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LOW DOSE COMPUTER TOMOGRAPHY EXAMINATIONS IN ACUTE ISCHEMIC STROKE AND TRANSIENT ISCHEMIC ATTACK IN ZAMBIA

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Abstract

Background. Imaging is crucial in stroke cases because it improves interpretation and makes it easier to distinguish between ischemic alterations and cerebral hemorrhage. Acute ischemic stroke (AIS) and transient ischemic attack (TIA) are medical emergencies that require immediate clinical and radiological evaluation to be treated. In AIS and TIA, computed tomography (CT) imaging can help patients by providing precise anatomic information for treatment planning and a faster and more accurate diagnosis. But, there is a risk to one's health from the ionising radiation that is received during a CT scan. To measure the radiation output of various CT scanners, the CT dose index (CTDI) is a standardised measure of the radiation dose output of a CT scanner. This study aimed to reduce the CTDI, without compromising image quality, in AIS and TIA imaging, across the various imaging sites in Zambia.

Methods. A quantitative, experimental research design was used The first stage involved a quantitative retrospective review of patients' files to ascertain the current CTDI values used in imaging patients with AIS and TIA. The prospective quantitative phase involved the development of new imaging parameters that helped reduce the CTDI. Data were analysed using Stata version 17. The study was conducted at five tertiary hospitals across Zambia. The sample was purposefully selected (n=100).

Conclusion. This study managed to maintain excellent image quality at lower CTDI, which is within international standards.

Keywords. Stroke, CT dose index, CT imaging parameters

INTRODUCTION

The World Health Organisation (WHO) defines stroke as the abrupt onset of clinical symptoms linked to a localised, sometimes widespread disruption of brain function that persists for longer than twenty-four hours. It may be fatal and has no other apparent cause besides vascular origin.[1] With an estimated 42.4 million instances in 2015, stroke is one of the leading causes of sensory dysfunction worldwide. In 80% of cases it leads to permanent motor impairments.[2] In Zambia stroke is the sixth most common cause of death, accounting for 4.3% of all recorded fatalities.[3]

A transient ischemic attack (TIA) is defined as a focal neurological impairment that dissipates in less than 24 hours. A TIA may develop into a stroke if it is not adequately handled. Conversely, acute ischemic stroke (AIS) happens when a blood artery in the brain or neck becomes clogged.[4]

The advent of sophisticated medical imaging technologies, such as computed tomography (CT), has improved the selection of suitable treatment alternatives. It is a practical issue for physicians to comprehend the different facets of these imaging modalities, such as which ones to use and how to do so, given the resources available at their local institution and the associated radiation hazards. According to Tsalafoutas et al[5] it is well known that CT scan procedures result in doses significantly higher than those of conventional radiography. Radiation exposure from two or three CT scans raises the risk of cancer; particularly in young patients. Therefore, the use of imaging parameters is of utmost importance to help reduce radiation dose to the patient while maintaining image quality. However, in Zambia, no effort has been made to reduce the radiation dose to patients with AIS/TIA who are undergo CT imaging. Therefore, this research helped to develop context-specific CT scan imaging parameters tailored for AIS and TIA patients that would help reduce the CT dose index (CTDI) in Zambia.

METHODOLOGY

A quantitative, experimental research approach was used and both retrospective and prospective data were collected.[6-8] The study was conducted at five tertiary hospitals in Zambia and was conducted over one year.

Purposeful sampling was used and the sample size for the retrospective brain CT scan images of AIS and TIA patients was determined using the following formula, as adopted by Renjith et al.[9]

$$n = \frac{Z^2 (p \times q)}{e^2}$$

Where: ***n*** = sample size

Z = standard error associated with the chosen level of confidence (1.96)

p = estimated percentage of stroke fatalities in Zambia (7% as estimated for Zambia by WHO[3])

q =100 – p

e = ± 5 acceptable sample error

$$n = \frac{Z^2 (p \times q)}{e^2}$$

$$n = \frac{1.96^2 (7 \times 93)}{5^2}$$

$$n = \frac{3.8416 (651)}{25}$$

$$n = 100.04$$

The data comprised 100 brain CT scan images for AIS and TIA patients and were analysed for the retrospective quantitative phase. The images were then reconstructed to improve on the image quality. These images were again reported on. The images were for the period January 2019 to December 2023. Images that did not meet this criterion were excluded.

The CT radiographer helped retrieve the brain CT images and the radiologist reported on them. The CT imaging parameters, CTDI values, image contrast, and the Alberta stroke programme early CT score (ASPECTS) were recorded during this phase.

A prospective comparative study design was more appropriate for evaluating the proposed imaging parameters for reducing CTDI. Based on the results from the retrospective and prospective reconstructed images of this study and the available resources, tailored CT imaging parameters for Zambia were developed. To discover a cause-and-effect relationship, this experimental research examined the interaction between independent and dependent variables using brain phantoms. This design allowed for direct comparisons of the before and after intervention imaging parameters. Therefore, using purely quantitative methods, in both retrospective and prospective stages, this research design helped the researcher collect data from large samples, thus making it possible to generalise the findings to a larger population.[10]

Before conducting this research study, ethical approval was obtained from the Lusaka APEX Medical University ethics committee (Ethics reference: 00740-24). The medical superintendents at the study sites in Zambia granted the researchers authorisation to begin the study. All pertinent authorities were informed of the identity of the researchers in a consistent and explicit manner throughout the research investigation. This research was conducted according to the International Code of Ethics of the World Medical Association (Declaration of Helsinki).[11]

Based on this declaration, the researchers handled the data in a private and secure manner. Maintaining the anonymity of personal data preserved patient anonymity. No personal information was reported or used as all: CT images were given a unique study number in place of patient names. In addition, the researchers were aware that looking at a patient's personal records or conducting CT scan examinations could violate their privacy and that permission from the patient should usually be obtained before doing so. However, since it was impossible to get in touch with every patient and ask for permission to use the retrospective brain CT images, permission was obtained from the heads of every study site where the data were kept. The research data were stored in a secure password-restricted computer for safety. The password was only shared with authorised individuals. During this research study all issues regarding plagiarism were observed.

RESULTS

From a range of TIA and AIS patients at the five study locations, 100 retrospective brain CT images were selected. In this study, descriptive statistics such as the mean and their associated standard deviations were reported after checking for the symmetric assumption which showed that there was no violation using the Kolmogorov tests. The frequencies and percentages of the categorical variables were reported. The z-test was used to check for the differences stratified by patient grouping, while the one-way analysis of variance (ANOVA) test was used for significant differences among sites for all parameters. Linear regression was used to check for predictors of the ASPECT score and contrast, which were treated as primary and secondary outcome variables with an interval measurement nature. Stata version 17 was used for analysis of data.

During the retrospective data analysis stage, 100 TIA and AIS original images were reported on by two radiologists, using the ASPECT scoring tool,[12] to determine whether the targeted sites of TIA and AIS were identified on a scale of 1 to 10, to determine the image contrast and the CTDI.[12-14]

The study involved 100 patients who were recruited from five different hospitals (Table 1). The majority of participants were from Site 3 which accounted for 86 (42.57%) of the total sample. This overall presentation may reflect the hospital's larger patient volume as it is one of the highest referral hospitals in Zambia. In contrast, Sites 4 and 5 had smaller sample sizes, representing 8.91% and 12.87% of the total sample, respectively, as their machines had constant breakdowns during the data collection period. Sites 2 and 1 accounted for 44 (21.78%) and 28 (13.86%), respectively.

Each hospital used imaging parameters for the brain, as set by the manufacturer: none had specific stroke imaging parameters. The baseline characteristics of the imaging parameters provide a foundation for understanding the potential impact of the intervention. Table 2 shows these characteristics. The exposure factor used in kilovolts (kV) was standardised across all sites, with a mean of 120 KV and no variation (SD ±0.00). This standardisation is crucial for ensuring consistency in imaging quality and minimising variability in diagnostic outcomes. However, the exposure factor in terms of milliamperes per second (mAs) showed some variation, with a mean of 324.28 (SD ±90.48).

The window level (WL) had a mean value of 40.86 (SD ±3.36), indicating relative consistency in this parameter. The window width (WW) had a mean value of 101.01 (SD ±20.39) and such a wide variation in the WW made it difficult to obtain consistence in image quality. The mean slice thickness was 3.14 mm (SD ±1.41).

The mean CT dose index (mGy) was 62.61 (SD ±16.06), reflecting the average radiation dose output by the CT scan machines during imaging. This value is above the acceptable reference value of 60mGy as recommended by the American Association of Physicists in Medicine and the International Commission on Radiologic Protection[15] for diagnostic imaging. Reducing radiation dose output, while maintaining diagnostic accuracy, is essential in medical imaging; the intervention's effectiveness in achieving this balance was important in this study.

The archived contrast of images obtained in this study had a mean value of 4.74 (SD ±4.28), indicating significant variability. The total ASPECT score index, which serves as a cumulative measure of the effectiveness of the imaging parameters, had a mean of 4.51 (SD ±3.99).

Imaging parameters at various sites were analysed, as shown in Table 3. The highest output image contrast was at Site 2 (5.93, SD ±4.66) and the lowest was at Site 1 (2.86, ±4.05). The highest ASPECT score was recorded at Site 5 (5.76, SD ±4.04), and the lowest was at Site 1 (1.95, SD ±3.33). At the above imaging parameters, the highest CT dose index output was at Sites 2 and 4 (76.14, SD ±0.00), while the lowest was at Site 3 (34.28, SD ±0.00).

Table 1. Baseline characteristics

VARIABLE		FREQUENCY (n=202)	PERCENTAGE (%)
Site	Site 1	44	(21.78%)
	Site 2	28	(13.86%)
	Site 3	86	(42.57%)
	Site 4	18	(8.91%)
	Site 5	26	(12.87%)
Group	Before intervention	100	(49.50%)
	After intervention	102	(50.50%)

Table 2. Parameter baseline characteristics

VARIABLE	MEAN (n=202)	(±SD)
Exposure factor used(kV)	120	(±0.00)
Exposure factor used (mAs)	324.28	(±90.48)
Window width (Hu)	101.01	(±20.39)
Window level (Hu)	40.86	(±3.36)
Slice thickness (mm)	3.14	(±1.41)
CT dose index (mGy)	62.61	(±16.06)
Image contrast	4.74	(±4.28)
Aspect score	4.51	(±3.99)

Table 3. Imaging parameters and output before intervention, across study sites

VARIABLE	SITE 1	SITE 2	SITE 3	SITE 4	SITE 5
Aspect score	1.95(±3.33)	5(±3.96)	4.72(±3.96)	5(±3.75)	5.76(±4.04)
CT dose index (mGy)	48.54(±0.00)	76.14(±0.00)	34.28(±0.00)	76.14(±0.00)	45.7(±0.00)
mAs	350(±0.00)	471(±0.00)	240(±0.00)	471(±0.00)	300(±0.00)
Window level	50(±0.00)	40(±0.00)	40(±0.00)	40(±0.00)	40(±0.00)
Window width	150(±0.00)	85(±0.00)	100(±0.00)	85(±0.00)	100(±0.00)
Contrast	2.22(±3.35)	5.93(±4.66)	4.69(±3.87)	4(±2.78)	4.69(±3.85)
Slice thickness	5(±0.00)	5(±0.00)	3(±0.30)	5(±0.00)	5(±0.00)
Kv	120(±0.00)	120(±0.00)	120(±0.00)	120(±0.00)	120(±0.00)

Table 4. Correlation between CT imaging parameters and output scores

Pearson correlation		**ASPECT**	**WW**
	ASPECT	1	-0.269 (p=0.0001)
	WW	-0.269 (p=0.0001)	1
Pearson correlation		**ASPECT**	**WL**
	ASPECT	1	-0.224 (p=0.0013)
	WL	-0.224 (p=0.0013)	1
Pearson correlation		**ASPECT**	**Slice thickness**
	ASPECT	1	-0.043 (0.535)
	Slice thickness	-0.043 (0.535)	1
Pearson correlation		**Contrast**	**Slice thickness**
	Contrast	1	-0.189 (0.007)
	Slice thickness	-0.189 (0.007)	1
Pearson correlation		**ASPECT**	**mAs**
	ASPECT	1	0.002 (0.974)
	mAs	0.002 (p=0.974)	1
Pearson correlation		**Contrast**	**WW**
	Contrast	1	-0.262 (0.0002)
	WW	-0.262 (0.0002)	1
Pearson correlation		**Contrast**	**WL**
	Contrast	1	-0.174 (0.013)
	WL	-0.174 (0.013)	1
Pearson correlation		**Radiation dose output**	**mAs**
	Radiation emitted	1	0.995 (0.0001)
	mAs	0.995 (0.001)	1

Table 5. New imaging parameters for AIS/TIA CT imaging

CLINICAL INDICATION	**SUGGESTED PROTOCOL**
Suspected AIS/TIA for ischemic assessment	Non-contrast CT brain with parameters set at WL=41, WW=66, 3mm slice thickness, 260mAs and 120kV
Suspected TIA/AIS for thrombus assessment/measurement, stenosis, plague	Non-contrast CT brain with parameters set at WL=41, WW=66, 1mm slice thickness, 260mAs and 120kV Contrast CT brain and neck with parameters at WL=31, WW=66, 1mm slice thickness, 260mAs and 120kV

Correlation analysis involved assessing the correlation between specific CT parameters and ASPECTS scores to explore potential associations, as well as CT parameters and the contrast of the image to surrounding tissue. The imaging parameters were also correlated to the CT dose index (mGy) output. Pearson's correlation test was used to assess the data, and a p-value of less than or equal to 0.05 was deemed significant. Table 4 shows the correlation findings. Pearson's linear correlation coefficient was calculated between the imaging parameters (mAs, WW, WL, and image slice thickness) and the average ASPECTS, contrast values and CDTI. Results were considered significant if the correlation exceeded 50% with a p-significance value <0.05.

Given the different imaging parameters used to acquire images of varied quality, ASPECTS and the high CT dose index output, the need for the development and standardisation of an AIS and TIA imaging parameters across multiple sites and scanner makes was confirmed.

In the prospective stage, the retrospective CT images were manipulated, so as to determine the best WW, WL and slice thickness that would help improve image quality. At this stage, the mAs and kV could not be manipulated. The next stage involved the development of imaging parameters in order to help reduce CTDI output without compromising on image quality. The preceding findings helped determine these parameters. The developed imaging parameters involved adjustments in terms of mAs, slice thickness, WL and WW. The kV was not manipulated as it was found to be standard, at 120, across all sites. The new imaging parameters are as shown in Table 5. These parameters were then tested on a phantom. The researchers confirmed these imaging parameters based on their expertise and experience, as the researchers consisted of radiographers and radiologists. The imaging parameters were ranked on a scale of 0 to 3, based on image quality produced at low CDTI output, with 3 being ranked as excellent, 2 as very good, 1 as good, and 0 as non-diagnostic. Images obtained from imaged phantoms, using these parameters were also rated as excellent, by the two radiologists in this study; on a scale of 0 to 3 (3=excellent, 2=very good, 1=good, 0=non-diagnostic).

DISCUSSION

According to the retrospective data, the study sites' volume CT dose index was 62.62mGy, ASPECTS average score was 4.44, and average image contrast was 4.28HU. In this research there was a variation in the mAs across the study sites, with an average of 325.7mAs. The highest mAs of 471mAs and the highest CT dose index of 76.14mGy were recorded at Sites 4 and 2. The lowest mAs of 240mAs, and CT dose index of 32.5mGy was at Site 3. The mAs and the CT dose index showed a strong positive correlation of r=0.995 (p=0.001). In contrast to the current CT dose index at our study sites, Inkoom et al.16 conducted a research at six CT facilities with adult patients receiving CT examinations. The study provided diagnostic reference values for routine brain scans of 39.0-58.6 mGy. This index, a standardised way to measure the CT system's dosage output, should match the projected doses at the time of the scan.

The kV at each location was 120 kV, fulfilling the goal of keeping imaging parameters consistent throughout the investigation sites. According to Mansouri et al.[17] it is crucial to provide as much information as possible to detect diseases during CT examinations to ensure a good diagnosis; this can be accomplished with a lower dose. They explain that lowering the radiation dose without sacrificing image quality is feasible, even if low tube voltage increases image noise. The American Association of Physicists in Medicine (AAPM)[18] and Farooq et al.[19] recommend a tube voltage between 80-240 kV for brain CT investigations.

According to Mohammadinejad et al.[20] the radiology community should continuously develop dose-reduction technology to lower radiation exposure to as low as reasonably attainable (ALARA) without compromising CT's diagnostic value. Two ways to reduce dosage reduction, according to Midya[21] are increasing the noise index or employing different types of tube current modulation, which changes mAs. This study's strategy to examine these specific imaging parameters within the constraints of clinical CT scanners was motivated by the reported variation in clinical practice between institutions and the worry about dosage reduction.

The retrospective findings also showed a negative correlation between the ASPECT scores and the WL (r=-0.2240) and WW (r=-0.269), respectively. There was a negative correlation between the image contrast, WL (r=-0.174), and WW (r=-0.262). Viriyavisuthisakul et al.[22] explain that lesion conspicuity and diagnostic accuracy are influenced by the parameters of WW and WL and physicians' capacity to identify parenchymal hypo attenuation is contingent upon WW and WL configurations. Viriyavisuthisakul et al.[23] and Lu[24] noted that the most important pre-processing step in examining anomalies in CT brain images for illness diagnosis is window setting: several techniques have been put out to choose the best window. The average WL and WW for the chosen study sites in this study were 42.15 HU and 107 HU, respectively, for imaging TIA/AIS patients. These values were also used in the diagnoses of other brain imaging conditions at the same study sites. This approach differs from a study by Byrne[25] that determined the optimal windowing level for stroke to be between 8 and 40 WL and 32 and 40 WW, respectively. Additionally, Czap et al.[26] describe that non-contrast CT can be utilised with a window width and level setting of 40/40 to accentuate the contrast for brain parenchyma in order to observe early ischemic alterations better.

At the research locations, the average slice thickness used was 4.13mm. This thickness showed a negative correlation to the ASPECTS score (r=-0.043, p-value=0.53) and image contrast (r=-0.189, p=0.007), respectively. The p-value for the slice thickness and ASPECT score was statistically insignificant (p=0.53) while that for slice thickness and contrast was statistically significant at p=0.007. Other scholars[27] have explained that a reduction in slice thickness correlates to low signal-to-noise level. According to Ligero[28] pixel size, reconstruction slice spacing, convolution kernel, and acquisition slice thickness are pertinent sources of radiomics variability with a fraction of less than 80% robust features.

This study showed significant differences in the CT scan imaging parameters employed in patients with AIS/TIA among the study locations within the same country, which led to variations in the results of the CT dose index, ASPECTS, and image contrast. According to De Jong,[29] many scholars believe that a protocol is crucial since it is utilised to determine whether the image produced guarantees the possibility of providing a precise, consistent diagnosis or to confirm whether or not an organ is normal.

Given the crucial role that imaging parameters play in effectively obtaining images of AIS/TIA patients while consuming the least amount of radiation, imaging parameters, which help reduce CTDI needed to be applied in Zambia. After carefully weighing the equipment that is accessible, and available resources, the following are the imaging parameters for imaging TIA and AIS patients, using CT, in Zambia.

- A 120Kv X-ray tube voltage. Since this is the typical tube current used at all study locations, it remains the same as what is currently being used at each site. This is nearly identical to the guidelines provided by the American Association of Physicists in Medicine[18] (AAPM), which states a tube voltage of 120–240 kV is recommended for brain CT examinations, depending on the brand and system.
- A product of 260 mAs for tube current and exposure time. Based on their clinical expertise and experience,

these researchers selected this mAs value because, in comparison to greater mAs currently employed across the study sites, it was established that this acquisition and the reconstruction parameters would not result in any losses in the delineation of ischemia lesions/quality. Patients who receive a low dose of 260 mAs are exposed to a dose that is statistically much lower than that of the research sites, particularly hospitals like LTH and CTH: both currently use a high current of 471 mAs, producing a high CTDI of 76.14mGy. In this new protocol, the CTDI was found to be at a maximum of 21 mGy, fulfilling the objective of obtaining diagnostic images with the lowest reasonably achievable data acquisition. Bodelle et al.30 found that patients experienced 1.77 mSv at nearly identical mAs rather than 2.33 mSv; p<0.01 was reached at the usual 340 mAs, signifying a 24.03% decrease.

To account for the marginally higher noise, images acquired at 260mAs will employ iterative reconstruction and decrease WW and WL (in contrast to the present procedures at the study locations). These imaging parameters managed to reduce the radiation dosage to 21 mGy, which is within international standards, unlike current imaging practices, hence the resolve to reduce mAs in order to archive the ALARA concept, while taking social and economic considerations into account.[31]

- Slice thickness of 3 mm, reconstructed using iterative reconstruction to 1 mm thickness without loss of contrast. This lower slice thickness increases the spatial resolution, as large slice thicknesses are affected by artifacts due to partial volume effects.[32] With the above slice thickness and iterative reconstruction of 1 mm slice thickness, clinicians can detect and quantify the thrombus burden. In the study, any loss of contrast resolution due to the thin slice selection is compensated by adjusting window levels.
- The imaging parameters were set at WL and WW ranges of 30 to 41 HU and 40 to 80 HU, respectively. To accurately depict specifics of particular brain region of interest, narrow WW customised to AIS or TIA diagnostic needs is required. Compared to the current imaging parameters at the five study sites, the sensitivity to detect AIS/TIA is higher (p=0.013 at this range of WL and p=0.0002 at this range of WW) and deviates from the standard brain window setting of WL=20 and WW=80HU recommended by the American College of Radiology.[12]

In contrast to our recommended methodology, Czap et al.[26] utilised a WW and WL of 40/40. Byrne et al.[25] employed a WL in the range of 8 to 40 and a WW of 32 to 40. In our study, the findings of a comparison test between the brain window and various window levels revealed that the proposed windowing would improve the diagnostic value as an image result of both the non-enhanced and enhanced brain CT scans of AIS/TIA patients. The study radiologists rated the images obtained, at these imaging parameters, as excellent.

CONCLUSION

The statistical results of the current study show great promise as a possible algorithm that may be applied to modern medical practice. Without sacrificing image quality, the results have helped create the first context-specific CT scanning imaging settings that are beneficial in lowering CTDI in AIS/TIA patients in Zambia.

No study has previously looked at the connection between AIS/TIA cases and CT imaging parameter values, such as window width and window level, as well as the reduction of mAs and slice thickness to suggested values that can lower the CT dose index by up to 72.42%, in Zambia. Therefore, the desired ALARA principle was achieved in this study, reducing the radiation dose index output without sacrificing image quality.

COMPETING INTERESTS

Nil

AUTHORS' CONTRIBUTIONS

NG (University of Zambia) was the main researcher. KM (University of Pretoria) was responsible for the supervision of the study in terms of ensuring validity and reliability. KT (University of Pretoria) was responsible for co-supervision of the study in terms of ensuring validity and reliability. JS (Levy Mwnawasa University Teaching Hospital) was the first research radiologist. RP (Maina Soko Hospital) was the second research radiologist

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DISCLAIMER

The views and opinions expressed in this article are those of the authors and are the product of professional research. They do not reflect the views of the affiliated institutions or that of the publisher.

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