Estimation of effective dose for contrast and non-contrast head computed tomography using dose length product and k conversion coefficient for adult patients in South-South Nigeria

Tobi A. C.[1*], Mokobia C.E.[1], Ikubor J. E.[2], Omojola A. D.[3] and Akpolile A.F.[1]

[1]Department of Physics, Faculty of Science, Delta State University, Abraka, Nigeria.
[2]Department of Radiology, Faculty of Clinical Medicine, College of Health Sciences, Delta State University, Abraka, Nigeria.
[3]Department of Radiology, Medical physics unit, Federal Medical Centre, Asaba, Nigeria.
*Corresponding author. E-mail: anwulitobi@gmail.com.

Accepted 17th November, 2020

The aim of this study is to estimate the effective dose of contrast and non-contrast computed tomography (CT) head examinations using Dose-Length Product (DLP) and conversion coefficient (k). The DLP for 462 adult patients referred for head CT examination (contrast and non-contrast) from four centres (A1, A2, A3 and A4) in Delta and Edo States were collated and the effective dose for head CT of contrast and non-contrast examinations was estimated by multiplying the dose length product by the k conversion coefficient (0.0021 $mSv \cdot mGy^{-1} \cdot cm^{-1}$). The minimum, maximum, standard deviation, mean, 50^{th} percentiles (median) and 75^{th} percentiles were analysed using statistical package for the social sciences (SPSS) version 22.0. The 50^{th} percentile (median) of the effective dose was compared with values published by other researchers in Nigeria, Africa, European Commission, Germany, Italy, Taiwan, Canada and Japan. The estimated effective dose for non-contrast CT head examinations for centres A1, A2 A3 and A4 were 3.7, 1.0, 0.8 and 1.3 mSv, respectively. The estimated effective dose for contrast CT head examinations for centres A1, A2, A3 and A4 were 6.9, 1.8, 1.4 and 3.1 mSv, respectively. The estimated effective doses were at par with other published studies for non-contrast examinations. Further optimization of scan protocols is required for contrast examinations.

Key words: Effective dose, computed tomography, dose-length product (DLP), head.

INTRODUCTION

The source of ionizing radiation can either be natural or man-made. The major man made source of ionizing radiation is from medical exposure. There is an increase in the rate of exposure from imaging modalities that utilize ionizing radiation such as x-ray radiography, mammography, fluoroscopy and computed tomography (CT). One limitation of CT scanning is that it delivers high dose of radiation during imaging. CT examinations represent a small fraction of all the radiological examinations but account for a greater portion of the total collective dose arising from diagnostic imaging (UNSCEAR, 2008).

There has been an increase in the number and use of CT scanners in Nigeria (Adejoh et al., 2017). The ICRP recommendation on the management of patient dose in CT requires a justified and optimised approach. Effective dose expressed in millisieverts (mSv) is one of the quantitative measures used in describing the radiation dose delivered from CT imaging. Effective dose takes into account the absorbed radiation dose to organs and its radiosensitivity. It is mostly used to track cumulative dose, and not for individual patient dose exposure (ICRP, 2007). Effective dose allows for comparison of dose amongst different imaging modalities. It is also used for the estimation of cancer induced

risk of the patients (Shrimpton et al., 2009). Effective dose for CT can be estimated by multiplying Dose length product (DLP) by k conversion coefficient. The k conversion coefficient is the region-specific normalised effective dose per dose length product in mSv $mGy^{-1}cm^{-1}$(European Commission, 2000). The conversion coefficient for each organ/part of the body varies due to the level of radiosensitivity of each of the exposed organs to radiation. For CT head, the conversion coefficient is 0.0021 $mSv{\cdot}mGy^{-1}{\cdot}cm^{-1}$, CT abdomen 0.015 $mSv{\cdot}mGy^{-1}{\cdot}cm^{-1}$, CT thorax 0.017 $mSv{\cdot}mGy^{-1}{\cdot}cm^{-1}$, CT chest 0.014 $mSv{\cdot}mGy^{-1}{\cdot}cm^{-1}$ and CT pelvis 0.019 $mSv{\cdot}mGy^{-1}{\cdot}cm^{-1}$ (AAPM, 2008). The aim of this study is to estimate the effective dose of contrast and non-contrast computed tomography head examinations using DLP and k conversion coefficient.

MATERIALS AND METHODS

This is a cross-sectional study in which the effective dose received by 462 adult patients (aged 18-95 years) who were referred for CT scan of the head (contrast and non-contrast) was evaluated in four radiological centres in South-South Nigeria. These centres are located in Edo (Benin City) and Delta (Oghara and Warri) **s**tates respectively. Two of the centres were in Government based facilities while the other two were in privately owned centres and are coded as A1, A2, A3 and A4 respectively. The CTDIvol and DLP values were collated from the console of each of the CT scanners over an eighteen month period (October 2018-March 2020). Ethical clearance from the Research and Ethics Committee was obtained from each of the study centres before commencement of the study. The technical characteristics of the four CT scanners used in this study are depicted in Table 1.

Table 1. Technical characteristics of the CT scanners.

Centre	Scanner model	Manufacturer	Installation date	Slice	Scan mode
A1	Aquillion	Toshiba	2009	64	Helical
A2	Revolution Acts	GE	2017	8	Helical/Axial
A3	Light speed Plus	GE	2012	4	Helical/Axial
A4	Bright speed	GE	2005	4	Helical/Axial

Three were manufactured by General Electric company (GE) while the fourth was by Toshiba. The number of slices of the CT scanners ranged from 4-64 slices with axial and helical modes (Table 1). The dose survey was carried out over a period of 18 months. The effective dose (ED) of all the patients of all the centres was calculated using the relation in Equation 1,

$$\text{Effective dose (ED)} = \text{DLP} \times k \quad (1)$$

Where k (k factor) is the conversion coefficient based on the head (k = 0.0021 $mSv{\cdot}mGy^{-1}{\cdot}cm^{-1}$for head) (AAPM, 2008).

The minimum, maximum, standard deviation, mean, 50^{th} percentiles (median) and 75^{th} percentiles were analysed using statistical package for the social sciences (SPSS) version 22.0.The 50^{th} percentile (median) of all the effective dose was compared with values published by other researchers in Nigeria, Africa, European Commission, Germany, Italy, Taiwan, Canada and Japan

RESULTS

A total of 215 female patients and 247 male patients were referred for head CT examinations (contrast and non-contrast) during the study period. Centre A2 performed the highest number of contrast examinations; this was followed by centres A4, A3 and A1. Centre A1 performed the highest number of non-contrast examinations; this was followed by centres A3, A4 and A2 (Table 2). The highest numbers of patients 164 (36%) were seen in centre A2. This was followed by centres A1, A4 and A3 (Figure1).

The estimated 50^{th}percentile (median) effective doses in centre A1 for non-contrast examinations in female, male and all patients were 3.57, 3.81 and 3.73 mSv, respectively. The

Table 2. Demographic characteristics of the study population.

Centres	Non-contrast head		Contrast head		ALL
	Female	Male	Female	Male	
A1	26	41	21	20	108
A2	9	13	69	73	164
A3	22	28	22	20	92
A4	10	24	36	28	98
ALL	67	106	148	141	462

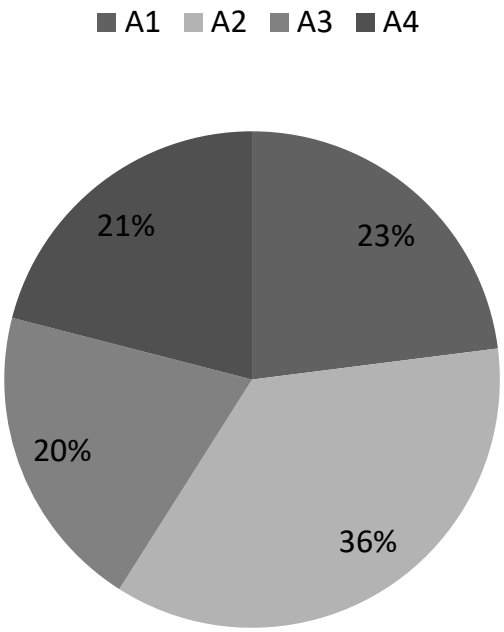

Figure 1. Distribution of patients referred for contrast and non-contrast head CT examinations in each of the study centre.

estimated 50thpercentile (median) effective doses in centre A1 for contrast examinations in female, male and all patients were 6.99, 6.83 and 6.99 mSv, respectively. The female patients in centre A1 had a lower effective dose compared to the male patients in non-contrast examinations; while the female patients recorded a higher effective dose in the contrast examinations (Table 3). The estimated 50thpercentile (median) effective doses in centre A2 for non-contrast examinations in female, male and all patients were 0.93, 0.97 and 0.96 mSv, respectively. The estimated 50thpercentile (median) effective doses in centre A2 for contrast examinations in female, male and all patients were 1.52, 1.86 and 1.75 mSv, respectively. The female patients in centre A2 had a lower effective dose compared to the male patients in both contrast and non-contrast examinations (Table 4).

The estimated 50thpercentile (median) effective doses in centre A3 for non-contrast examinations in female, male and all patients were 0.69, 0.91 and 0.79 mSv, respectively. The estimated 50thpercentile (median) effective doses in centre A3 for contrast examinations in female, male and all patients were1.36, 1.36 and 1.37 mSv, respectively. The female patients in centre A3 had a lower effective dose compared to the male patients in non-contrast examinations. The male and female patients both had the same value of effective dose in contrast examinations (Table 5).

The estimated 50thpercentile (median) effective doses in centre A4 for non-contrast examinations in female, male and all patients were 1.34, 1.29 and 1.32 mSv, respectively. The estimated 50thpercentile (median) effective doses

Table 3. Effective dose at centre A1.

Examination	No of patients	Min value	Max value	Mean(SE)	SD	50th percentile (Median)	75th percentile
Head							
Non- contrast							
Female	26	3.19	5.92	3.85(0.15)	0.78	3.57	3.9
Male	41	3.19	6.1	4.12(0.12)	0.77	3.81	4.5
All	67	3.19	6.1	4.03(0.1)	0.81	3.73	4.4
Head contrast							
Female	21	5.47	11.04	7.33(0.31)	1.43	6.99	7.8
Male	20	4.76	9.92	7.16(0.31)	1.37	6.83	7.6
All	41	4.76	11.04	7.25(0.22)	1.39	6.99	7.8

SE- Standard error.

Table 4. Effective dose at centre A2.

Examination	No of patients	Min value	Max value	Mean(SE)	SD	50th percentile Median	75th percentile
Head non contrast							
Female	9	0.68	1.26	0.97(0.06)	0.17	0.93	1.1
Male	13	0.67	1.44	0.99(0.06)	0.22	0.97	1.1
All	22	0.67	1.44	0.98(0.04)	0.2	0.96	1.1
Head contrast							
Female	69	1.2	2.77	1.62(0.04)	0.32	1.53	1.8
Male	73	1.02	2.99	1.89(0.03)	0.29	1.86	2.0
All	142	1.02	2.99	1.76(0.03)	0.33	1.75	2.0

SE- Standard error.

Table 5. Effective dose at centre A3.

Examination	No of patients	Min value	Max value	Mean	Standard deviation	50th percentile	75th percentile
Head non contrast							
Female	22	0.63	1.27	0.8(0.04)	0.21	0.69	1.0
Male	28	0.65	1.33	0.95(0.04)	0.22	0.91	1.1
All	50	0.63	1.33	0.88(0.03)	0.23	0.79	1.1
Head contrast							
Female	22	0.07	1.58	1.24(0.07)	0.37	1.36	1.2
Male	20	0.68	1.88	1.26(0.09)	0.38	1.36	1.3
All	42	0.07	1.88	1.28(0.06)	0.37	1.37	1.4

SE- Standard error.

in centre A4 for contrast examinations in female, male and all patients were 3.49, 3.0 and 3.06 mSv, respectively. In centre A4, the female patients had a higher effective dose value compared to the male patients in both contrast and non-contrast examinations (Table 6). A comparison of the effective dose in all the centres for non-contrast examinations shows that centre A3 had the lowest value of effective dose. This is closely followed by centre A2 then A4 and A1, respectively (Figure 2). A comparison of the effective dose in all the centres for contrast examinations also shows that centre A3 had the lowest effective dose. This is followed

Table 6. Effective dose at centre A4.

Examination	No of patients	Min value	Max value	Mean(SE)	Standard deviation	50thpercentile	75thpercentile
Head non contrast							
Female	10	0.76	1.39	1.2 (0.08)	0.25	1.34	1.4
Male	24	0.34	1.89	1.31(0.09)	0.45	1.29	1.7
All	34	0.34	1.89	1.27(0.07)	0.4	1.32	1.5
Head contrast							
Female	36	1.46	4.38	3.26(0.15)	0.87	3.49	4.2
Male	28	2.09	3.39	2.89(0.08)	0.4	3	3.1
All	64	1.46	4.38	3.1 (0.09)	0.72	3.06	3.7

SE-Standard error.

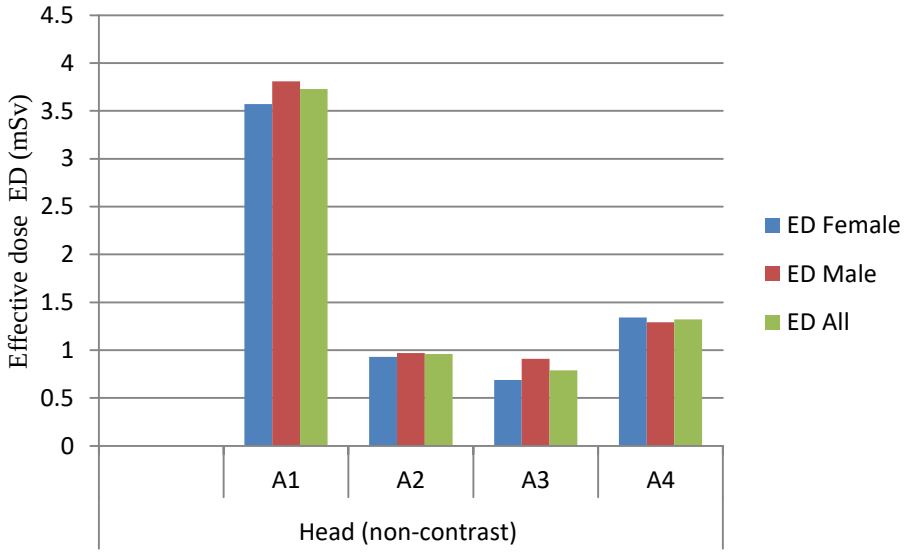

Figure 2. Comparison of effective dose (ED) values of non-contrast head CT for all the centres.

by A2, A4 and A1 (Figure 3).

Comparison of the effective dose values for non-contrast examinations with that of published studies is depicted in Table 7. Centre A1 had the highest value. Other centres in this study have values that are at par with other published studies (Table 7). Comparison of the effective dose values for contrast examinations with that of published studies still shows that centre A1 had the highest value. This is followed closely by Adejoh et al. (2015) (a published study in Nigeria). The other centres in this study have values that are at par with the other published studies (Table 8).

DISCUSSION

The effective dose in this study was calculated using DLP and k conversion coefficient as suggested by the European Commission (2000). The effective dose for contrast head CT examinations in centre A1 was 5.24% higher than the effective dose in centre A2, 5.62% higher than the effective dose in centre A3 and 3.93% higher than the effective dose in centre A4 (Table 8).The effective dose of the female patients for contrast head CT examinations in centre A1 was 0.16% higher than the male effective dose. The effective dose of the female patients for contrast CT head examinations in centre A2 was 0.33% lower than the male effective dose. Both male and female effective doses for contrast CT head examinations were the same. The effective dose of the female patients for contrast CT head examinations in centre A4 was 0.49% higher than the male effective dose. The estimated effective doses for

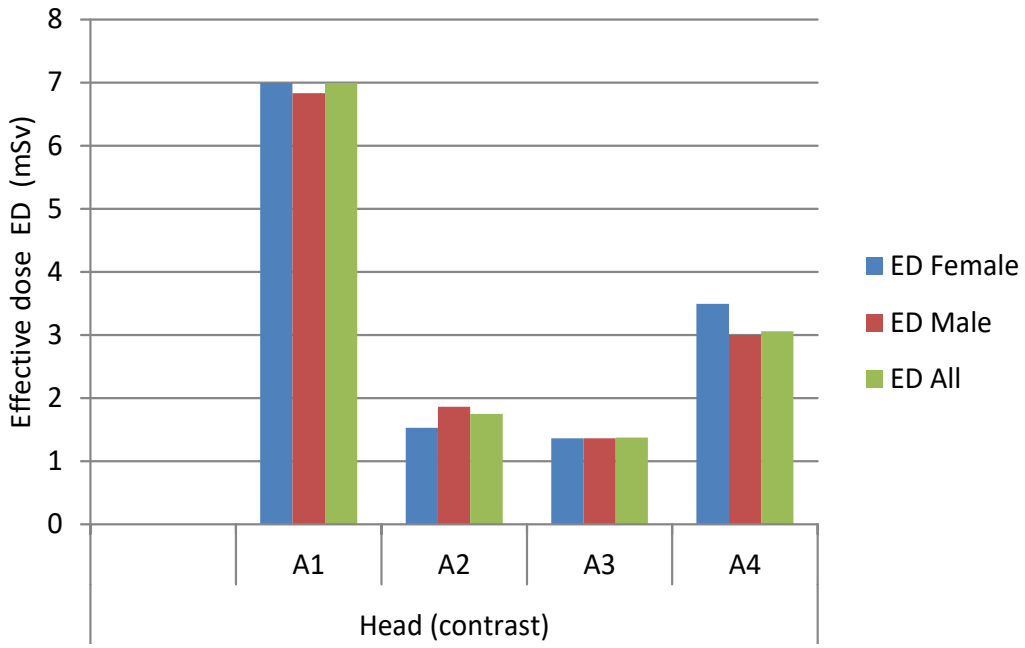

Figure 3. Comparison of effective dose (ED) values of contrast head CT.

Table 7. Comparison of effective dose values of the head (contrast) with that of published studies.

Variables	Location	Year	Effective dose (mSv)
This Study			
A1	Oghara	2020	3.7
A2	Benin	2020	1.0
A3	Warri	2020	0.8
A4	Benin	2020	1.3
Ogbole and Obed (2014)	Ibadan, Nigeria	2014	2.8
Mundi et al. (2015)	Abuja, Nigeria	2015	3.1
Adejoh et al(2015)	Nnewi, Nigeria	2015	3.1
Abdukadir et al. (2016)	North-Central Nigeria	2016	1.7
Opadele et al. (2018)	South-West Nigeria	2018	1.9
Ekpo et al. (2018)	Nigeria	2018	2.8
European commission (2004)	Europe	2004	2.2
Brix et al. (2003)	Germany	2010	2.3
Wambani et al. (2010)	Kenya	2010	3.1
Tsai et al. (2007)	Taiwan	2007	2.0
Origgi et al. (2006)	Italy	2006	1.8
Osei et al. (2013)	Canada	2013	1.8

Table 8. Comparison of effective dose values of the head (contrast) with that of published studies.

Variables	Location	Year	Effective dose (mSv)
This study			
A1	Oghara	2020	6.9
A2	Benin	2020	1.8
A3	Warri	2020	1.4
A4	Benin	2020	3.1
Adejoh et al. (2015)	Nigeria	2015	6.1
Heidi et al. (2002)	Canada	2002	4.0
Yamauchi-Kawara et al. (2010)	Japan	2010	4.2

non-contrast examinations in three of the centres (A2, A3 and A4) were below the recommended limits for natural background radiation (public) but higher for occupational exposures (medical population). The obtained effective dose for centre A1 was 0.7% higher than the recommended limit for natural background radiation (public) and also higher for occupational exposures (medical population). The wide variation of effective dose estimated from this study may be due to the different scanner types, scan protocols and scan parameters. This is the first time effective doses of CT head examination have been estimated in each of the centres. A difference of 20% was noticed from the estimated effective dose using DLP and k conversion factor and measured effective dose in a study by Kobayashi et al. (2013).

Conclusion

This study has successfully estimated the effective dose of contrast and non-contrast CT head examinations in the four centres. The estimated effective doses are at par with other published studies for non-contrast head CT examinations. Further optimization of scan protocols is required for contrast head CT examinations.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

ACKNOWLEDGEMENTS

The authors appreciate the management and staff of the Radiology Departments of Delta State University teaching hospital Oghara, Lily hospital Warri, University of Benin teaching hospital Benin City and Raytouch diagnostic centre Benin City.

REFERENCES

AAPM. (2008). American Association of Physicists in Medicine AAPM , The measurement, reporting, and management of radiation dose in CT. AAPM report No.93. Report of AAPM Task Group 23 of the Diagnostic Imaging Council CT Committee. College Park, MD

Abdukadir, M.K., Schandof, C., and Hasford, F. (2016). Determination of computed Tomography Diagnostic Reference Levels in North-Central Nigeria. Pacific Journal of Science and Technology. 17(2):341-349.

Adejoh, T, Nzotta, C.C, Aronu, M.E, and Dambele, M.Y (2017). Diagnostic reference levels for computed tomography of the head in Anambra State of Nigeria. West Africa journal radiology; 24(2) :142-146

Adejoh, T., Christian, N.C., Nkubli, F.B., and Dlama, J.Z., (2015). Effective Dose Levels from Computed Tomography of the Head during Contrast Studies in Nigeria. Health, **7**, 915-919

Brix, G., Nagel, H.D., Stamm, G., Veit, R., Lechel, U., Griebel, J. and Galanski, M. (2003). Radiation Exposure in Multi-Slice versus Single-Slice Spiral CT: Results of a Nationwide Survey. European Radiology, 13, 1979-1991.

Ekpo, E.U, Adejoh, T, Akwo, J.D, Owujekwe, C.E, Modu, A.A, Abba, M, Adesina, K.A, Omiyi, D.O, and Chiegwu, U.H (2018). Diagnostic reference levels for common computed tomography (CT) examinations: results from the first Nigerian nationwide dose survey. Journal of Radiological Protection,38(2): 525-535

European Commission (2000). European guidelines for quality criteria for computed tomography. Report EUR 16262 EN. Office for Official Publications of the European Commission, Luxembourg, 66-78.

Heidi, R.C., Timothy, R.P.L., Ting-Yim, L., and William, D.P. (2002). Dynamic, Contrast-Enhanced CT of Human Brain Tumors: Quantitative Assessment of Blood Volume, Blood Flow, and Microvascular Permeability: Report of Two Cases. American Journal of Neuro-Radiology, 23: 828-832.

ICRP. (2007). International Commission on Radiological Protection,

Recommendations of the International Commission on Radiological Protection. ICRP Publication 103.Annals of ICRP, 37: 1-332.

Kobayashi, M., Ootsuka, T., and Suzuki S (2013). Evaluation and examination of accuracy for the conversion factors of effective dose per dose-length product Nippon HoshasenGijutsunGakkaizasshi 69(1): 19-27

Mundi, A.A, Hammed, S, Dlama, J, Abdul-Jamiu, A, Peter, E, Itopa, R and Goriya K. (2015). Diagnostic Reference Level for Adult Brain Computed Tomography Scans: A Case Study of a Tertiary Health Care Centre in Nigeria, IOSR Journal of Dental and Medical Sciences, 14(1): 66-75

Ogbole, G.I., and Obed, R. (2014). Radiation Doses in Computed Tomography: Need for Optimization and Application of Dose Reference Levels in Nigeria West African Journal of Radiology, 21: 1-6.

Opadele, E.A., Akpochafor, O.M., Ezike, C.J., and Aweda, A.M., (2018). Diagnostic Reference Level in Computed Tomography: An Evaluation of CT-Protocol Dose Index in a Diagnostic Facility. African journal of medical physics, 1(1): 36-42

Origgi, D., Vigorito, S., Villa, G., Bellomi, M., and Tosi, G. (2006). Survey of Computed Tomography Techniques and Absorbed Dose in Italian Hospitals: A Comparison between Two Methods to Estimate the Dose-Length Product and the Effective Dose and to Verify Fulfillment of the Diagnostic Reference Levels. European Radiology, 16: 227-237.

Osei, E.K., and Darko, J.A. (2013). Survey of Organ Equivalent and Effective Doses from Diagnostic Radiology Procedures. ISRN Radiology, 2013, Article ID: 204346.

Shrimpton, P.C, and Wall, B.F (2009). "Effective dose and dose-length product in CT." Radiology 250(2): 604-605.

UNSCEAR (2008). United Nations Scientific Committee on the Effects of Atomic Radiation. Sources and effects of ionizing radiation. Reportvol 1. Dose Assessment methodologies.

Yamauchi-Kawara, C., Fujii, K., Aoyama, T., Yamauchi, M., and Koyama, S. (2010). Radiation Dose Evaluation in Multidetector-row CT Imaging for acute stroke with an anthropomorphic phantom. British Journal of Radiology, 83(996): 1029-1041,