhancement in CTPAs in a South African tertiary academic hospital setting.



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List of abbreviations / Glossary of terms:

CMJAH – Charlotte Maxeke Johannesburg academic hospital

CTPA – Computed tomography pulmonary angiogram

DVT – Deep venous thrombosis

HU – Hounsfield units

IV – Intravenous

MPA – Main pulmonary artery

PACS – Picture archiving and communication system

PE – Pulmonary embolism

ROI – Region of interest

1. Introduction:

Pulmonary embolism (PE) is obstruction of the pulmonary vascular bed by embolic material originating elsewhere in the body and can be classified as acute or chronic. Pulmonary embolism is not a disease in itself, but rather a complication of a pre-existing condition. Deep venous thrombosis (DVT) of the lower limbs is by far the most common cause.

The exact prevalence of PE in South Africa is not known, but in 2016, 2124 deaths due to pulmonary vascular disease was reported, which includes PE (1).

Previous studies reported the incidence of PE to be up to 600,000 cases per year in the US and 60-70 per 100,000 in Europe (2–4). It is the 3rd most common cause of acute cardiovascular disease (5). Of preventable in-patient deaths, PE is the most common, with a mean age of presentation of 46,8 (3). The incidence rises exponentially with increasing age (6). It is stated that incidence of PE is likely significantly higher than suggested by literature, as silent PE can be present in up to 50% of patients with DVT (2,7). If left untreated, the mortality rate of acute PE is as high as 30%, compared to 8% in treated cases, while sudden death ensues in up to 10% of patients (2). Overall mortality at 3 months has been reported to be up to 15% (8). Chronic thromboembolic pulmonary hypertension, being a serious and life threatening condition, has an incidence of up to 4% following PE (2).

Since the advent of multidetector CT in the early 1990's, computed tomography pulmonary angiogram (CTPA) has been the gold standard with sensitivity reported as high as 90-100% and specificity of up to 89-94% (5).

At Charlotte Maxeke Johannesburg Academic Hospital (CMJAH), the current radiographic examination of choice for suspected PE is CTPA involving a

standardised protocol. Intravenous (IV) contrast is injected via injector, followed by bolus tracking by measuring contrast density within the pulmonary trunk. Helical scanning of the thorax ensues following detection of the appropriate density. This protocol is in line with international standards. Patients are referred to the radiology department for CTPA from CMJAH, as well as various surrounding hospitals without CT facilities. CPTA examinations are performed during normal working hours as well as after-hours, as it is nearly always an urgent study. CMJAH radiology department performs in excess of 50 CTPA examinations per month. These studies are viewed on workstations by radiology registrars and reviewed by consultant radiologists. CTPA studies are sometimes repeated if deemed indeterminate by the interpreting radiologist. This is however mostly a subjective assessment.

Patients with suspected PE are classified into low, medium or high likelihood using a Modified Wells score by treating clinicians. CTPA examination is subsequently requested according to a treatment algorithm.

Clinical management is heavily reliant on CTPA results in our setting, with a positive result resulting in either fibrinolysis or therapeutic anticoagulation. A negative result prompts the search for an alternative diagnosis.

Acute pulmonary emboli are diagnosed by visualising complete arterial occlusion and non-opacification of the entire lumen, with a central arterial filling defect or a peripheral filling defect with acute angles with the arterial wall (5). Chronic emboli are diagnosed by visualising complete occlusion and non-enhancement of a vessels that is smaller than similar order vessels, peripheral filling defect with obtuse angles to the vessel wall, thick-walled and irregular arteries, band or web-like filling defects or emboli with acute appearance being present for more than 3 months (5).

It is thus clear, in order to diagnose PE, adequate amounts of contrast within the pulmonary arteries are required at the time of scanning.

Indeterminate CTPA has been reported to be up to 10,8%, with poor contrast enhancement of the pulmonary arteries cited as the 2nd most common cause after motion artefact and is present in 40% of indeterminate studies (9).

Causative factors for poor contrast enhancement include poor timing of bolus administration, either too early or too late. Reasons for this include radiographer and protocol related factors, patient cardiac status and anatomic variations. Less frequently increased body habitus leads to increased absorption of the X-ray beam, which affects the attenuation in the pulmonary arteries (9).

An indeterminate study can have serious clinical implications. In one study by Jones *et al* (9), an indeterminate result was interpreted as a negative study by clinicians in up to 22% of cases. 4,2% of patients with an indeterminate CTPA were found to have PE at subsequent imaging (9). Although this number might seem low, given the high mortality rate of untreated PE, this is significant. 8,2% of patients with an indeterminate CTPA were treated empirically for venous thrombo-embolism (9), exposing them to possible life threatening haemorrhagic complications related to anticoagulation. 33% of patients with an indeterminate CTPA underwent follow-up imaging (9), exposing them to additional radiation as well as risk of contrast nephropathy and anaphylaxis resulting from intravenous Iodine contrast administration (10). Furthermore, repeating examinations in a resource limited environment such as South Africa, is not always feasible. The added cost of repeat studies is also disadvantageous.

According to Wittram (5), adequacy of contrast enhancement should be assessed by measuring the Hounsfield Units (HU) within the main pulmonary artery and should be at least 211 HU for a diagnostic study. A required level of 211HU will theoretically enable visualisation of 99,75% of all emboli according to experimental work by Meaney *et al* (11). The required level of 211HU was corroborated in another study and it suggests that there is a significant correlation between suboptimal pulmonary arterial contrast enhancement and indeterminate CTPA's (12).

The Royal College of Radiologists 2013 guideline (reviewed 2017), recommends that audits of CTPA examinations be performed to assess adequacy of contrast enhancement. A target of 210HU should be used and no more than 11% of studies should have contrast enhancement less than this. Prospective audits are advised assessing at least 30 consecutive CTPA examinations. Findings can then be used to improve protocol if found to be suboptimal (13). Some studies and audits recommend the use of 250HU as required enhancement, however there is no scientific basis for this suggested level. (9,14,15).

An audit by Afzal *et al* (16) in USA found that 12,3% of CTPA studies at one hospital had suboptimal contrast enhancement (<211HU). Two other hospitals had suboptimal contrast enhancement in 2,3% and 9,5% of cases, respectively.

Jones et al, (9) found in a large retrospective looking at 3612 CTPA studies in USA that approximately 3% of studies were suboptimal due to poor contrast enhancement (<250HU).

Mussaraf *et al* (17) did an audit of 50 CTPA's in England finding 16% of them having suboptimal contrast enhancement (<211HU) and made protocol changes accordingly.

A quality audit by Mander *et al* (14) using a more conservative level of 250 HU for adequacy as in the study cited above by Jones *et al*, found that 25% of cases in an Australian setting were suboptimal. Of CTPA's with contrast enhancement less that 250HU, 57% were indeterminate.

Similarly, an audit done at St Peter's Hospital in England (15) of 100 CTPA's using 250HU as standard, found that 47% of cases were inadequate. Protocol changes minimised this to 19%.

Lloyd (12) demonstrated that changes to protocol resulted in increased pulmonary arterial enhancement and a subsequent decrease in the amount of indeterminate CTPA's.

At CMJAH, a bolus of iodinated contrast (usually 80ml of 350mg Iodine/ml Omnipaque) with a preferred flow rate of >3ml/s and a contrast bolus threshold of 110HU are used routinely for CTPAs. No departmental audit of the efficacy of this protocol has been conducted.

To the best of our knowledge, nor has such an audit been performed in South Africa.

Our proposed audit can prove adequacy of local protocol and technique, or prompt changes to ensure adequate contrast enhancement and therefore less indeterminate studies and potentially improve patient care.

Therefore, the aim of this audit is to assess the adequacy of contrast enhancement of CTPA examinations at CMJAH radiology department.

2. Study objectives

The primary objective of this prospective audit is to determine whether CTPA's at CMJAH have adequate contrast enhancement. Contrast enhancement of >210HU in

the main pulmonary artery will be deemed as adequate as per the Royal College of Radiology audit guidelines. Suboptimal contrast enhancement in up to 11% studies will be considered acceptable.

Secondary objectives include:

Effect of the following on contrast enhancement

- Gauge of IV cannula
- Site of IV cannula
- Flow rate
- Volume of contrast
- Contrast leakage from infusion line or drip site
- Time of scan acquisition (day shift versus after hours shift)

3. **Methods**

This prospective audit will evaluate all in- and outpatient consecutive CTPA studies performed for suspected PE over a period of 3 - 4 months at CMJAH radiology department.

Sample size:

Given a prevalence of suboptimal scans of 11%, with 5% margin of error, the calculated sample size is 120 – 170.

Approximately 50 CTPAs are performed per month, therefore the target sample size is anticipated to be achieved in 3 - 4months.

Inclusion criteria:

CTPA for suspected PE

Adult patient (>18years)

Exclusion criteria:

Non-adult patient (<18years)

Radiographer checklist incomplete

Information on PACS insufficient to evaluate study

No informed consent from participant/referring clinician where the participant is unable to give consent

Method:

Each patient referred for CTPA that fits the inclusion criteria will be enrolled into the study. The radiographer on duty will complete a questionnaire prior to performing the scan. The questionnaire will include: IV cannula size, location of IV cannula, flow rate of the injector, volume of contrast or whether there was leakage of contrast from the infusion line or drip site. Informed consent from the patient for the study will be taken by the radiographer prior to the scan.

CT technique -

CTPA's will be performed on either a 64 or 128 slice Phillips CT scanner according to departmental protocol (Appendix 1). Examinations are to be performed with the patient in the supine position with arms placed above head. Scans are acquired in cranial-caudal direction, from lung apices to mid-low liver. Usually 80ml 350 mg Iodine/ml (Omnipaque) of non-ionic iodinated intravenous contrast material is administered through the IV cannula, via an Optivantage pump injector at a rate determined by the radiographer (preferably >3ml/s), depending on the IV line gauge and position. Bolus tracking will be used with a region of interest (ROI), centred

within the main pulmonary artery (MPA), at the level of its bifurcation, with scanning to be initiated after a 6,2s delay once a level of 110HU is reached within the ROI.

Image analysis and review of reports -

All images will be viewed on a PACS workstation by the researcher.

In order to assess the contrast enhancement of every CTPA, a circular ROI within the MPA at its largest axial diameter will be placed by the researcher on each study at a slice thickness of 1mm. The ROI diameter should be approximately 50% of the vessel diameter. The HU at this level will be documented.

Endpoint

3 - 4 months of consecutive CTPAs to collect data.

4. **Data analysis:**

Data from the radiographer checklists, patient data and HU reading in the MPA by the researcher will be captured on a customized MS Excel spreadsheet by the researcher. (Appendix 2 and 3)

All data will be stored on a password protected computer. This password will be known to the primary investigator only.

The descriptive statistics mean, median, standard deviation and inter-quartile range will be used to describe the continuous variables such as the contrast volume. Frequencies and proportions will be used to describe the categorical variables such as whether a scan was suboptimal or not. The Chi-squared test will be used to test for associations between categorical variables. The t-test will be used to compare means of continuous variables between the scans that were suboptimal and those which were not. If the data is not normally distributed a non-parametric alternative will be used.

Logistic regression will be used to model whether scans were sub-optimal or not, controlling for possible risk factors such as flow rate, contrast volume and other variables. Tests will be evaluated at 5% level of significance. All analysis will be done using STATA 15.

5. Ethics

The radiographer on duty will obtain informed consent from the participant to be enrolled in the study (see Appendix 4). Patients will be counselled that their study will be assessed for adequacy over and above routine reporting. This will be at no increased risk to the patient and the patient may elect to terminate their participation at any point during the study without adversely affecting their care or management. CTPA's will be booked by clinicians and accepted by radiologists without any knowledge of the audit, thus there will be no artificial increase in the number of CPTA examinations performed. The audit will be completely anonymous, by using study numbers in the data management stages. The identifying information that is linked to the study code will be kept in a separate, password protected database. Access to this database will be restricted to the primary investigator. The audit will assess routine CTPA examinations without making changes to any technique or protocol. Under no circumstances will any CTPA be cancelled or delayed due to the audit. Workflow will not be disturbed, as CTPA studies will be done as per local protocol and radiographer questionnaire and patient consent will take a few minutes to complete. These studies will not gain preference over any other CT examination. This audit will have no influence on reporting done by radiologists as the audit will be performed well after real time reporting of the studies was performed.

Permission has been granted by CMJAH Radiology acting HOD.

The protocol for the proposed study will be submitted for approval to the Committee of Human Research of the Faculty of Health Sciences, University of Witwatersrand.

6. Timing

	Dec 2018 – March 2019	**April 2019**	**May – August 2019**	**September 2019**	**October 2019**	**November 2019**
Literature review						
Preparing protocol						
Protocol assessment						
Ethics application						
Collecting data						
Data analysis						
Write-up						

7. Funding

Hospital funds for performing CTPA's.

Administrative costs are to be self-funded by the researcher:

Printing - R2000; Transport / Fuel R500.

8. Problems

None anticipated

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Appendix 1:

Parameters for CTPA (Protocol used at CMJAH)

Scan Type	**Slice Thickness**	**Pitch**	**Collimation**	**kV**	**Eff mAs**	**Algorithm**	
Helical	1 mm	0,798	0.625	120	50	Standard	

Appendix 2

Questionnaire for radiographer: (Please circle or fill in)

IV cannula size: Blue 22G / Pink 20G / Green 18G / Grey 16G / Orange 14G / Central line

IV cannula site: Antecubital fossa / Forearm / Hand / Neck / Lower extremity / Other _____

If Central line: Subclavian / Internal Jugular / Femoral

Flow rate: _____ml/s

Contrast volume: _____mls

Contrast leakage: Yes / No

Appendix 3:

Data collection spreadsheet

Study number	Patient age	Patient gender	Time scan done	HU (MPA)	IV cannula size	IV cannula site	Flow rate	Volume of contrast	Contrast leakage

Appendix 4

Study information sheet

Prospective audit of the adequacy of contrast enhancement in CTPAs in a South African tertiary academic hospital setting.

Good day,

I, Derik Basson, a doctor, am doing an audit on some of the scans we perform (CTPAs). An audit is a process used to determine whether we are achieving certain standards in our practices. I am are inviting you to take part in this audit by allowing us to use your scan's technical information. This audit will not affect your scan or your result in any way. The radiographer will complete a questionnaire with some information about how we are about to perform the scan. All we require is your permission to use your scan in our audit. There will be no added risk to you for being part of this audit as we are not changing anything, but only reviewing our current practices. By partaking in this audit, you give us the opportunity to improve our practices and help patients. Participation is voluntary and you will not be negatively affected if you refuse. This audit will be completely anonymous.

This study has been approved by the Human Research Ethics Committee (Medical) of the University of the Witwatersrand, Johannesburg ("Committee"). A principal function of this Committee is to safeguard the rights and dignity of all human subjects who agree to participate in a research project and the integrity of the research

If you have any concern over the way the study is being conducted, please contact the Chairperson of this Committee who is Professor Clement Penny, who may be contacted on

telephone number 011 717 2301, or by e-mail on Clement.Penny@wits.ac.za. The telephone numbers for the Committee secretariat are 011 717 2700/1234 and the e-mail addresses are Zanele.Ndlovu@wits.ac.za and Rhulani.Mukansi@wits.ac.za

Thank you for reading this Study Information Sheet.

Informed consent

I have read the above information, or it has been read to me. I have had a chance to ask questions about it and these questions have been answered to my satisfaction. I understand the study aims and that there are no added risks to me. I understand that I may stop being part of the study at any point. I give my permission for my scan quality to be looked at by the researcher.

Name of Participant_____

Signature of Participant _____ OR Thumbprint

Date _____

Day/month/year

In case of patient not being able to give informed consent due to clinical circumstances, we request the referring clinician to provide consent for participation in the audit.

Name of clinician_____

Signature of Clinician_____

Date _____

Day/month/year

Appendix 5

GAUTENG PROVINCE
HEALTH
REPUBLIC OF SOUTH AFRICA

CHARLOTTE MAXEKE JOHANNESBURG ACADEMIC HOSPITAL
Department of Diagnostic Radiology
Enquiries: (011) 488 3368

02 April 2019

Dear Dr Derik Basson
Registrar in Diagnostic Radiology

Re: Request to conduct a study on quality of CTPAs in adult patients in the Diagnostic Radiology CT Department at the Charlotte Maxeke Johannesburg Academic Hospital.

Study title: Quality of CTPAs (CT pulmonary angiograms) in adult patients

Dr Derik Basson is one of the Registrars in the Diagnostic Radiology Department and with the University of the Witwatersrand. He has requested permission to conduct a study on quality of CTPAs in adult patients at Charlotte Maxeke Johannesburg Academic Hospital.

As the acting Clinical Head of the Department, I grant you the permission to conduct the above study in the CT unit.

Please liaise with the relevant Consultant and Radiography department manager in charge of the CT unit with regard to the logistics and practical aspects of conducting the study.

I hope you find the above in order.

Yours faithfully,

Dr Kevin Sneider
Acting Clinical Head
Department of Diagnostic Radiology
Charlotte Maxeke Johannesburg Academic Hospital

CC: Mrs. G. Bogoshi CEO, CMJA Hospital

UNIVERSITY OF THE WITWATERSRAND JOHANNESBURG

R49 Dr DJ Basson

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)
CLEARANCE CERTIFICATE NO. M190454

NAME: (Principal Investigator)	Dr DJ Basson
DEPARTMENT:	School of Clinical Medicine Department of Radiation Sciences Division of Diagnostic and Interventional Radiology Charlotte Maxeke Johannesburg Academic Hospital
PROJECT TITLE:	*An audit of the adequacy of contrast enhancement in CTPA's in a South African tertiary academic hospital setting* ***Revised study title noted on 2021/04/07***
DATE CONSIDERED:	2019/04/26
DECISION:	Approved unconditionally
CONDITIONS:	
SUPERVISOR:	Dr H Moodley
APPROVED BY:	CB Penny Dr CB Penny, Chairperson, HREC (Medical)
DATE OF APPROVAL:	2019/10/08

This Clearance Certificate is valid for 5 years from the date of approval. An extension may be applied for.

DECLARATION OF INVESTIGATORS

To be completed in duplicate and **ONE COPY** returned to the Research Office secretariat on the 3rd floor, Phillip Tobias Building, Parktown, University of the Witwatersrand, Johannesburg.

I/we fully understand the conditions under which I am/we are authorized to carry out the above-mentioned research and I/we undertake to ensure compliance with these conditions. Should any departure be contemplated from the research protocol as approved, I/we undertake to submit details to the Committee. **I agree to submit a yearly progress report**. When a funder requires annual re-certification, the application date will be one year after the date when the study was initially reviewed. In this case, the study was initially reviewed in **April** and therefore reports and re-certification will be due in the month of **April** each year. Unreported changes to the study may invalidate the clearance given by the HREC (Medical).

Signature of Principal Investigator _____ Date _____

Turnitin.docx

by Derik Basson

Submission date: 18-Nov-2021 05:34PM (UTC+0200)
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Introduction

Untreated or undiagnosed pulmonary embolism (PE) carries a high mortality and morbidity, therefore, accurate diagnosis is imperative. Computed tomography pulmonary angiogram (CTPA) is the preferred method in the diagnosis of PE,[1] however suboptimal studies have been estimated at 6.6%.[2] Suboptimal contrast opacification has been cited as the second most common cause of indeterminate CTPA studies.[2,3] The exact prevalence of PE in South Africa is not known, however in 2016, 2124 deaths due to pulmonary vascular disease were reported, which includes PE.[4]

Audits of CTPAs have been recommended by the Royal College of Radiologists (RCR) in order to limit indeterminate CTPAs due to suboptimal enhancement. The RCR guideline (2013) recommends a maximum of 11% CTPAs can have suboptimal contrast enhancement (<210HU).[5] Several international audits have been performed, reporting a percentage of CTPA studies with suboptimal contrast opacification varying between 1.5 and 18% .[6–9] Some had decreased suboptimal rates following protocol changes, which were prompted by an audit.[7,9]

To the best of our knowledge, no such audit has been performed in South Africa.

Therefore, this audit primarily assessed the adequacy of contrast enhancement of CTPA examinations at a South African tertiary radiology department and secondarily the influence of certain technical factors.

Materials and methods

Patient selection

A single-centre retrospective and prospective audit was performed at a large tertiary hospital in South Africa, which included routine in- and outpatient CTPA referrals from this hospital as well as a network of referral hospitals and clinics.

The retrospective audit was conducted using all consecutive CTPA studies for suspected PE in adult patients (18 years or older) from December 2019, while the prospective audit included all consecutive CTPA studies from January to March 2020. Informed consent was obtained for the prospective audit. Additionally, the prospective audit incorporated a questionnaire that was completed by the radiographer acquiring the scan, which included technical factors, namely IV cannula size, location of IV cannula, flow rate of the injector, volume of contrast, presence of contrast leakage and the time the scan was acquired.

Data from the radiographer checklists and HU reading in the main pulmonary artery (MPA) were captured and the HU was further categorised as optimal (≥210HU) or suboptimal (<210HU).

CTPA technique

CTPAs were performed on either a Phillips 64 slice Brilliance, 128 slice Ingenuity or Siemens 64 slice Somatom CT scanner. Examinations were performed with the patient in the supine position with arms placed above the head and scans were acquired in a cranio-caudal direction, from lung apices to mid-low liver. Patients were instructed to inspire and hold their breath, after which scanning was performed at full inspiration. Usually 80-100ml 350 mg Iodine/ml of non-ionic iodinated intravenous contrast material (Omnipaque) was administered through the IV cannula, via an Guerbet Optivantage pump injector at a rate determined by the radiographer (preferably >3ml/s), depending on the IV line size and position. Bolus tracking was used with a region of interest (ROI), centred within the main

pulmonary artery (MPA), at the level of its bifurcation, with scanning to be initiated after a 6,2s delay once a level of 110HU was reached within the ROI.

Image analysis and measurement of contrast enhancement

All images were viewed on a Philips Enterprise PACS workstation by the researcher. The contrast enhancement of every CTPA was assessed by placing a circular ROI within the MPA at its largest axial diameter on each study at a slice thickness of 1mm. (Figure 1) The ROI diameter was 50% of the vessel diameter. The HU obtained at this level was recorded.

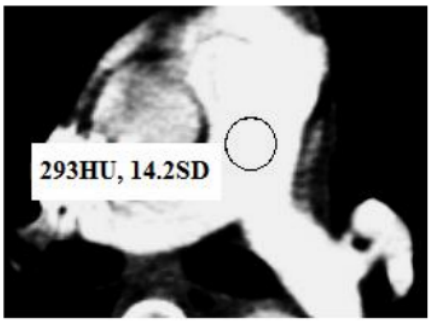


FIGURE 1: Contrast enhancement: HU measurement in MPA: 293 HU (Optimal)

Statistical analysis

Descriptive statistics namely frequencies and percentages were calculated for categorical data and medians and percentiles were calculated for numerical data. The Shapiro-Wilk test was used to investigate if numerical variables followed a normal distribution. Analytical statistics namely the Chi-Square test or Fisher's exact test was used to compare frequencies of HU optimal versus HU suboptimal. The Mann-Whitney U-test was used to compare median values for the two independent groups: optimal HU versus suboptimal HU. A significance level (α) of 0.05 was used. All data analysis was done using SAS Version 9.2.

Ethical considerations

Ethics approval by the Human Research Ethics Committee of our university was obtained.

Results

Contrast opacification audit

A total of 63 (retrospectively) and 130 patients (prospectively) were included with suboptimal contrast enhancement rates of 19% (n=12) and 21% (n=27) respectively. 19 CTPAs were excluded from the prospective audit due to incomplete informed consent. Figure 2 summarizes the CTPA audit results.

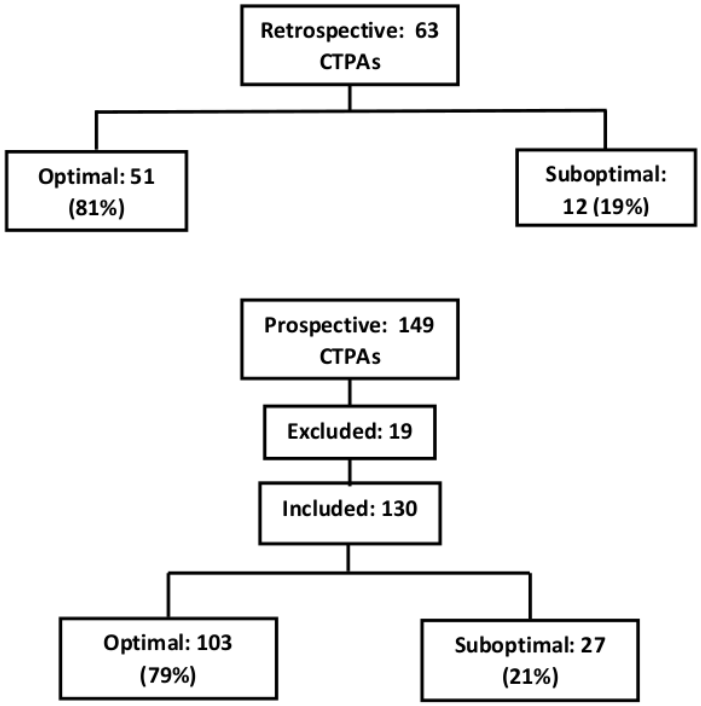


FIGURE 2: Flow diagram of the CTPA contrast opacification audit results

Technical factors

The majority of CTPAs were performed with a 20G IV cannula (n = 86, 66%) (Figure 3), whilst the most were in the forearm (n = 44, 34%), then the hand and antecubital fossa (Figure 4). The IV cannula sizes were not significantly different between the optimal versus suboptimal contrast enhancement groups (p-value 0.20). Similarly, the IV cannula sites were not significantly different between the two groups (p-value 0.65).

The majority of CTPAs were performed with 100-120 mls of contrast (n = 56, 43%) (Figure 6) at 3mls/s (n = 82, 63%) (Figure 5).

Both optimal and suboptimal groups had a median flow rate of 3ml/s, while both groups had a median contrast volume of 80ml, with no significant differences (p-values 0.94 & 0.55 respectively). The rate of suboptimally contrast opacified studies between flow rates of ≥4ml/s and <4ml/s were not significantly different (p-value 0.59).

The majority of the CTPAs were performed during the day (n = 73, 56%). Additionally the time of the scan acquisition, i.e. day vs afterhours shifts and presence of contrast leakage made no significant difference to the rate of suboptimal contrast enhancement (p – value 0.21 and 0.60 respectively).

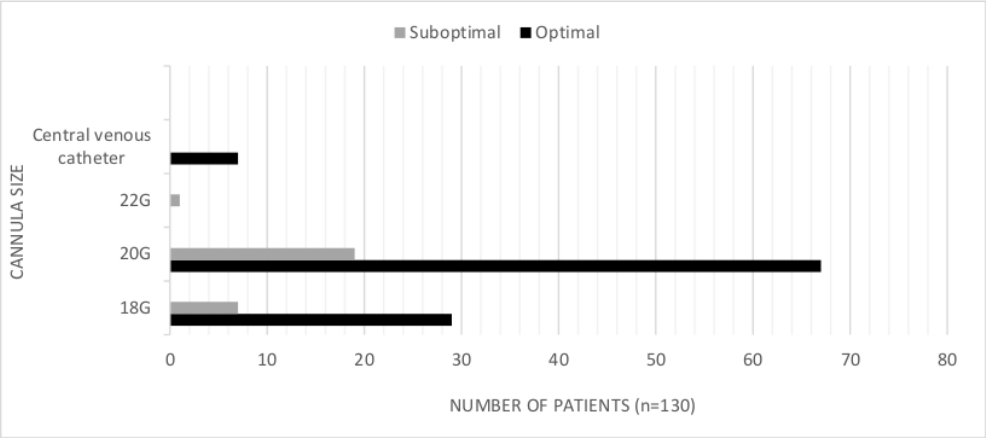


FIGURE 3: Adequacy of contrast enhancement versus IV cannula size

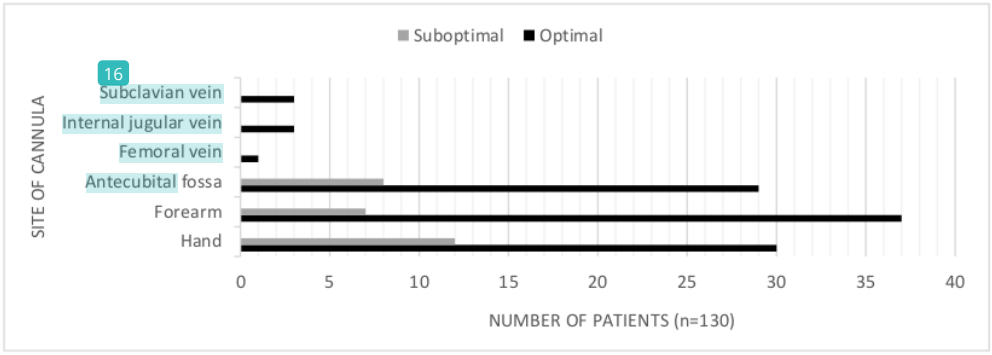


FIGURE 4: Adequacy of contrast enhancement versus IV cannula site

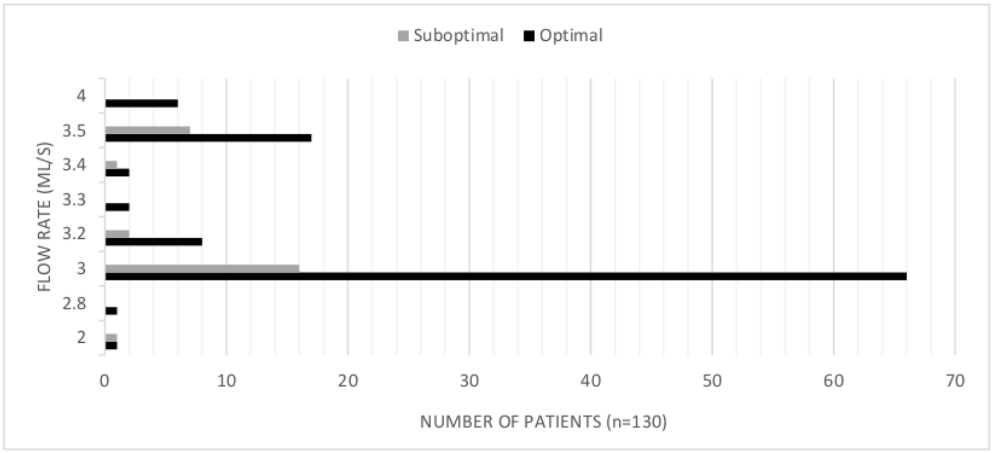


FIGURE 5: Adequacy of contrast enhancement versus flow rate

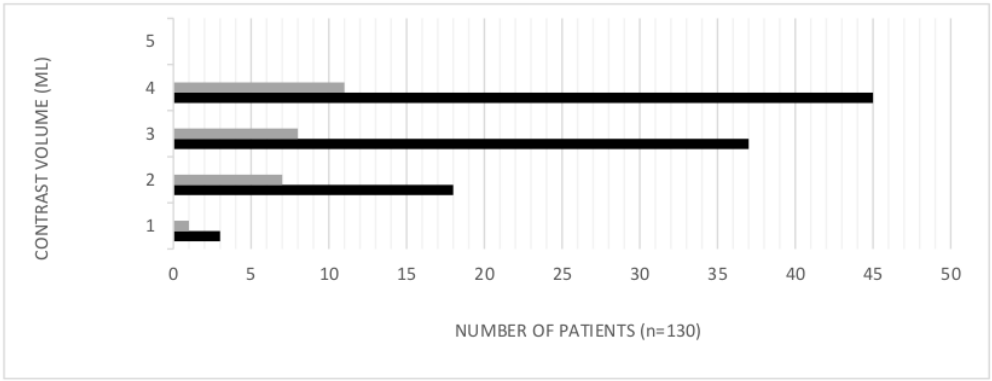


FIGURE 6: Adequacy of contrast enhancement versus contrast volume

Discussion

This audit established that the rate of suboptimal CTPAs was too high according to the international guideline set by the RCR[5] and was greater than when compared with international audits (1.5-18%).[6–9] The suboptimal rate of 21% in the prospective audit compared closely to the 19% in the retrospective audit, which indicates there was no radiographer bias in the prospective studies.

This high rate of suboptimal contrast enhancement is undesirable as it contributes to indeterminate studies and can lead to misdiagnosis, repeated examinations, radiation dose or unnecessary anticoagulation, all of which are detrimental to the patient.

We found the effects of the variables (position of IV cannula, size of IV cannula, flow rate, volume of contrast, time of study and contrast leakage) on the rate of suboptimal contrast enhancement to be non - significant. These findings provide some insight into what does not contribute to suboptimal contrast opacification, but has to be interpreted in light of the limitations subsequently discussed.

There were higher rates of suboptimal contrast enhancement when IV cannulas were positioned in the hand (28.6%), compared to 15.9% in the forearm and 21.6% in the antecubital fossa, however, this small difference was not significant (p-value 0.15). This is comparable to findings by Marshall et al [10] with a larger sample size of 1500 and Roggenland et al[11]. These two studies also found no significant difference between different IV cannula sizes, although, similar to our audit, they had a limited frequency of 22G IV cannulas. The RCR and American College of Radiology recommends a 20G or a bigger IV cannula in the antecubital fossa or forearm, but there is no other literature supporting this practice for CTPAs.[5,10,12] They also do not stipulate recommendations for contrast volume. Contrast

opacification is related to iodine flow rate, which is a function of iodine concentration and flow rate.[13] Our protocol utilized a concentration of 350mg Iodine/ml, which has been shown to be superior to lower concentrations.[14,15] It can therefore be postulated that IV cannula size should only impact contrast opacification when it restricts flow rate. The recommended minimum flow rate for general CT angiograms is 3ml/s,[12] while a flow rate of 4ml/s or higher has been recommended for CTPAs internationally.[11,16–18]. Flow rates of 3ml/s have been safely achieved with 22G IV cannulae,[19] thus the use of 22G cannulas can in theory still be sufficient. Power injectors have a predetermined pressure limit which can be exceeded in case of access vein size and IV cannula size mismatch and this will lead to an automatic decrease in the flow rate.[20] Therefore the IV cannula size and access vein size should be considered as a continuum.

Our study only had 6 CTPAs with a flow rate of ≥4ml/s, and although none of them had suboptimal contrast opacification, we could not prove any significant difference in the rate of suboptimally contrast enhanced CTPAs between this and flow rates <4ml/s (p-value 0.59). The significance is limited by the small number of CTPAs with flow rates ≥4ml/s. Several international studies have achieved lower rates of suboptimal contrast opacification, compared to ours, utilizing flow rates higher than 4ml/s. Lloyd et al[9] achieved a 9% rate of suboptimal contrast opacification (<210HU) utilizing a flow rate of 4ml/s, while Menon et al[21] had <2% suboptimally opacified studies when using a flow rate of 5ml/s. Similarly, Hendriks et al[22] did not have suboptimal CTPAs with a flow rate of ≥ 4,2ml/s, however, they used a less strict cut-off of 180HU. Ozawa et al[23] achieved a significant decrease in suboptimal contrast enhancement by increasing flow rate from 2ml/s to 3 ml/s. Therefore, the high frequency of relatively low flow rates (<4ml/s) in this audit might be contributing to

the high rate of suboptimally opacified studies, however, this requires further investigation. Employing a saline chaser bolus may be helpful in addition to using a higher flow rate.

The contrast volume did not have any significant effect on the rate of suboptimal contrast opacification. This is similar to Goble et al[15] who found no significant difference in rates of suboptimal contrast opacification between 100ml and 75ml contrast volume when using a cut-off of 250HU. Another study by Chen et al[14] found no significant difference in the rate of suboptimally opacified studies between 75ml and 60ml contrast volume, also using 250HU as the cut-off. Hendriks et al[22] have suggested individualised contrast volume protocols according to body weight.

Other possible explanations for the high rate of suboptimally opacified studies can include factors which we did not evaluate in this audit such as cardiovascular status, body habitus, patient age, respiratory rate and IV cannula size to access site mismatch. Scanning at maximal inspiration, as utilised in our protocol, has shown inferior contrast enhancement compared to minimal inspiration and expiration.[3,24,25] A circulation adjusted protocol with scan initiation 10 seconds after bolus triggering at 150HU or a fixed scan delay of 19 seconds after injection was suggested as optimal.[26] The use of a multiphasic injection with an exponential decrease in injection rate as opposed to a uniphasic injection rate with a rapid decline results in more uniform and steady state enhancement, which provides more room for error with regards to timing of scan acquisition.[15] These may be possible strategies to improve our CTPA scanning protocol and require further investigation.

Limitations of the study

The small sample size limited the significance, especially the low number of CTPAs with high flow rates (≥4ml/s) and a single CTPA with a 22G IV cannula. As this was an audit, variables could not be controlled, which led to an unequal distribution within variables. This audit did not account for patient age, weight and cardiovascular status and respiratory motion which have all been shown to affect contrast enhancement .[2,11] There was one reader which limits reliability, however the HU measurement in the MPA is an objective measurement that requires minimal expertise and the addition of the retrospective audit improved the reliability. The amount of contrast leakage was not quantified.

Recommendations

We suggest that CTPA protocol at this hospital be assessed and adjusted to achieve a lower rate of suboptimal contrast enhancement. This will lead to less indeterminate studies, less repeated studies and improved patient care. Alterations that have been advised and shown to be helpful include scanning at minimal inspiration or expiration,[3,24,25] changing timing after bolus tracking, use of a saline chaser and use of a test bolus.[5] Although this study found no significant difference in the effect of IV cannula size on the rate of suboptimally opacified CTPAs, we do not have sufficient evidence to support the use of 22G cannulas, therefore, the use of a 20G or larger cannula is still preferred and in line with current international recommendations. We suggest that CTPAs not be cancelled when IV access is peripheral to the antecubital fossa if it can tolerate acceptable flow rates, as we did not find any significant difference in the rate of suboptimally opacified studies with IV access distal to the antecubital fossa. We do not have enough evidence for an optimal minimum flow rate, but the limited findings of this audit together with international findings in favour of high flow rates (≥4ml/s) warrants the investigation of higher flow rates in our setting. Further studies are still required to assess the minimum required flow rate for consistent optimal contrast opacification.

The use of protocols adjusting contrast volume according to body weight and using a multiphasic injection can be investigated. Following any changes to current practice, further audits should be performed to assess any subsequent improvement in the rate of suboptimal opacification.

We recommend that similar audits be performed at other institutions to ensure optimal contrast enhancement is being achieved and local guidelines established.

Conclusion

This audit proves that the rate of suboptimally enhanced CTPAs at this hospital, according to the RCR recommendations, was too high. Causes for suboptimal contrast enhancement are multifactorial and we could not prove any significant impact with regards to the size of IV cannula, position of IV cannula, volume of contrast, time of study acquisition and contrast leakage on the rate of suboptimally opacified CTPAs. Although evidence from this study is limited, the use of high flow rates (≥4ml/s) should be explored in an attempt to reduce suboptimal opacification.

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