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# Radiation dose on whole brain computed tomography in comprehensive stroke imaging using axial volumetric 320-detector CT.

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**Background** : *The 320- detector row CT scanner with a larger z-coverage (16 cm) competently enables whole brain imaging that is need for patients who are been requested for comprehensive stroke imaging with axial volume mode which exposes the patient to a relatively high dose of radiation.*

**Objective** : *The purpose of the study is to determine the radiation dose on whole brain computed tomography in comprehensive stroke imaging using Axial Volumetric 320-detector MDCT.*

**Designs** : *Observational retrospective study.*

**Setting** : *Advanced Diagnostic Imaging Center (AIMC), Ramathibodi Hospital, Bangkok.*

**Material and Method** : *The collected data include scan parameters and radiation doses for CT perfusion of the brain examination in comprehensive stroke imaging using the combo protocol in axial volume mode. The effective dose, E, is determined and compared with other studies. Twenty-one patients, 11males and 10 females, with their age range of 6 - 77 years and mean age of 45.4 years were studied.*

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**Results** : *Range of cumulative radiation dose for $CTDI_{vol}$, DLP and E were 142.9 - 313.4 mGy, 2286.6 - 5014.2 mGy.cm and 4.8 - 10.5 mSv respectively. The cumulative dose, average dose, and average dose per volume scan of $CTDI_{vol}$, DLP and E were 200.5, 40.8 and 10.7 mGy; 3206.8, 652.6 and 171.3 mGy.cm and 6.7, 1.4, and 0.4 mSv consecutively.*

**Conclusions** : *The high radiation dose in this study resulted from large z-coverage of axial volume mode, high tube current and large number of total volume scans. The data were compared with DRLs and other studies for the setup of the dose reduction protocols appropriate for various age and groups of the patients size in future study. Although the high radiation dose is one of the main concerns, this investigation resulted in the elimination of the brain coverage limitation. The lower settings on scan parameters can reduce the volume of the contrast media and the acquisition time.*

**Keywords** : *320-detector CT, combined CTA and CTP, radiation dose, comprehensive stroke imaging.*

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**เหตุผลของการทำวิจัย** : *เครื่องเอกซเรย์คอมพิวเตอร์ชนิด 320 แถวหัววัดที่เปิดได้กว้างครอบคลุมแนวหัวท้าย (Z- direction) ของร่างกาย สามารถถ่ายภาพสมองทั้งศีรษะได้ ผู้ป่วยโรคหลอดเลือดสมองที่เข้ารับบริการตรวจวินิจฉัยด้วยเทคนิค Axial volume mode ได้รับปริมาณรังสีค่อนข้างสูง จึงนำไปสู่วัตถุประสงค์ของการศึกษาในครั้งนี้*

**วัตถุประสงค์** : *เพื่อหาปริมาณรังสีที่ผู้ป่วยโรคหลอดเลือดสมองได้รับจากการตรวจโดยใช้เทคนิค Axial volume mode ด้วยเครื่องเอกซเรย์คอมพิวเตอร์ชนิด 320 แถวหัววัด*

**รูปแบบงานวิจัย** : *การวิจัยโดยการสังเกตแบบไปข้างหลัง (Observational retrospective study)*

**สถานที่ทำการศึกษา** : *ศูนย์รังสีวินิจฉัยก้าวหน้า (AIMC) โรงพยาบาลรามาธิบดี กรุงเทพมหานคร*

**ตัวอย่างและวิธีการศึกษา** : *ผู้ป่วย 21 ราย เป็นเพศชาย 11 ราย และเพศหญิง 10 ราย มีช่วงอายุระหว่าง 6 - 77 ปี และอายุเฉลี่ย 45.5 ปี เก็บข้อมูลด้านปัจจัยที่มีผลต่อเทคนิคการตรวจ และปริมาณรังสีที่ได้รับจากการตรวจ CT Perfusion ของสมอง ด้วยเทคนิค Combo protocol โดยใช้ Axial volume mode ปริมาณรังสียังผลได้จากการคำนวณและนำไปเปรียบเทียบกับปริมาณรังสีอ้างอิงมาตรฐาน*

**ผลการศึกษา** : *ปริมาณรังสีสะสมรวม ได้แก่ CT Dose Index ($CTDI_{vol}$), Dose Length Product (DLP) และปริมาณรังสียังผล มีค่าระหว่าง 142.9 - 313.4 มิลลิเกรย์, 2286.6 - 5014.2 มิลลิเกรย์.ซม. และ 4.8 - 10.5 มิลลิซีเวิร์ท ตามลำดับ ปริมาณรังสีสะสมรวม ปริมาณรังสีเฉลี่ย และปริมาณรังสีเฉลี่ยต่อจำนวนชุดการตรวจของ $CTDI_{vol}$, DLP และ Effective dose มีค่าเรียงตามลำดับดังนี้ 200.5, 40.8 และ 10.7 มิลลิเกรย์ สำหรับค่า $CTDI_{vol}$ ; 3206.8, 652.6 และ 171.3 มิลลิเกรย์.ซม. สำหรับ DLP และ 6.7, 1.4, และ 0.4 มิลลิซีเวิร์ทสำหรับ Effective dose*

**สรุป** : *ปริมาณรังสีสะสมรวมมีค่าสูง เนื่องจากการเปิดลำรังสีครอบคลุมส่วนที่ต้องการตรวจได้กว้างขึ้น (large z-coverage) อีกทั้งมีการใช้กระแสไส้หลอดที่สูง และจำนวนชุดของการตรวจที่มาก ข้อมูลที่ได้จากการศึกษาครั้งนี้ได้ถูกนำไปเปรียบเทียบกับระดับปริมาณรังสีอ้างอิงอื่น ๆ เพื่อจัดทำโปรโตคอลเพื่อปรับลดปริมาณรังสีให้เหมาะสมกับอายุและขนาดของผู้ป่วยในอนาคต แม้ว่าปริมาณรังสีที่ผู้ป่วยได้รับจะมีค่าสูง แต่ประโยชน์ที่ได้รับจากการตรวจด้วยเทคนิคนี้ สามารถแก้ไขข้อจำกัดเรื่องขอบเขตการตรวจ CT Perfusion ของสมอง สามารถลดปริมาณสารทึบรังสีให้กับผู้ป่วย ทั้งยังช่วยลดเวลาในการตรวจให้สั้นลง*

**คำสำคัญ** : *เครื่องเอกซเรย์คอมพิวเตอร์ชนิด 320 แถวหัววัด, CTA และ CTP ทำการตรวจในครั้งเดียวกัน, ปริมาณรังสี, ภาพถ่ายโรคหลอดเลือดสมอง.*

The characteristics of the 320-MDCT leading to the presumption of axial volumetric mode, provides dynamic volume scanning and enable larger area of coverage. As for the 320-row CT scanner, it has the ability of scanning the entire organs in a single rotation such as the brain. This can provide a combo protocol, the same dataset of CT angiography and CT perfusion in just one examination. The visualization of the dynamic vascular and perfusion of the entire brain after contrast medium administration intravenously in a very short scan time is available to efficiently increase the management of stroke's patient. The superior in clinical applications demonstrate the occlusion of arterial blood vessels and extension or location of infarcts at the vertex of the brain. Furthermore, the very rapid procedures help particularly unconscious patient.

At present, CT scans have become the major sources of radiation exposure to diagnostic X-rays as they represent the highest share of collective doses from radiation. This is the major concern for the increasing use of CT in which the justification of such a study should be considered. The optimization of image quality and patient dose is a dynamic process that aims to give sufficient diagnostic image quality with the minimum dose to the patient. This involves inputs from the radiologist, radiographer and medical physicist. [1] As the use of radiation has been rising along with the tendency to in appropriately use CT on patients, the cost-risk-benefit must be considered effectively. However, CT doses seem to be lower in updated reports, because of the concerns for radiation and the advances in CT technology. [2] Technologists and radiologists should produce and interpret the images of acceptable quality, and not of the highest quality from very high dose scans which would only increase the radiation dose.

Diagnostic reference levels (DRLs) are applicable for standard procedures in all areas of diagnostic radiology particularly a high reduction in risk examinations. They help to raise the awareness of radiation usage. DRLs are practical tools to manage radiation dose to patients; thus, they promoted the attainment of the optimum use of radiation exposure for a specific medical imaging protocol. [3]

At the Advanced Diagnostic Imaging Center (AIMC), Ramathibodi Hospital, the patients are requested for the diagnostic of lesion in the brain. In some cases the 320-row MDCT (Aquilion ONE, Toshiba Medical Systems Corporation, Japan) scanner has been used for axial volume mode feasibility to cover whole brain, i.e., to visualize both dynamic flow and perfusion by combining CT Angiography, CT Venography and CT Perfusion in a single procedure. The same data set achieves with only one administration of the contrast medium.

Nevertheless, the axial volume mode 320-detector CT also produces relatively high dose to the patient. The purpose of the study is to determine the radiation dose on the whole brain via computed tomography in comprehensive stroke imaging using Axial Volumetric 320-detector MDCT.

## Materials and Methods

Toshiba Aquilion ONE 320-detector CT scanner was used in this study. All patients underwent whole brain computed tomography in comprehensive stroke imaging using axial volume mode at the AIMC Center, Ramathibodi Hospital from 2010 to 2012 were recruited. Patients who underwent helical scan mode

of CT of the head region were excluded from this study.

The study was been carried out in the following sequence; the quality control of CT scanner was performed according to IAEA Human Health Series No.19 protocol to verify the dose values displayed on the CT monitor console.[4] The patient data for combined CT Angiography and CT Perfusion (or combo protocol) of the brain examination in comprehensive stroke imaging were collected, the scan parameters and radiation dose were also recorded. Dose length product, DLP (units: mGy cm), an indicator of the mean absorbed dose to the patient of each series in CT exam, defined as the product of $CTDI_{vol}$ and the scan length, is determined. The effective dose (E) is calculated approximately from the multiplication of DLP and the conversion coefficient, mSv/mGy•cm in the head region. [5] The mean radiation dose in terms of $CTDI_{vol}$, DLP and E were compared with data of national and international references.

## Results

Quality control of MDCT scanner had been performed before research data collection to assure the accuracy and stability of the system. The $C_{a,100}$ in air, integrated over 100 mm pencil ion chamber was measured using head and body protocols in all $kV_p$ setting and for each slice collimation. The calculated $CTDI_{vol}$ was performed in the cylindrical polymethylacrylate head and body phantoms (16 cm and 32 cm in diameter), the measured values and the monitor displayed were in tolerance range according to IEC standard specification.

There were 21 patients 11 male and 10 female, whose age range was , 6 - 77 years; mean age, 45.4 years. The patients' parameters collected from the Picture Archiving and Communication System (PACS) of Ramathibodi Hospital, from 2010 to 2012 are displayed in Table 1.

All recorded parameters were tube voltage 80 $kV_p$, beam width 320 × 0.5mm, coverage 16 cm and rotation time 0.75 second. The mean and range of $CTDI_{vol}$, DLP and effective dose in terms of cumulative dose, average dose and average dose per volume are shown in Table 2.

## Discussion

As the effective dose represents the patient risk from radiation, this results in very high values in case number 1 and 2 of 8.6 mSv even though the $CTDI_{vol}$ and DLP are low. As they are pediatric patient of 6 - 7 years old of higher radiation risk than adult, the conversion factor (0.004 mSv/mGy.cm) is greater than twice of adult (0.0021 mSv/mGy.cm). As the small number of pediatric patient data of 2 cases, the data were separated. Only adult patients, case number 3 to 21, were analyzed and compared with radiation dose reference values. In terms of cumulative radiation doses, the maximum effective dose was 10.5 mSv for 19 scans performed with 4,271 total mAs, case number 17, and the minimum effective dose was 4.80 mSv for 19 scans performed with 1,987 total mAs, the same $kV_p$, rotation time, nominal beam width and coverage area parameters (case number 11).

In terms of cumulative dose, average dose, and average dose per volume scan, the mean values of $CTDI_{vol}$, DLP and effective dose using axial volume mode were: 200.5, 40.8 and 10.7 mGy, respectively; and 3,206.8, 652.6 and 171.3 mGy.cm; 6.7, 1.4 and 0.4 mSv consecutively.

**Table 1.** The parameters and radiation dose of 21 patients who underwent. Comprehensive stroke imaging using axial volume mode.

| Case No/ Age (year)/ Gender (M/F) | Number of volume scan | Total mAs | Cumalative $CTDI_{vol}$ (mGy) | Cumalative DLP (mGy.cm) | Cumalative Effective Dose (mSv) |
|---|---|---|---|---|---|
| 1/6/F | 19 | n/a | 154.0 | 2157.0 | 8.6 |
| 2/7/F | 19 | 1875 | 134.8 | 2156.9 | 8.6 |
| 3/20/M | 19 | 1987 | 142.9 | 2286.6 | 4.8 |
| 4/21/F | 19 | 2025 | 200.0 | 3192.9 | 6.7 |
| 5/21/F | 19 | 2813 | 145.6 | 2329.7 | 4.9 |
| 6/22/F | 19 | 2025 | 145.6 | 2329.7 | 4.9 |
| 7/39/M | 24 | 3383 | 240.0 | 3829.9 | 8.0 |
| 8/42/F | 19 | 2821 | 202.7 | 3243.6 | 6.8 |
| 9/42/M | 19 | 2821 | 202.7 | 3243.6 | 6.8 |
| 10/44/M | 19 | 2821 | 202.7 | 3243.6 | 6.8 |
| 11/49/M | 19 | 1987 | 142.9 | 2286.6 | 4.8 |
| 12/49/F | 19 | 2821 | 202.7 | 3243.6 | 6.8 |
| 13/51/M | 19 | 2821 | 202.7 | 3243.6 | 6.8 |
| 14/51/M | 19 | 2821 | 202.7 | 3243.6 | 6.8 |
| 15/64/F | 10 | 2600 | 184.1 | 2943.6 | 6.2 |
| 16/66/M | 19 | 2821 | 202.7 | 3243.6 | 6.8 |
| 17/66/M | 19 | 4271 | 313.4 | 5014.2 | 10.5 |
| 18/70/F | 19 | 2821 | 202.7 | 3243.6 | 6.8 |
| 19/73/M | 19 | n/a | 185.4 | 2965.9 | 6.2 |
| 20/73/M | 19 | 2821 | 202.7 | 3243.6 | 6.8 |
| 21/77/F | 24 | 2814 | 285.4 | 4557.0 | 9.6 |

Note: (n/a) The data did not display on monitor in PACS.

**Table 2.** Mean and range of $CTDI_{vol}$, DLP and effective dose using axial volume mode.

| Radiation dose | $CTDI_{vol}$ (mGy) | | DLP (mGy.cm) | | Effective Dose (mSv) | |
|---|---|---|---|---|---|---|
| | Mean | Range | Mean | Range | Mean | Range |
| Cumulative dose | 200.5 | 142.9 - 313.4 | 3206.8 | 2286.6 - 5014.2 | 6.7 | 4.8 - 10.5 |
| Average dose | 40.8 | 28.6 - 62.7 | 652.6 | 457.3 - 1002.8 | 1.4 | 1.0 - 2.1 |
| Average dose per volume scan | 10.7 | 7.5 - 18.4 | 171.3 | 120.4 - 294.4 | 0.4 | 0.3 - 0.6 |

In this study, the radiation dose for comprehensive stroke imaging using axial volume mode combining CTA, CTV of the intracranial vessels and CTP in the same procedure (combo protocol) on the 320-detector row CT scanner with a 16-cm scanning length and covering the entire the brain was performed without gantry angulation, unenhanced CT of the brain and helical scan of neck CTA was excluded.

The comparison of radiation dose used this study (axial volume mode, combo protocol) and reference dose data in CT perfusion of the brain are shown in Table 3.

From Table 3, the mean $CTDI_{vol}$ in the combo protocol for whole-brain perfusion with the 320-detector row CT scanner in this study is 200.5 mGy, the lowest but the mean DLP and effective dose are the highest due to the larger z-coverage of the 320-detector row CT (16 cm in this protocol) compared with 64, 256 -detector row CT (3.2 cm - 12.8 cm). At the same 16 cm scan length, the DLP of 3,206.8 mGy.cm in this study was approximately threefold of Shankar *et al.* (1,000 mGy.cm). As the result, the increasing sampling interval and the lower mAs can reduce the radiation dose.

The mean effective dose of 6.7 mSv was twice greater than the same modality (Aquilion ONE) because in this study the total scan time was 60 seconds and tube current was varying. On the contrary, the scan time 29.8 seconds and mA 100 were used in Diekmann *et al*. whereas the tube voltage, 80 $kV_p$, beam width (collimation) 320 × 0.5mm and area of coverage 16 cm were the same. Similarly, the effective dose in 4D CTA-CTP combined protocol was 5.4 mSv, due to the constant 100 mA, the rotation time between 0.5 and 1 second were used in Siebert *et al,* contributing to the lower effective dose slightly lower than this study. Figures 1, 2 and 3 show the mean $CTDI_{vol}$, DLP and effective dose among this study (axial volume mode, combo protocol) and other references in CT perfusion of the brain.

**Table 3.** Mean values of $CTDI_{vol}$, DLP and Effective dose in this study (cumulative dose) and published data in CT perfusion of the brain.

| CT Perfusion study | Number of detector row/ coverage in z- direction | $CTDI_{vol}$ (mGy) | DLP (mGy.cm) | Effective Dose (mSv) |
|---|---|---|---|---|
| This study | Aquilion ONE /16 cm | 200.5 | 3206.8 | 6.7 |
| Diekmann S, et al.[6] | Aquilion ONE/16 cm | n/a | n/a | 3.6 |
| | Toshiba 64/3.2 cm | n/a | n/a | 5.8 |
| Siebert E, et al. [7] | Aquilion ONE/16 cm | n/a | 2355.4 | 5.4 |
| Shankar JJ, et al.[8] | Aquilion ONE/16 cm | n/a | 1000 | n/a |
| Murayama K, et al. [9] | Toshiba 256/12.8cm | n/a | n/a | 3.5 |
| Arandjic D, et al. [10] | GE VCT 64/4 cm | 590 | 2360 | 5.4 |
| | GE HD 750/4 cm | 680 | 2740 | 6.3 |
| | GE HD 750/8 cm | 230 | 2120 | 4.9 |
| Mnyusiwalla A, et al. [11] | GE VCT 64/4cm | n/a | n/a | 4.9 |
| Cohnen M, et al. [12] | Siemens 64/3.84 cm | n/a | n/a | 5.0 |

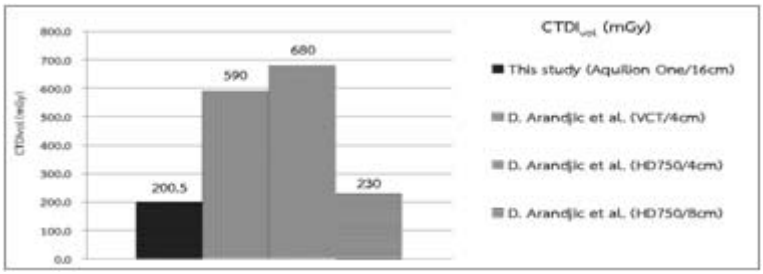


**Figure 1.** The mean value $CTDI_{vol}$ among this study (axial volume mode, combo protocol) and other references in CT perfusion of the brain.

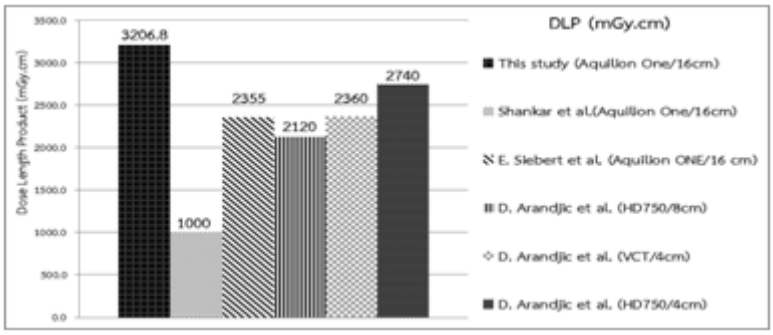


**Figure 2.** The mean dose-length product among this study (axial volume mode, combo protocol) and other references in CT perfusion of the brain.

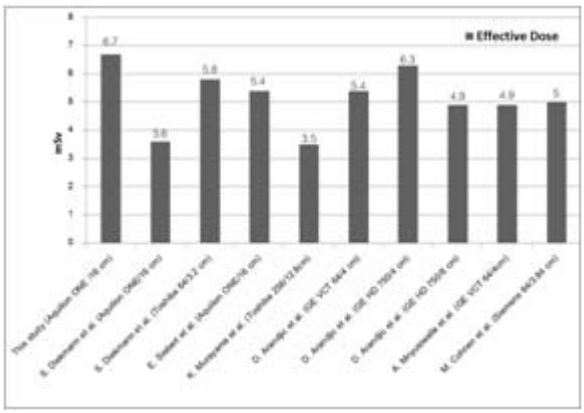


**Figure 3.** The mean effective dose among this study (axial volume mode, combo protocol) and other references in CT perfusion of the brain.

## Conclusion

The radiation dose on the whole brain via computed tomography in comprehensive stroke imaging using axial 320-row MDCT volumetric mode is higher than the DRLs in terms of mean DLP and effective dose due to the large z-coverage, high tube current and several number of the total volume scan. Although the higher radiation dose is one of the main

concerns, but the notably advantage of whole brain computed tomography in comprehensive stroke imaging using axial 320-row MDCT volumetric mode can eliminate the limitation of brain coverage. Even though the high cumulative $CTDI_{vol}$ in this study (142.9 - 313.4 mGy), but they are less than the FDA recommendation for maximum dose of 500 mGy. [13]

Furthermore, CTA, CTV and CTP information can be obtained from the same procedure, reduce volume of contrast media, decrease the acquisition time compared with standard routine (CTA, CTV and CTP) alone. Besides, the first volume of scan can be used as the non-contrast enhancement of the head CT, similarly to the last volume scan can be used as the contrast enhancement of the head CT. The image quality can be improved by increasing the tube current.

Dose reduction should be considered by means of reducing the scan coverage of less than 16 cm according to the clinical consideration, tube current (mA) per volume, especially in mask and CTA volume, total exposure time by increasing the time interval and the number of total volume scans.

Although the optimization of CT perfusion protocol is excluded from this study, these recommendations should be applied for high value in comprehensive stroke imaging in the future. Otherwise, the qualitative image quality by means of radiologist blinding score is recommended.

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