A Comparison of patient dose levels between 3 / 4 vessel conventional Angiography and Computed Tomography Angiography during examinations to investigate Subarachnoid Haemorrhage.

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Spanton, David and Strudwick, Ruth (2007). A comparison of patient dose levels between 3/4 vessel conventional angiography and computed tomography angiography during examinations to investigate subarachnoid haemorrhage. Radiography, 13 (3). pp. 173-179. ISSN 1078-8174.

The published version of this article is available here: http://www.radiographyonline.com/article/S1078-8174(06)00016-2/abstract

Abstract

The aim of this study was to investigate and compare the levels of ionising radiation dose received by patients whilst undergoing radiological examination for Subarachnoid haemorrahage by: conventional angiography (single and bi plane) and Computed Tomography angiography. The results obtained from previous examinations have been compared to consider which method of investigation delivers the lowest ionising radiation dose to the patient. Consideration was also given to comparing single plane angiography to bi plane angiography as empirical evidence suggested that radiologists received no formal training and only a small amount of informal training on newly installed equipment at the hospital in which the research was carried out. Would this lead to patients being inadvertently exposed to increased radiation as radiologists familiarised themselves with the equipment?

The dose received by 30 patients examined for SAH by each modality was converted to effective dose (mSv) for comparison. These results were then further compared by removing the lowest and highest recorded doses to eliminate any bias that may have been caused by skewed data. The results showed that CTA consistently delivered a lower dose to patients than single or bi plane angiography and that bi plane delivered a lower mean average dose than single plane angiography, with or without any skewed data.

Key Words:

Subarachnoid haemorrhage (SAH)
Single plane angiography
Bi plane angiography
Computed tomography angiography (CTA)
Radiation dose

1. Introduction

The purpose of this research project is to compare ionising radiation levels received by patients undergoing examination to investigate subarachnoid haemorrhage. The most frequently used radiological modalities for this examination are conventional angiography and computed tomography angiography (CTA). The reason for comparing CTA with conventional angiography is that there is evidence that CTA will become more routinely used than conventional angiography [1, 2], because, it is claimed to be a less invasive and more patient friendly procedure. However, there appears to have been little consideration given to the amount of ionising radiation received by the patients.

At the site the researchers chose to conduct the research, (a large hospital in the East Anglia region); a single plane angiography suite has been replaced (April 2004) by a newer design bi plane angiography suite. It was considered worthwhile by the researchers to also compare the ionising radiation doses received by the patients from each imaging modality.

1.1 Subarachnoid Haemorrhage

Subarachnoid haemorrhage (SAH) is an acute extravasation of blood that accumulates in the subarachnoid space, often following aneurismal rupture, commonly in the circle of Willis. The subarachnoid space separates the arachnoid, a delicate serous membrane and the pia mater, a fine connective tissue containing numerous minute blood vessels [3]. The haemorrhages are usually defined by how they originated, i.e. the result of traumatic head injury or those that occurred spontaneously. Most SAH are aneurysmal in origin and account for approximately 85% of SAH. Although the incident rate of SAH is quite low, approximately 8-12 cases per 100,000 population every year [(4)], the consequences of SAH can be very serious with approximately 50% of patients presenting with SAH dying within the first few days and many others suffering physical and/or psychological impairment [(5)].

The low incident rate makes detection for general practitioners (GPs) very difficult [(5)], they will most likely encounter patients with SAH once every eight years. The main clinical indication is severe headache with sudden onset (nearly all within seconds). However, only one in eight patients presenting with sudden severe onset headache as the only symptom will have SAH. Once at the hospital other potential diagnostic pitfalls are present, patients may present with atypical conditions such as: coma, seizure, delirium or focal stroke. As a result of the uncertainty in being able to definitely diagnose SAH, early referral to hospital is very important to the patient's welfare [(5)].

1.2 X-Rays

X-rays are used for both CTA and conventional angiography, the x-rays or "photons" cause interactions with orbital electrons of an atom, which can be so violent that the electron ejected from the atom moves away with significant energy. The now positively charged atom is missing an electron and this formation of a positive-negative ion pair inside the cell is called *ionisation* [(6)]. X-rays can interact in different ways with the body, they can:

- Pass straight through unaffected.

- Lose no energy, but alter direction (elastic scatter).
- Be stopped by structures within the body and lose all energy (photoelectric effect) resulting in total absorption.
- Alter direction, losing some energy (Compton scatter), resulting in partial absorption.

Only absorbed energy has the potential to cause biological damage. The unit Gray (Gy) is used when measuring absorbed dose and is equal to the measure of energy deposited in joules per kilogram (Jkg^{-1}), 1 Gy =1 Jkg^{-1}. 1 Gy is then divided into smaller units to measure small doses, milligray (mGy) and microgray (μGy). As absorbed energy, ionising radiation is very harmful unless distributed evenly and in low doses throughout the body [(6)]. However the very nature of ionising radiation is that it produces small clusters of ion pairs and as such it only requires a small radiation exposure to create millions of ion pairs in the exposed tissues. Even a small dose (μGy) of ionising radiation has the potential to damage sensitive macromolecules, which could lead to delayed but increased risks of cancer to the patient, or cause genetic changes in future generations. If high doses are received the risks are higher and more likely to kill cells or cause temporary or permanent changes in tissue function.

This would be of special concern if the patient were pregnant, especially in the first trimester. The main risks to the foetus from *in utero* irradiation are; cancer induction, malformation (e.g. small head size) or mental retardation [(7)], however if the examination does not include the abdomen (as SAH does not) then the foetal dose would be from scattered radiation and relatively low. Therefore not only is the correct diagnosis important to the patient's welfare but also that the lowest amount of ionising radiation possible is received during the diagnostic process.

1.3 Basic principles of CT and Angiography

CT

The x-ray tube is rotated on a special gantry around the patient as the transmitted x-ray beam is monitored by an array of detectors [(8)]. Raw data obtained by the detectors is then computer-processed and a grey scale image is constructed and displayed on a monitor. By convention the Hounsfield scale is used to measure the grey shades, e.g. water has a value of 0, bone +2000 (white) and air –1000 (black). Although there is no upper limit on the scale, medical scanners typically measure to around +3000 Hounsfield Units.

Angiography

Angiography uses an x-ray tube and image intensifier mounted at opposing points of a C arm. The area of interest is positioned between the tube and intensifier and the C arm can be repositioned to achieve different projections [(9)]. Single plane angiography uses just one C arm whereas bi plane angiography uses two, usually at 90^0 to each other so that two projections can be obtained at the same time. The attenuated x-ray beam passes to the image intensifier where it is processed, to be received by a television monitor as the original image [(9)].

2. Literature Review

Angiography is used to assess vascular abnormalities within the central nervous system (CNS), such as arteriosclerosis, aneurysms, transient ischemic attacks and SAH [(10)]. It is also used for interventional procedures, which are generally performed after non-invasive evaluation techniques have been employed. These interventional procedures are performed under sterile conditions within a specialised imaging suite with multi-planar imaging and digital subtraction facilities. For routine imaging angiographic x-ray tubes should have a minimum focal spot size of 1.3mm and a magnification spot size of 0.3mm. The procedure for SAH requires introducing a catheter into the vascular system guided by fluoroscopy, ideally into the femoral artery but the brachial or axillary arteries could be used depending on the patient's medical history. The image intensifier must be able to move around the patient to allow various tube angles without moving the patient [(10)].

2.1 Reducing Radiation Exposure to Patient and Staff

Radiation exposure during fluoroscopy is directly proportional to the length of time the unit is activated [(11)]. Therefore radiation doses during angiography examinations can be kept to a minimum by:

- Not exposing the patient if not viewing the TV image.
- Pre-planning images i.e. ensure correct patient position before imaging.
- Avoiding redundant projections.
- Operators must be aware of the 5-minute time notifications.

Operator's exposure can be reduced by maintaining as much distance away from the patient as possible and warning other staff when they are about to expose, allowing them time to move away from the patient. The patient's radiation dose can be minimised by decreasing the image intensifier (II) to patient air gap [12]. The II will intercept the primary beam sooner and reduce scattered radiation. Operator's exposure will also be reduced by the correct use of personal protective equipment, these include:

- Lead aprons – which must be stored correctly when not in use. Lead aprons will reduce radiation exposure by at least 80% [11].
- Thyroid shields.
- Optically clear lead glasses – can reduce operator's exposure by 85 – 90%, but because of the relatively high threshold for developing cataracts, they need only be worn by staff with very high fluoroscopy schedules.
- Lead gloves – worn at operator's discretion.
- Radiation Monitoring Dosimeter Badges.

CTA is considered less invasive to the patient as the procedure does not require catheterisation but instead uses a peripheral intravenous injection via an automated pump system [13]. This requires careful timing so that the contrast is in the vascular area of interest during the CTA examination. At the hospital site chosen to conduct the research Siemens Combined Applications to Reduce Exposure (CARE Bolus) programme was used to ensure optimised contrast monitoring. A radiation dose consideration here for staff is that there is no requirement for them to be present in the room during scanning.

To keep the radiation dose as low as possible, operators must consider the image quality needed, which can be achieved by the correct use of the equipment and keeping the equipment in optimal condition [14]. The dose can be limited by selecting a low integrated tube current (mAs), a limited scan range and a high pitch [14]. To maintain the CT scanner in optimal condition, a daily calibration is required by performing a series of blank scans (i.e. scans with only air around the gantry). Also image quality and constancy must be maintained by use of phantom measurements, all of which will help ensure the patient receives as low a dose as possible.

2.2 Comparisons of Conventional Angiography and CTA [13]

Conventional Angiography projections.

Single plane angiography can only acquire one projection of a vascular structure per contrast injection; bi plane can acquire two projections. If more projections are required, additional contrast media and ionising radiation will be necessary.

CTA projections.

CTA acquires the necessary data for 3D imaging with one contrast media injection. Further projections can be reconstructed using this information without additional contrast or ionising radiation.

Conventional Angiography contrast media.

As the contrast media is introduced arterially patients must recover under nursing observation and total bed rest for at least 6-8 hours, an overnight stay in hospital may also be necessary.

CTA contrast media.

Peripheral intravenous injections do not require nursing observations or bed rest.

Conventional Angiography complications.

Complications that can arise from conventional angiography include: reactions to the contrast media, thromboembolic complications from catheterisation of arteries possibly leading to infarctions, strokes, arterial dissections, pseudoaneurysms, and arterial bleeding. In neuro angiography the risk of a transient ischemic attack or stroke is approximately 4% and the risk of developing a permanent neurologic deficit from a disabling stroke approximately 1%.

CTA complications.

Although the same contrast media is used, peripheral intravenous injections greatly reduce the risk of complications.

Conventional Angiography imaging.

With conventional angiography a 2D image is produced from a 3D structure. Any structures or blood vessels overlapping the area of interest may obscure the image.

CTA imaging.

CTA produces information that can be converted to a 3D image any overlying structures may be removed during the post processing procedure.

2.3 Route to Diagnosis

Aneurysms that cause SAH may occur at any point within the cerebral circulatory system, they occur most frequently around the circle of Willis in the following areas:

- The origin of the posterior communicating artery (27%)

- The junction of the anterior communicating and anterior cerebral artery (27%)
- Bifurcation or trifurcation of the main middle cerebral trunk (20%)
- The terminal segment of the internal carotid artery (6%) [15]

Aneurysms occurring in the peripheral vessels are not so common and account for the remaining 20%, in the posterior fossa aneurysms that have caused SAH have been detected by vertebral arteriography and mainly found in the following regions:

- At the basilar termination
- At the junction of the posterior communicating and posterior cerebral arteries
- At the origin of the posterior inferior cerebellar artery from the vertebral artery
- At the vertebrobasilar junction [15]

Generally aneurysms occur at points of bifurcation of cerebral arteries. It has been suggested that this is caused by a defect in the vessel's muscle coat which leads not only to the theory of congenital defect but also to other factors such as age, atheroma and hypertension playing a part in the etiology [15].

A clinician should be capable of diagnosing migraine from SAH type headaches themselves [16]. The patient with suspected SAH should then be sent immediately for an unenhanced CT scan (CT scan without contrast medium). This, will provide proof of a haemorrhage in up to 98% of SAH patients if a modern scanner is used and the scan takes place within 48 hours of ictus. An unenhanced CT scan should be the first line of investigation as the non invasive scan will in a large proportion of cases confirm SAH by demonstrating the presence of blood in the basal cisterns or over the cortex of the brain [15]. However a significant proportion will demonstrate a negative diagnosis and angiography would be the next line of diagnosis. CTA is most likely to be used where available, concentrating on the circle of Willis and middle cerebral bifurcation, where most bleeding aneurysms occur [15]. If the CT diagnosis is positive, the causative lesion could be localised to one hemisphere or to the posterior fossa. This angiogram may be limited to a single carotid angiogram or vertebral angiogram, avoiding the 3 or 4 vessel angiogram, but the neuroradiologist would decide this.

CT scan should be the first step to diagnosis [17, 18]. The scan would be 95% sensitive to the SAH if completed within 24 hours of the ictus, after which the sensitivity would reduce [18]. There is the possibility of a false-positive diagnosis of SAH if generalised brain oedema has occurred as it causes venous congestion within the subarachnoid space, which could mimic SAH [17]. Gijn and Rinkel (2001) [17] claim that the sensitivity of CTA compared with conventional angiography is 85-98%, however they discovered that on occasion CTA detected aneurysms that were missed by conventional angiography. Following results of one study, conducted by Velthuis et al. (1998) [2], which compared CTA to conventional angiography, Gijn and Rinkel (2001) [17] reported that participating neurosurgeons rated CTA as being equal to or better than conventional angiography in 83% of 87 aneurysms.

Pederson et al. (2001) [19] published results of a comparative study of CTA and single plane angiography for the detection of aneurysms. The aims of the study were to compare CTA with single plane angiography, compare their findings with two, blinded, independent reviewers and to evaluate CTA accuracy after one years experience. Their results revealed that initially CTA did not compare statistically with the angiography results. In the first year CTA had a detection rate of 88%, with missed aneurysms and false-negative results being the main cause of failure. However after one years experience at detecting with CTA the detection rate was up to 94% compared to angiography, the same factors were the main contributors to the failure rate, but the gap was closing. The main reason for missing aneurysms from CTA results was the size of the aneurysm [(19)]. They concluded that although CTA was very good at demonstrating the vascular anatomy, conventional angiography was of more diagnostic value for the evaluation of aneurysms less than 5mm in diameter, a finding supported by Waldlaw and White (2000) [(4)] and White et al. (2001) [(20)].

Waldlaw and White (2000) [(4)] claim that studies conducted to test sensitivity of CTA in patients with SAH are likely to have overestimated accuracy, their reasons for claiming this are:

i. The number of aneurysms present is higher than if asymptomatic patients are studied and they believe that statistical mathematical modeling would support the theory that a higher number of aneurysms present increases the sensitivity and specificity of the tests.
ii. The reviewers will look harder for aneurysms if there is a high possibility that one or more will be present. Control groups without SAH have been used in a small number of trials to reduce this bias but as none of the control groups had corroborative angiography, they warn that caution must be used when interpreting the results.
iii. Subarachnoid blood present can draw the reviewer’s attention to the aneurysm.

iv. Studies that demonstrate increased accuracy in CTA are more likely to be submitted by researchers and subsequently published than those that show CTA as being less accurate.

As well as the claims made by Whitelaw and White (2000) [4], all of the authors studied claimed that for detection of SAH, angiography was still considered to be the gold standard modality. Kaiser (2003) [21] claims that despite the disadvantages i.e. its invasive nature, risk of complications, longer examination time needed, extra staffing requirements and radiation exposure to patient and operators. The advantages of high spatial and temporal resolution, digital subtraction to isolate the blood vessels, opportunity to apply interventional procedures immediately to treat lesions and 3 dimensional rotational capability which can assist to define aneurysm necks all combine to make angiography the optimum imaging modality, although CTA with its capability of producing 3D images that can be manipulated by the CT operator after the examination has completed, reduced risks from contrast media, improving sensitivity is increasingly becoming a serious challenge to angiography [21].

3. Statement of Purpose

The single plane suite had been established at the site for several years and all the radiologists were familiar with the equipment and proficient at using it. However empirical evidence suggests that the radiologists receive no formal training and only a small amount of informal training in the use of the newly installed equipment. If this is the case they may be inadvertently exposing the patient to ionising radiation for longer as they familiarise themselves with the equipment, resulting in an increased dose to the patient. Therefore with those considerations in mind the aim and the objectives of this research project are as follows:

3.1 Aim.

To investigate and compare the levels of ionising radiation dose received by patients whilst undergoing radiological examinations for SAH by:

- CTA
- Conventional Angiography (single plane)
- Conventional Angiography (bi plane)

The results obtained from previous examinations can then be compared to consider which method of investigation delivers the lowest ionising radiation dose to the patient.

3.2 Objectives

- To outline the three methods available.

- To identify the safety issues and protocols/procedures already in place to minimise radiation dose to patients.
- To compare patient dose from each modality.
- To analyse the results.
- To discuss the results and relate them to the literature.

4. Methodology

As the study in question relies on obtaining data on doses received by patients during investigation for SAH it was apparent that a quantitative approach was necessary, also if not all the recorded data was to be used but a sample of them, then inferential statistics could also be appropriate. However the descriptive statistical approach would allow for the results to be compared and determine any significant differences. It was decided to use a quantitative survey with descriptive statistics and to follow aspects of Burns (2000) [(22)] linear sequence to develop the research design and methodology.

For this project a research hypothesis was selected because it was considered extremely likely by the researchers that the patients examined by bi plane angiography would be receiving a higher dose than those examined by single plane. Also it was considered likely that both these modalities would deliver a higher dose to the patient than CTA.

The location chosen to undertake the study was a large training hospital in the East Anglian region. It was chosen because the single plane angiography suite had recently been replaced with a bi plane suite and the radiation doses received by patients were easily obtainable. Also it meant that there was a good possibility that the same staff carried out the examination from both modalities. During discussion with senior neurological staff it became apparent that CTA protocols for investigating SAH had been in place and used for several years and were well established.

The CTA samples were taken from a time period from May 2003 to October 2003. For convenience to the researchers they were obtained from an audit that had been undertaken by a senior radiographer and selected at random, the only criteria being that they had been examined for SAH. The single plane angiography samples were taken between April 2000 and September 2003 and selected at random, using the same criteria as the CTA samples. The bi plane samples were taken between June 2004 and October 2004; due to a shortage of recorded results it was not possible to randomly select samples so all the recorded results for SAH were used. The reason for the longer time scale with the single plane samples was to try to reduce any bias caused by operators having time to become accustomed to using the equipment in comparison to bi plane angiography.

A sample size of 30 dose levels for each group was chosen, not by using a formula but based on empirical evidence that during similar studies conducted by the National Radiation Protection Board (NRPB) they used a sample size of 20. Also when using parametric statistics a sample group of 30 is large enough to represent a larger group and the results will be valid [(23)]. It was decided to increase the size to enhance the chances of significant differences being detected.

Ethics and patient confidentiality were of prime importance in deciding how to collect the data. The bi plane angiography data was obtainable without using any patient identification (ID), the CTA and single plane results however required the use of the patient's hospital ID number to locate the doses they received, recorded on the hospital's computer system. Once collected however the ID numbers were no longer necessary and so have not been included in any section of the project. At this stage the doses were recorded by different methods, the CTA results were recorded as Dose Length Product (DLP) in mGycm and both angiography dose levels were recorded as Dose Area Product (DAP) in $mGycm^2$. To establish the most accurate method of converting the results to a comparable set of figures, the East Anglian Radiation Protection Board (EARPB) was contacted, and following advice conversion tables supplied by the EARPB were utilised to convert the single and bi plane angiography results to an effective dose, and a conversion co-efficient produced in the 2002 audit by Yates and Pike (2002) [(24)] was used to convert CTA results to an effective dose, measured in mSv which would make the results amenable to comparison and analysis.

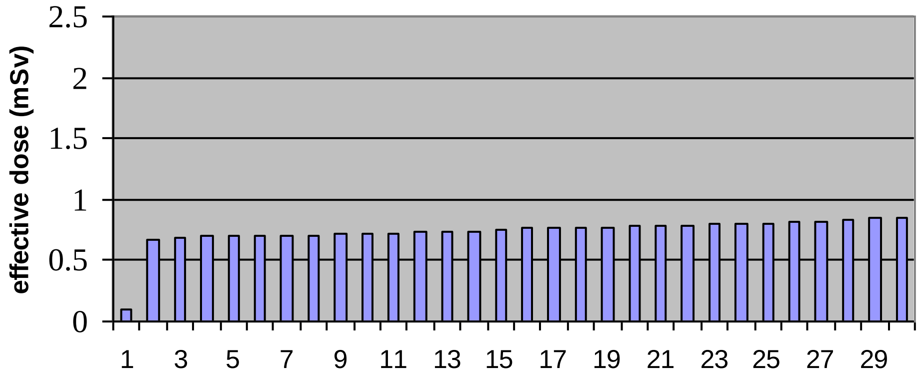
It was decided to employ multivariate tests that would consider all the results of each group at once, Macnee (2004) [(25)] argues that for parametric results either ANOVA (analysis of variance) or one-way ANOVA should be used. ANOVA is useful as it can compare how the results vary within the group to how they vary compared to results from other groups [(25)]. This means that the ANOVA test analyses variance, and then compares that variance within a set of results and with the other sets of results [(25)].

Taking into account the research issues raised, the following research design was adopted: A quantitative research method using descriptive statistics was used. Data from the three modalities was collected as previously described and converted to an effective dose (mSv) ensuring patient confidentiality at all times. Once the data was collected graphs were produced highlighting the mean and median averages. The parametric one-way ANOVA test tool was used to test any significant differences between the sets of results; a box chart demonstrated any skewed data. The hypothesis is that bi plane angiography will deliver a higher radiation dose to the patient than single plane angiography and that both these modalities will deliver a higher radiation dose than CTA.

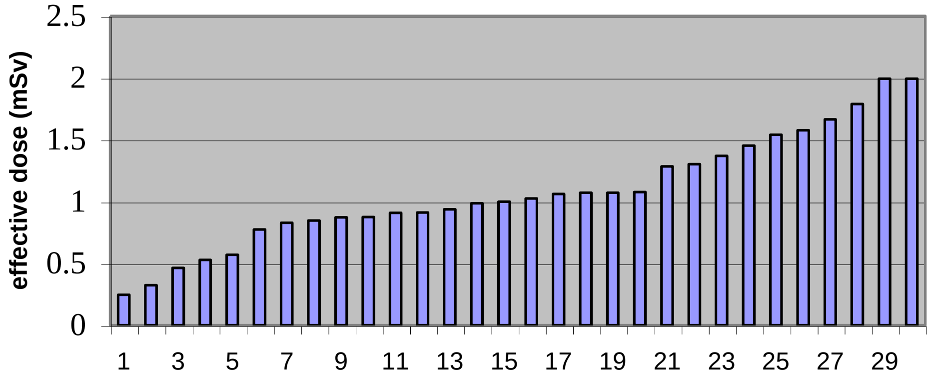
<u>5. Results Section</u>

Effective Dose Results from all Modalities.

CTA Figure 1



SINGLE PLANE Figure 2



BI PLANE Figure 3

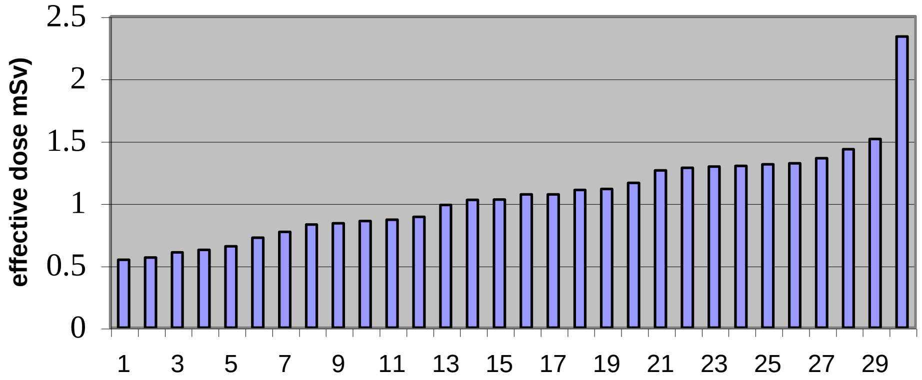


Figure 1 shows the effective dose received by the CTA sample group and demonstrates a consistently even spread between 0.65 - 0.85 mSv except for one sample which was 0.1 mSv. Of the 30 samples 21 were within the 0.7 - 0.8 mSv range suggesting that overall CTA was delivering a consistent dose to patients except for 9 samples, 8 of which were either just below or above the 0.7 - 0.8 mSv range.

Figure 2 shows that single plane angiography results ranged from 0.25 mSv up to almost 2 mSv with a more gradual increase. 3 samples were in the >0.5 mSv range, 12 were in the 0.5 - 1 mSv range, 9 in the 1 – 1.5 mSv range and 6 in the 1.5 – 2 mSv range.

Figure 3 shows that bi plane angiography samples overall ranged from 0.5 - 1.5 mSv with a steep increase up to nearly 2.5 mSv. There are no samples in the >0.5 mSv range, 13 in the 0.5 – 1 mSv range, 15 in the 1 – 1.5 range, 1 in the 1.5 – 2 mSv range and 1 <2 mSv.

Figure 4 Box Plot of all the results

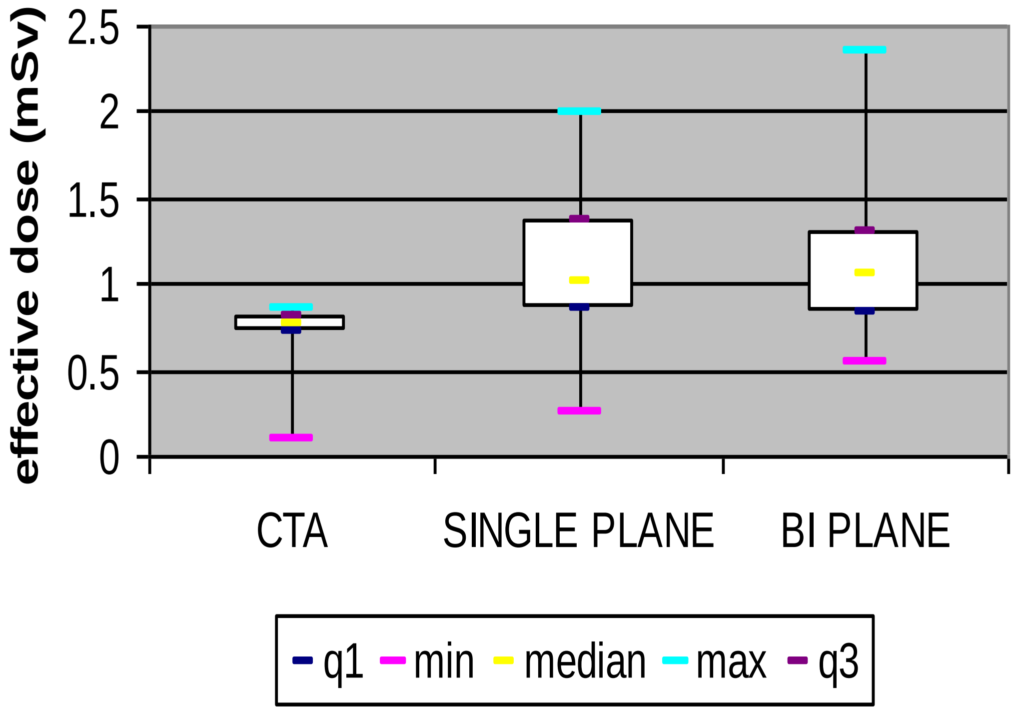
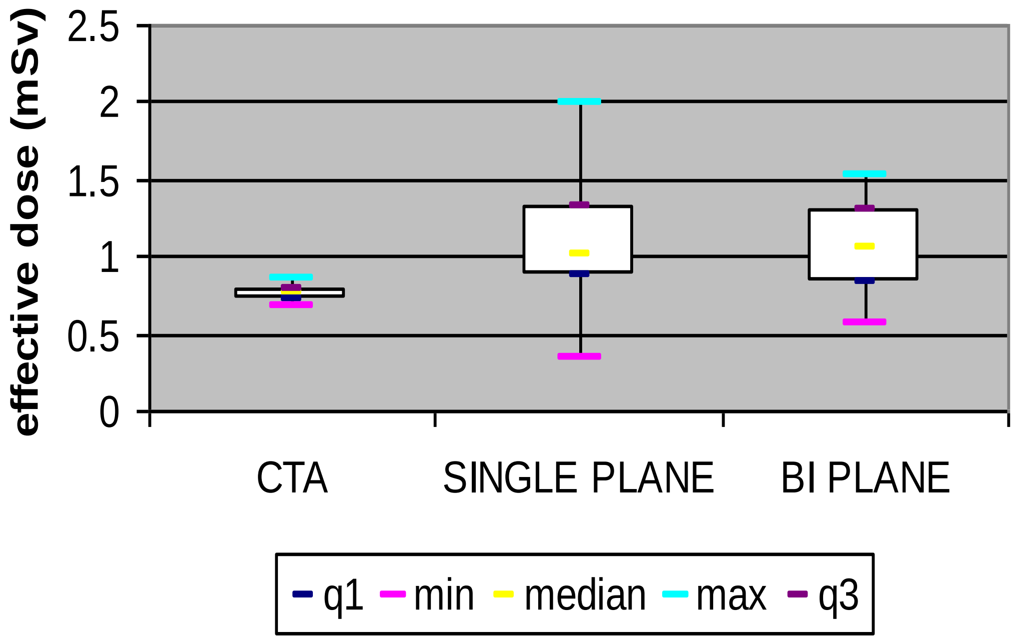


Figure 4 demonstrates the spread of the effective dose received by patients from the three modalities . The bottom line (q1) represents the lowest dose and the top line (q3) the highest. The white box represents the middle 50% of effective dose received, the bottom line up to the box the lower 25% (1st quartile) of results and from the top of the box to the top line the upper 25% (3rd quartile) of results. CTA and single plane angiography both have a wider spread in the 1st quartile due to the low value dose levels demonstrated in figures 1 and 2. Bi plane angiography however has a wider spread in the 3rd quartile due to the high value dose level demonstrated in figure 3. The middle 50% of effective dose levels in CTA are far more compact than both sets of angiography results suggesting that the dose levels similar and more consistent in CTA.

Figure 5 Box Plot without upper and lower values



As the upper and lower doses received by patients may have skewed the data, figure 5 was produced without the extreme values. The CTA results are now very different; the spread between the 1st and 3rd quartiles is greatly reduced demonstrating a consistent effective dose level received by patients. Single plane results are less affected, they still show a high value of almost 2 mSv and the lower value has only slightly changed from approximately 0.25 to 0.325 mSv. The maximum level in Bi plane angiography has reduced from 2.34 to 1.5 mSv and whilst not delivering as consistent a dose as CTA it now compares favourably to single plane angiography.

Figure 6

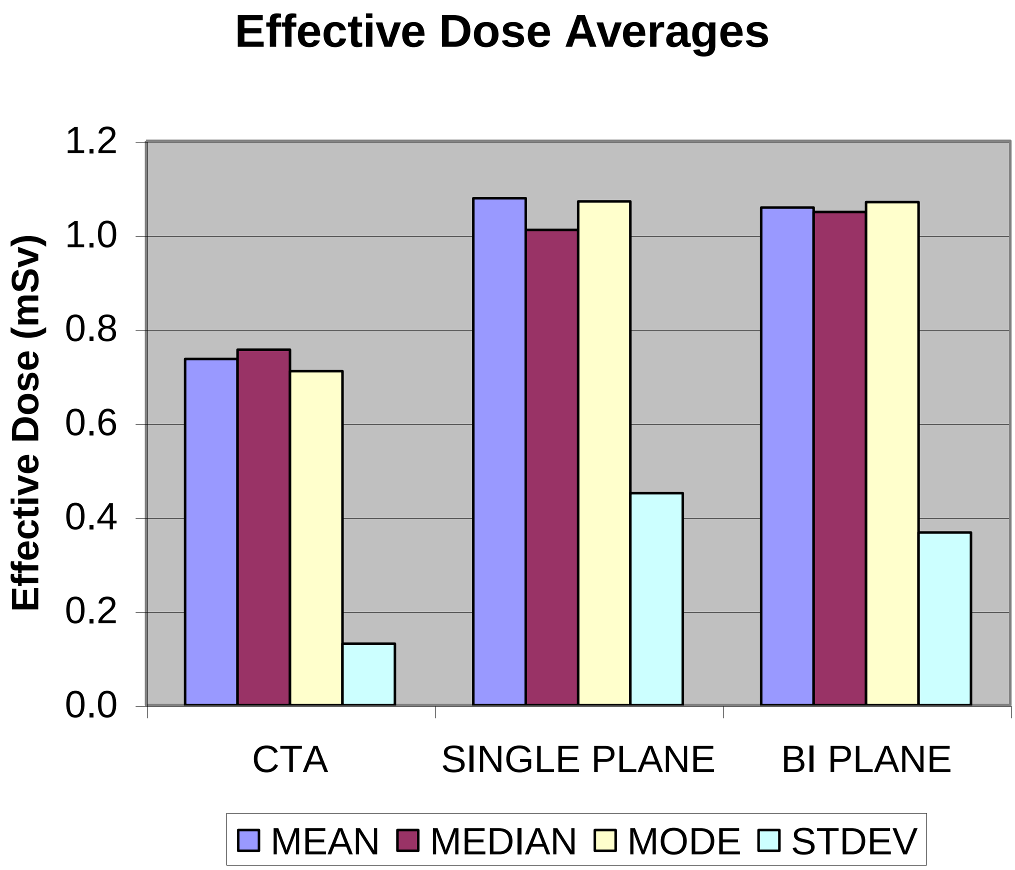
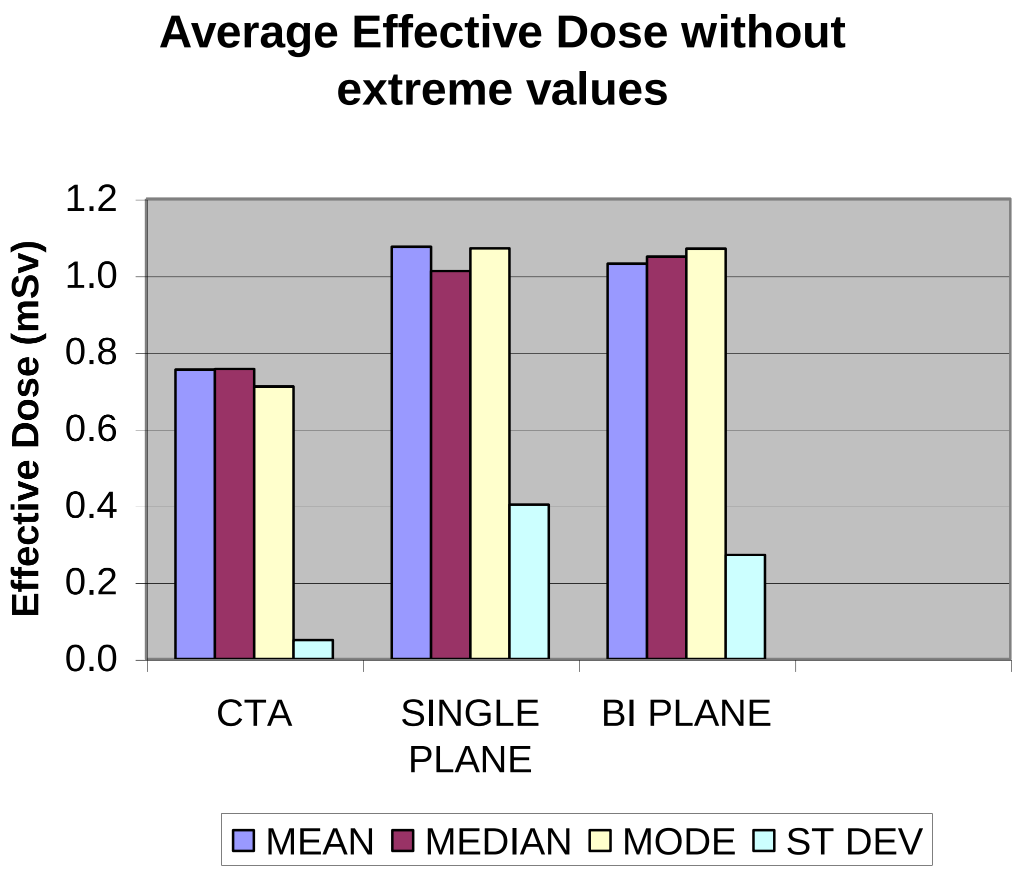


Figure 6 was produced to compare the mean, median and mode averages and the standard deviation (STDEV) using results from appendix 8. CTA results varied by 0.0456 with mode (0.7104) the lowest and median (0.756) the highest. For single plane angiography the median scored the lowest (1.0110) and the mean highest (1.0779) a difference of 0.0669. For bi plane angiography mode scored highest (1.0700) and median lowest (1.049) a difference of 0.0119. STDEV is highest in single plane angiography (0.4508) followed by bi plane angiography (0.3673) and CTA (0.1306).

Figure 7



Once the extreme values are removed (figure 7) the STDEV is reduced in all three modalities (CTA 0.0491, single plane 0.4019 and bi plane 0.2714) bi plane angiography has the largest reduction (0.1159) followed by CTA (0.0815) and single plane angiography (0.0489). The mean increases in CTA (0.7547) and reduces in single and bi plane angiography (1.0749 and 1.0307 respectively). The median remains the same as before in all modalities, as does the mode.

One-way ANOVA for 3 independent Samples.

Figure 8

	CTA	Single Plane	Bi Plane
Sample group size	30	30	30
Group total	22.0802	32.336	31.742
Mean	0.736	1.0779	1.0581
Variance	0.017	0.2032	0.1349
STDEV	0.1306	0.4508	0.3673

Tukey HSD Test

CTA vs. Single plane angiography $P<.01$

CTA vs. Bi plane angiography $P<.01$

Single plane vs. Bi plane angiography non-significant.

Full results can be seen in appendix 10.

One-way ANOVA for 3 Independent Samples.

Figure 9.

	CTA	Single Plane	Bi Plane
Sample group size	28	28	28
Group total	21.1322	30.096	28.86
Mean	0.7547	1.0749	1.0307
Variance	0.0024	0.1615	0.0737
STDEV	0.0491	0.4019	0.2714

Tukey HSD Test

CTA vs. Single plane angiography $P<.01$

CTA vs. Bi plane angiography $P<.01$

Single plane vs. Biplane angiography non-significant.

6. Discussion

The research hypothesis that was chosen for this project was that bi plane angiography would deliver a higher radiation dose than single plane angiography and that both conventional modalities would deliver a higher dose than CTA. Figures 6 and 7 clearly demonstrate that the first part of the hypothesis was incorrect. With or without the extreme values single plane angiography delivered a higher mean average radiation dose to the patient than bi plane angiography. The second part of the hypothesis was correct as both single and bi plane angiography delivered a higher mean average radiation dose to the patient than CTA.

Therefore, to avoid the incorrect hypotheses, a null hypothesis could have been selected, as well as predicting there will be no difference it can also be used if the researcher wishes to exercise caution concerning making predictions before the results have been analysed [(25)]. This was not taken into account when the research hypotheses were selected or the possibility that there might be unforeseen circumstances, which may affect the results.

All sets of samples were selected using just one criteria; that they had been examined for SAH. This was a weakness in the design, which was soon apparent within the results section. Figures 1, 2 and 3 demonstrate the individual dose levels received from each examination, and that CTA consistently delivers the lowest radiation dose. In CTA the results are consistently within the 0.6 – 0.9 mSv range confirming that the patients were examined under similar conditions, i.e. that the same CT protocols were performed for each examination. However, the graph also demonstrates one set of results as only 0.1 mSv, because of the methods employed to collect the data there is no definite reason why. It could be that the patient had a reaction to the contrast media, an inability to remain motionless, a claustrophobic reaction to the scanner, a scanner malfunction or other possibilities, which necessitated abandoning the examination, and the patient receiving a lower radiation dose.

Due to the uncertainty about why one set of results is different, it may be necessary to revise the method used to collect the samples, the only criteria considered was that the patients had been examined for SAH, no consideration was given to whether the examination was completed or successful. Figure 2 demonstrates a much wider spread within the single plane angiography results, again there is no certainty that all the examinations were completed or if any patients suffered a contrast reaction causing the examination to be aborted.

Figure 3 shows that bi plane angiography has a similar spread to single plane angiography except for one set of results, which was much higher than the rest, this may be because it was a more complex examination than the others and required more images. The spread in figures 2 and 3 also reflects the fact that conventional angiography allows the neuroradiologist the option of applying interventional procedures immediately to treat lesions, which although increasing the dose initially received by the patient may remove the need to repeat procedures at a later date [21].

As the three graphs highlighted areas where the data may be skewed (figure 1 negatively skewed and figure 3 positively skewed) it was decided to produce two sets of data, one set with all the results incorporated and one set with the highest and lowest results removed, this would highlight any inaccuracies produced by the skewed data. Box plots (figures 4 and 5) were produced to demonstrate the spread of the data, figure 4 demonstrates that there was a larger spread on CTA between the lowest result to the 1^{st} quartile, but between the 1^{st} and 3^{rd} quartile the results are very compact and also there is very little spread from the 3^{rd} quartile to the maximum dose level, confirming that CTA produces a consistently low effective radiation dose to the patient.

Figure 4 demonstrates that single plane and bi plane angiography deliver comparable results within the middle 50% of results, but the lower and upper results highlight the possibility that not being limited to set protocols as in CTA the neuroradiologist has the opportunity to either end the examination as soon as possible or to prolong it to investigate as deemed necessary.

Once the highest and lowest values had been removed (figure 5) the results for CTA became more compact, demonstrating a consistent radiation dose level received by patients. The results for single plane angiography did not change but for bi plane angiography the spread from the 3^{rd} quartile to the maximum value is reduced from nearly 2.5 mSv to 1.5 mSv. These results were reflected in figures 6 and 7, where the mean and median averages improved for CTA and bi plane results once the extreme values were removed and single plane averages changed the least. All modalities however had improved standard deviation results demonstrating that once the extreme values were removed there is a more normal distribution amongst the results.

This flaw was not anticipated at the design stage and could have implications for reproducibility, i.e. the skewed data may not be present in later studies. During the design the only criteria used was that the patients presenting with SAH had their dose levels recorded, considerations that should have been taken into account are:

- Was the examination successfully concluded? If yes then the dose levels would be used.
- For angiography, were any interventional procedures implemented? If yes then the dose levels would not be used.

To test whether the skewed data had influenced the results the ANOVA test tool was implemented to demonstrate any significant differences. Figures 8 and 9 show that although the extreme values affected the mean averages, with them single plane angiography delivered an average dose of 1.0779 mSv and bi plane 1.0581 mSv and without them single plane angiography delivered an average dose of 1.0749 mSv and bi plane 1.0307 mSv. The difference between single and bi plane angiography was non-significant with both sets of results whilst CTA had a significant difference of <.01 to all groups it was compared with.

Ethics and patient confidentiality were considered to be of prime importance in relation to data collection, however as previously discussed this has created flaws within the design. The researchers should have retained the patient identification until the study was completed. It would have been possible then, once all the results were analysed to discover why certain sets of data were far lower or higher than all the others. The conversions from DAP and DLP to effective dose (mSv) were uncomplicated and would be reproducible either at the centre chosen for the study or at other centres providing the correct conversion co-efficients were available.

There are three common measures, known as measures of central tendency; mean, median and mode [22]. These have all been utilised in figures 6 and 7, mode is not as precise as mean or median [22] it was included for comparison, for this and future studies it may be preferable to omit this measurement. The ANOVA test tool was implemented in preference to others even though the results overall did not appear bell shaped on a graph (figures 1,2 and 3) as Macnee (2004) [25] claimed they would have to. The test tool demonstrated any significant differences adequately and there does not appear to be any reason to change for future studies.

Overall the study design was satisfactory and met the demands of the researchers, however mode would not be used as an average measurement and the data collection method would need to be improved for future studies.

Radiation during fluoroscopy is directly proportional to the length of time the fluoroscopy unit is activated [11]. Figures 2 and 3 demonstrate there is a difference in time the unit is activated, but because of the data collection flaws it is not known whether any of the methods employed to keep radiation dose to a minimum were used or not. Operator's exposure to radiation was not measured at any time during the study, but it was observed that lead aprons which had been correctly stored were worn by staff at all times during the examinations that the researchers participated in, reducing radiation exposure by 80% [11].

The consistently low doses recorded by CTA in figure 1 would seem to bear out the assertion that radiation doses can be kept low by correct use of the equipment and keeping the equipment in optimal condition [(14)]. During conversation with neurological staff it was confirmed that daily calibration by performing a series of blank scans was routinely carried out.

Conventional angiography will require increased radiation and additional contrast media if more projections are required [(13)] whereas CTA can reconstruct further projections after the examination without the use of extra contrast media or ionising radiation dose to the patient. This is highlighted by all the graphs as single and bi plane angiography consistently delivers a higher dose than CTA. Again it cannot be confirmed as the sole reason (because of the data collection method) but it is possible that the wide spread of results in figure 4 demonstrate the acquisition of further projections by the radiologist and also possibly the early termination of some examinations.

Considering the consistently low doses recorded from CTA and the increased sensitivity of CTA compared with conventional angiography [(18)] there appears to be an improving argument for selecting CTA over conventional angiography. As CT scanner design improves it would be worthwhile to consider later studies than those by Waldlaw and White (2000) [(4)], White et al. (2001) [(20)] and Pederson (2001) [(19)] to investigate whether CTA is improving at detecting aneurysms less than 5mm in diameter.

7. Conclusion

Although the initial consideration was to compare the radiation dose received by patients it has become apparent during this study that CTA and conventional angiography both have strengths and weaknesses and that the radiation dose to the patient will not be an issue on its own. CTA consistently delivers a lower dose and the post processing 3D images can be of great value to the radiologist. However as highlighted, CTA was less effective at detecting aneurysms smaller than 5mm in diameter than conventional angiography [4, 20, 19].

Also conventional angiography is still considered the gold standard for detection of SAH [4, 21, 17] but it has disadvantages compared to CTA [13]. As stated, the hypothesis was that bi plane angiography would deliver a higher radiation dose to the patient as radiologists may inadvertently irradiate the patient for longer as they familiarised themselves with the new equipment. This has neither been proved nor disproved by this study, so while remaining the gold standard for detection of SAH it is possible that bi plane angiography may produce lower radiation doses to patients in future examinations.

The ANOVA results also demonstrate that there is no significant difference between single plane and bi plane angiography, again this does not answer whether radiologists are inadvertently exposing patients to increased radiation. To achieve this a further study is recommended using the results obtained in this study when the bi plane angiography suite was installed, and comparing them with to results obtained a year later. A similar study could be undertaken with CTA, since the site chosen for investigation has replaced the scanner used for CTA with a newer 16 slice scanner. This provides an excellent opportunity to establish whether the newer scanner will deliver a lower radiation dose to patients than the scanner previously used.

Both these suggestions would have increased the validity of this study. CTA is increasingly being used to investigate for SAH with its use of 3D imaging and reduced risks to the patient from contrast media and improving sensitivity [21] but it is widely acknowledged that conventional angiography (either single or bi plane) is still the gold standard in investigation for SAH. Therefore both modalities have a very important role to play and rather than considering them separately they should be considered as compatible tools at the radiologist's disposal.

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