

# A Study on the Mitigation of the Exposure Dose Applying Bolus Tracking in Brain Perfusion CT Scan

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## 뇌 관류 CT검사에서 Bolus Tracking 기법을 적용한 피폭선량 저감화에 관한 연구

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**Abstract** This study was conducted to analyze the patient's exposed dose targeting the patients who had acute ischemic stroke symptoms and CT brain perfusion scan, by comparing fixed time technique and bolus tracking technique which was provided by the manufacturer and to identify the Time graph to implement the usability of contrast medium's tracking technique the best contrast enhancement intervals. CTDI<sub>VOL</sub> of PCT in patient appeared to be 431.72mGy in fixed scan delay protocol, whereas 323.61mGy in Bolus tracking technique. The value of DLP appeared to be 1243.47mGy-cm in fixed scan delay protocol, whereas 932mGy-cm in Bolus tracking technique. Time graph appeared to be various in fixed scan delay protocol, whereas the optimal time graph could be obtained in Bolus tracking. The exposure dose could be reduced by 25% applying Bolus tracking technique when taking brain perfusion CT scan.

**Key Words** : Perfusion CT, Bolus tracking, Fixed time technique, Dose, Time graph

요 약 급성기 허혈성 뇌졸중 증상이 있는 뇌 관류 CT 검사를 시행한 환자를 대상으로 장비사가 제시한 고정 시간 기법(Fixed time technique)과 조영제 추적 기법(Bolus tracking technique)을 비교하여 환자의 피폭선량을 분석하고자 하였으며, 조영제 추적 기법의 유용성과 최적의 조영증강 구간을 구현하는 Time graph를 알아보기 위한 것이다. 환자에서는 PCT의 CTDI<sub>VOL</sub>은 고정시간기법에서 431.72mGy, Bolus tracking에서 323.61mGy로 측정되었고, DLP값은 고정시간기법에서 1243.47mGy-cm, Bolus tracking에서 932mGy-cm로 측정되었다. Time graph는 고정시간기법에서 다양하게 나타났으나, Bolus tracking 기법에서는 최적의 Time graph를 얻을 수 있었으며, 뇌 관류 CT검사 시 Bolus tracking 기법을 적용하여 피폭선량을 25% 정도 감소시킬 수 있었다.

주제어 : 뇌 관류 CT, 조영제 추적기법, 고정시간기법, 피폭선량, 시간그래프

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## 1. Introduction

Despite the development of medical technology and the changes in health care awareness, cerebrovascular disease, along with cardiovascular disease, is one of the biggest causes of death[1]. Especially, because acute stroke causes death and long term disability, prompt diagnosis and treatment is important[2]. CT examination is widely used for its ability to detect stroke early on. The usefulness of CT examination is higher than the dangers of radiation. The justification for diagnostic imaging tests lie in that they provide more benefits than harm which has been established firmly, and there is no limitation to the dose of radiation the patient is exposed to[3]. Thin slice thickness is used for increased information along with CT equipments development, and patients who need repeated examinations are also increased as well as the selection of multi-phase in many examination categories. Therefore, medical radiation exposure risks could only be higher[4][5]. Especially, based on the recommendation in the ICRP 1990 and 2007, brain exposure could cause serious harm. Therefore, the weight in the tissues for patient exposure was increased, and salivary glands were classified as a tissue. The increase of weight in the tissues of the cerebral region means that in diagnostics of this region, the dangers have increased[6][7]. Also, the U.S. Food and Drug Administration reported a need for immediate measures for excessive exposure to radiation during CT scans for diagnosis and treatment of stroke. Accordingly, assessment of patients' dose and plans for the protocol inspection and dose reduction are urgently required. Regarding dosimetry in the field of CT, used indicators are average absorbed dose( $CTDI_{vol}$ ), which is a volumetric CT dose index, integrated absorbed dose(DLP) along the paralleled line on the rotating axis, and the comparison method between other diagnostic procedures and the patient dose(Effective dose).

This study was conducted to compare and evaluate

the dose and contrast enhancement intervals, and their reduction and optimization were tried to be identified when fixed time scan delay(FTSD), a parameter provided by manufacturer and contrast agent tracking method(bolus tracking; BT), is applied at the time of perfusion CT scans of acute ischemic stroke patient.

## 2. Materials and Methods

### 2.1 Materials

The study subjects were 60 call patients(Men:32 Women:28 Average age:58.5) in Seoul K hospital from 2010 November to 2011 May. The patients, had diagnosis of brain perfusion CT scan prescriptions among five symptoms of suspected brain infarctions suggested by the American Stroke Association. Targeting 30 patients(Men:18 Women:12 Average age:57.3) with fixed-time technique and 30 patients(Men:14 Women:16 Average age:58.5) with contrast agent tracking techniques as provided by the manufacturer, the test was conducted with comparison and analysis(Table 1).

<Table 1> Cerebral infarction suspicious symptoms proposed by the American Stroke Association.

- |  |
|--|
| 1. Numbness or Weakness : sudden numbness or weakness of the face, arm or leg, especially on one side of the body. |
| 2. Confusion : sudden trouble speaking or understanding.   |
| 3. Eyesight : sudden trouble seeing in one or both eyes.   |
| 4. Dizziness : sudden trouble walking, loss of balance or coordination.  |
| 5. Headache : sudden severe headache with no known cause.  |

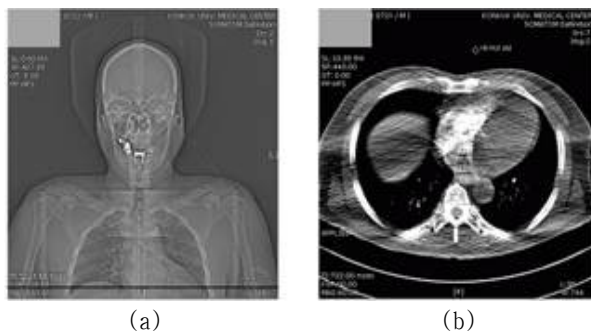
### 2.2 Equipment

- (1) 64 Slice dual source scanner(SOMATOM Definition, SIEMENS, Erlangen, Germany)
- (2) SyngoMMWP VE30A Multiworkplays (SIEMENS, Germany)
- (3) Dual flow injector(Stellant, MEDRAD Inc, USA)
- (4) Contrast media(Ultravist 370, Bayer AG, Germany)

(5) Advantage workstation(version 4.3, GE Healthcare, USA)

### 2.3 Method of measuring the exposure dose

Through the test, three indicators of non-contrast enhancement CT(NCECT), which plays a critical role in treatment, perfusion computed tomography(PCT) for prediction of the penumbra areas, and infarction size and dose report where the computed tomography angiography(CTA) was conducted for occlusion vessels 5minutes later[8]. The test was designed in a manner that 40 seconds of scan delay time was set to fixed time scan delay(FTSD) at the same time of contrast agent injection, bolus line was set at the mid-heart level for contrast agent tracking method(bolus tracking; BT), and the scan was set to start as contrast agents are full in the right atrium after 4 seconds of contrast agent injection. Effective dose was calculated using a conversion factor, and the graph was evaluated by expressing the artery and interested areas of veins as Hounsfield Unit(HU) values resulting from the blood flow changes(Figure 1).



[Fig. 1] CT image for bolus tracking.  
(a) Pre-monitoring (b) Monitoring image

### 2.4 The evaluation of effective dose and time graph

The effective dose evaluation was calculated using the conversion factor that represents effective dose

ratio per DLP per body part. In the time graph, the X axis is the time, and the Y axis represents HU value. The 1<sup>st</sup> graph is the Artery's Region Of Interest(ROI), 2<sup>nd</sup> graph is the Vein's Region Of Interest(ROI), represented in HU value according to the blood flow changes.

### 2.5 Statistical methods

Data analysis was done using statistical package program SPSS(statistical package of the social science)18.0 version for window. The measured value was represented as average  $\pm$  standard deviation. In the patient radiation exposure measurement, the evaluation of CTDI<sub>vol</sub> and DLP values were done though two sample T-tests. Statistical significance was set within the range of ( $p < 0.05$ ).

## 3. Results

### 3.1 Measurement of exposure dose of patients

During CT brain perfusion scan of the patient radiation exposure measurement, the CTDI<sub>vol</sub> and DLP were as below. CTDI<sub>vol</sub> in fixed time scan delay(FTSD) was measured as 431.7mGy, DLP was measured as 1243.4mGy and Total DLP was measured as 3203.5mGy·cm. CTDI<sub>vol</sub> of contrast agent tracking method(bolustracking;BT) was measured as 323.6mGy, DLP was measured as 932.0mGy and the Total DLP was measured as 2718.8mGy·cm, which showed approximately 25% dose decrease. In application of dye tracking technique, the exposure dose showed decrease of 25.1%, showing statistical significance ( $p < 0.05$ ). Also in Total DLP it showed decrease from 3203.5mGy·cm to 2718.8mGy·cm ( $p < 0.05$ )(Table 2).

<Table 2> Results of CTDIvol and DLP value measured from patient dose(unit: mGy, mGy·cm)

Variable	Bolus Tracking	Fixed Time Scan Delay	p value
	Mean±SD	Mean±SD	
NCECT (CTDI <sub>vol</sub> )	56.18±0.01	56.16±0.01	0.342
NCECT (DLP)	960.73±0.45	965.70±29.39	0.359
PCT (CTDI <sub>vol</sub> )	323.61±0.00	431.72±0.26	0.001
PCT (DLP)	932.00±0.00	1243.47±0.51	0.001
CTA (CTDI <sub>vol</sub> )	41.10±0.07	41.11±0.07	0.567
CTA (DLP)	938.80±26.70	952.37±48.82	0.648
Total DLP	2718.87±92.67	3203.53±63.56	0.001

### 3.2 The evaluation of effective dose for patients

The effective dose for patients is a category evaluating the specific tissues' and organs' actual dose including the perspective of probable risk, considering the weight ( $W_T$ ) representing specific radio-sensitivity. The measured effective dose is as below. Effective dose showed PCT 2.61mSv and Total 9.93mSv in Fixed-time technique, and contrast agent tracking method(bolustracking;BT) showed PCT 1.96mSv and Total 8.42mSv, which showed approximately 15% decrease(Table 3).

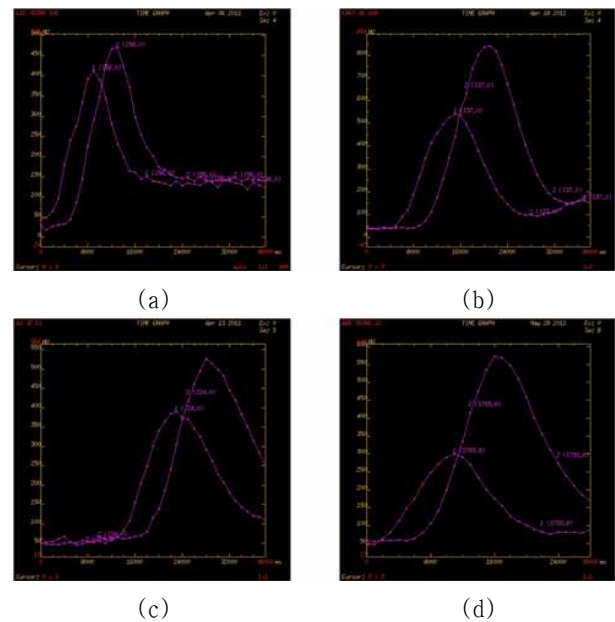
<Table 3> The effective dose of patient (unit: mSv)

Variable	Bolus tracking	Fixed time scan delay
NCECT Eff.	2.01	2.02
PCT Eff.	1.96	2.61
CTA Eff.	2.91	2.95
Total Eff.	8.42	9.93

### 3.3 Time graph evaluation

In the time graph evaluation, even though the scans were 40seconds in length in the set time method, the speed of blood flow in every patient was different,

resulting in a varied graph. However, with the dye tracking technique, it receives 4 seconds of delay and 2 times of 1second monitoring, moves on to table and starts expanding through the arteries at 12 seconds on the scanned graph, showing its peak at 21 seconds, and almost empties at 33 seconds. In the vein graph, it starts expanding through the veins at 16 seconds on the scanned graph, showing its peak at 26 seconds, and almost empties at 40 seconds. The transit time of Artery ROI is 21 seconds, where as in the Vein ROI, it is 23 seconds. Time graph showed various results in fixed time scan delay(FTSD) due to the different blood flow speeds, and in contrast agent tracking method(bolus tracking; BT), optimal contrast enhancement interval was implemented without the front and the back delaying time by tracking the blood flow(Figure 2).



[Fig. 2] Time graph based on change in blood flow.

(a)(b)(c) fixed time technique (d) bolus tracking

## 4. Conclusions and discussion

The purpose of treatment of acute stroke is to

reopen the blocked blood vessels in order to revive the reversible penumbra to minimize neurological deficit[9]. In this regard, cerebral perfusion imaging is important in prognosis and treatment decisions. Cerebral CT examination is an examination where the time a dye flow time is successively imaged to show the increase in dye in the ROI according to time[10]. In cerebral CT examination, the characteristics and role of blood are very important. Based on these characteristics, a perfusion map can be obtained and this map shows close relations between the ischemic tissues[11]. Cerebral CT examination is done to quickly and accurately evaluates the ischemic penumbra region. In diagnosing acute stroke, the sensitivity is 92% and specificity is 100%, which is very high[12]. Also, when conducting CTA using dual energy, using the subtraction method it helps greatly in evaluating blood vessels[13].

When using fixed time method in this study, through various factors the speed of blood flow was shown as different. However, using dye tracking techniques, an optimal dye increase graph could be obtained through tracing the speed of blood flow. Also, through decrease in scanning time, the exposure dose was lowered. Contrast agent tracking method(bolus tracking; BT) could be identified to reduce the exposed dose to 1/4 level at brain perfusion CT scans and to lower the effective dose below ICRP recommended dose; in this way, its great usefulness was proven. Also the effective dose was shown as below the ICRP recommended dose, and optimal dye increase region could be implemented. In conclusion, doctors in the department of radiology using X-rays and radiologists should examine the protocols and evaluate the dose measurements in order to continuously decrease the radiation dose to within the range that does not affect diagnosis.

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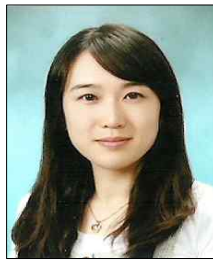
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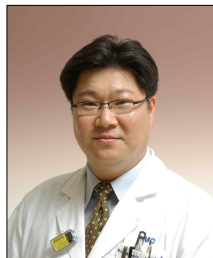
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