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Patient Exposure Dose in a Videofluoroscopic Swallowing Study

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Abstract

Objective: Videofluoroscopic Swallowing Studies (VFSS) are considered the standard imaging technique to investigate swallowing physiology and dysphagia. VFSS involves the use of X-rays, and there is increasing concern about patient radiation doses in VFSS diagnostic. A few studies have evaluated the dose of radiation a patient receives during VFSS; however, in these studies, the patient exposure dose was determined using a calculation from dose area product.

Therefore, we investigated patients' actual Entrance Skin Dose (ESD) during VFSS using a fiber-optic sensor attached to the patient's skin for direct reading of the patient's ESD. Moreover, we examined the Effective Dose (ED) from ESD. In this study, we clarify the ESD during VFSS in clinic.

Material and Methods: All examinations were performed using a consecutive fluoroscopy and Image Intensifier (I.I.). The control system for this equipment sets the X-ray exposure kV and mA automatically (67 kV to 97 kV and 0.9 mA to 2.5 mA). I.I. size was 10 inches. The source to I.I. distance was 148 cm, and the distance between the source and the patient entrance surface was approximately 90 cm to 100 cm. We used the dosimeter adheres directly to a patient's skin and displays the patient's ESD and dose rate in real time during radiological examination. We investigated 20 patients from October 2016 to April 2017. The technique used in our VFSS procedure differs from that used in the usual VFSS procedure.

Results: The male: female ratio was 11:9. The average VFSS procedure time was 4.3 ± 1.4 min, and the average ESD was 18.6 ± 8.7 mGyper VFSS procedure. In addition, the average ED was 0.9 ± 0.4 mSv. The correlation coefficient between fluoroscopy time and ESD was R2=0.39 (p<0.01).

Conclusion: Our findings showed that the potential risk from radiation exposure in VFSS is lower compared with other common radiological investigative methods. ESD in patients undergoing VFSS and this technique helps evaluate ED in a more efficient way. We showed that the dose received by patients in significantly low; therefore, we propose that VFSS can be used as a low-risk diagnostic method.

Keywords: Videofluoroscopy; Patient's entrance skin dose; Deglutition disorders; Effective dose

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Introduction

Videofluoroscopic Swallowing Studies (VFSS) are considered the gold standard diagnostic imaging technique to investigate swallowing physiology, dysphagia, and the swallowing process [1,2]. VFSS involves the use of X-rays, and there is increasing concern about radiation doses in VFSS diagnostic and interventional procedures [3,4]. The Food and Drug Administration and the International Commission on Radiological Protection recommend that the dose of radiation that each patient receives should be measured and recorded [5-10].

VFSS can be useful to characterize swallowing abnormalities affecting patients with dysphagia; however, some patients may undergo multiple VFSS procedures, further increasing the risk of radiation-related side effects. Previous reports in interventional radiology have measured patients' radiation exposure dose using Dose-Area-Product (DAP) [11,12], which is a calculation. To the best of our knowledge, a few studies concerning the dose of radiation a patient receives during VFSS have used DAP [13,14]. DAP is a calculation of a patient's exposure dose. In contrast, in this study, we used a scintillation fiber-optic sensor dosimeter can be attached directly to the patient's skin for direct reading of the Entrance Skin Dose (ESD).

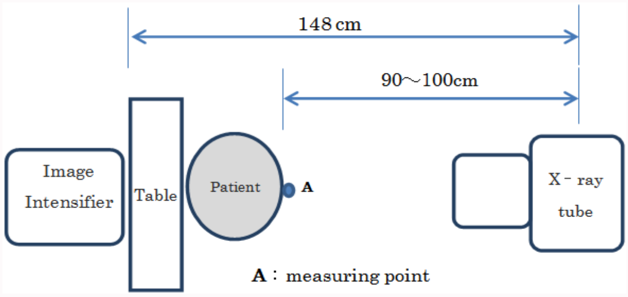

Figure 1: Experimental setup for the radiation measurement points used in this study. We measured the patient's entrance skin dose using a scintillation fiber optic dosimeter sensor (A).

In this study, we clarify the ESD during VFSS in-clinic.

Materials and Methods

Facilities

All examinations were performed using a ZEXIRA digital fluororadiography system (Canon Medical Systems, Tokyo, Japan). The control system for this equipment sets the X-ray exposure kV and mA automatically (67 kV to 97 kV and 0.9 mA to 2.5 mA). Consecutive fluoroscopy was used and the permanent filtration was 1.2 mmAl. The filter is attached to the fluororadiography system in the clinical setting. Image intensifier size was 10 inches. The entrance exposure area was the same as the actual diameter setting of the image intensifier. The X-ray exposure factors for all systems were as follows: The source to image intensifier distance was 148 cm, and the distance between the source and the patient entrance surface was approximately 90 cm to 100 cm (Figure 1). Collimation was routinely performed to exclude patients' eyes from the primary beam. However, the irradiated area included the cervical spine, thyroid, submandibular gland, parotid gland, and mandible (Figure 2). X-ray technicians were routinely present, in addition to the consulting physician.

Methods of VFSS procedure

The technique used in our VFSS procedure differs from that used in the usual VFSS procedure. Patients eat and drink in the following order: A jelly, agar, thickened water, water, and cookies containing barium. However, depending on the patient's swallowing ability, eating was stopped on the instructions of the attending physician. Patients were assessed in a seated posture, on a chair or wheelchair. When using a variable-angle wheelchair ("VFSS chair"), VFSS was performed at an angle the patient would normally be in when eating; screened in the lateral and frontal positions.

Participants

VFSS procedures were performed in 20 adult patients at Tohoku Medical and Pharmaceutical University Hospital (Sendai, Japan) between October 2016 and April 2017.

Dosimeter

We used the MIDSOF sensor (measuring range: 10 μGy to 1000 Gy: Figure 3) to each patient's neck. The MIDSOF dosimeter adheres directly to a patient's skin and displays the patient's ESD and dose rate in real time during radiological examination. The position of the dosimeter was also changed when the patient was moved from lateral to front. Direct readings are possible without energy correction. Thus, MIDSOF measurements included backscatter from patient low-energy dependence [15,16].

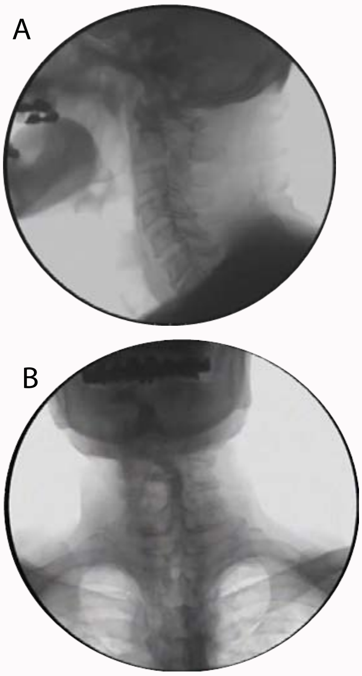

Figure 2: Fluoroscopic image in the videofluoroscopic swallowing studies (VFSS). A): Lateral position, B): Front position.
Collimation was performed to exclude patients' eyes from the primary beam. However, the exposure beam included the cervical spine, thyroid, submandibular gland, parotid gland, and mandible.

Figure 3: The scintillation fiberoptic dosimeter sensor (MIDSOF; AcroBio Co., Tokyo, Japan).

Calculation software

From these results, we also investigated the Effective Dose (ED) using the PCXMC. It calculates ED to patients undergoing any type of medical radiographic X-ray examination. The ED is defined for an adult person and has been used as an indicator of risk for late effects of radiation. We use an average patient model with PCXMC. It is using patient anatomical data, in the form of mathematical hermaphrodite phantom models, with Monte Carlo techniques.

Results

The data for the included 20 patients are shown in Table 1. Five of the 20 patients were evaluated in the lateral plane, only. Figure 4 shows the relationship between the fluoroscopy time and the ESD. The correlation coefficient between fluoroscopy time and ESD was $R^2=0.39$ ($p<0.01$). Table 2 shows patients' individual data, namely age, sex, body weight, exposure time (lateral, front), exposure dose

Table 1: Patients' measurement data (n=20).

Male/Female ratio	11:09
Average body weight (kg)	51.1 ± 15.9
Average age (y)	80.6 ± 10.8
Average fluoroscopy time (min) lateral	4.3 ± 1.4
Average Entrance skin Dose (mGy) lateral	18.6 ± 8.7
Average Effective dose (mSv)	0.9 ± 0.4

(lateral, front), ED. No additional time was needed to perform the clinical measurements compared with normal exams from patient entry to exit.

Discussion

In this study, we measured the ESD received by patients undergoing VFSS. Previous studies evaluated fluoroscopy time and ED in videofluoroscopy. For example, Zammit Maempel et al. [13] reported a mean screening time of 181s and mean ED of 0.2 mSv; Kim et al. [14], reported a mean screening time of 4.82 min and mean ED of 1.23 mSv; Wright et al. [17], reported a mean screening time of 286s and mean ED of 0.4 mSv; while Chau et al. [18], showed a mean screening time of 4.23 min and mean ED of 0.31 mSv. The mean screening time in our study of 4.3 min and mean ED of 0.9 mSv. Compared to the previous study, both fluoroscopy time and ED ware within the range of the previous studies. Our study uses consecutive fluoroscopy, but using pulsed fluoroscopy and additional filter may reduce the exposure dose [19].

To our knowledge, ours is the first study to report the actual ESD dose received by a patient during VFSS and not a calculation. Figure 4 shows the relationship between fluoroscopy time and ESD with correlation coefficient of R^2=0.39 (p<0.01), which was not a strong correlation as in previous study [20]. Because fluoroscopy uses an automatic brightness control system, if the cervical spine is included in the region of interest, the exposure dose may increase even with short-duration fluoroscopy.

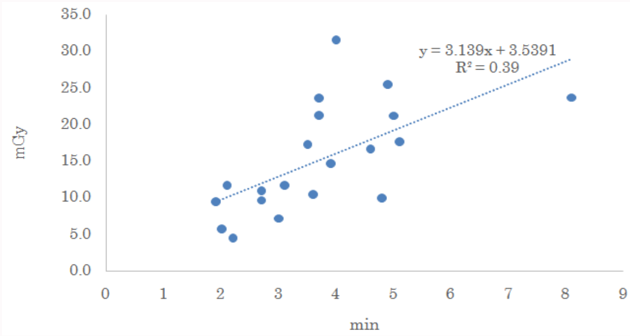

Figure 4: Relationship between fluoroscopy time (min) and entrance skin dose (mGy) in the lateral position.

The average ESD in our study was 18.6 ± 8.7 mGyper VFSS procedure, which was somewhat higher than the skin dose value (12.79 mGy) estimated in our phantom study [21]. The reason for this is that the distance to the X-ray tube and phantom surface was 110 cm, whereas in the current clinical study, the distance between the X-ray tube and the patient's skin surface was approximately 90 cm to 100 cm. Furthermore, while the tube voltage and tube current were 70 kV to 71 kV and 1.0 mA to 1.1 mA, respectively, in the phantom study,

Table 2: Individual data for the 20 included patients.

Sl. No	Age	M/F	Body Weight (kg)	Exposure time (min)	Exposure time (min)	Entrance skin dose (mGy)	Entrance skin dose (mGy)	Effective dose (mSv)
				Lateral	Front	Lateral	Front	
1	89	M	52	3	0.8	7.2	1.4	0.4
2	97	M	41.7	8.1	-	23.7	-	1.13
3	71	M	47.7	5	-	21.2	-	1.01
4	59	F	40	2	0.8	5.8	1.2	0.33
5	79	M	44.9	3.5	0.6	17.3	2.9	0.97
6	94	F	43.9	4.8	0.4	10	1.8	0.56
7	72	M	71	2.1	0.3	11.7	2.9	0.7
8	75	F	36.8	5.1	1	17.7	7.4	1.2
9	77	M	62	2.7	0.3	11	3	0.67
10	91	F	49.5	1.9	-	9.5	-	0.45
11	83	F	33.3	2.7	-	9.7	-	0.46
12	86	M	33.7	3.6	1.2	10.5	8.5	0.91
13	91	M	51.1	4.6	0.5	16.7	5.2	1.05
14	78	F	40.3	3.9	0.4	14.7	3.3	0.86
15	54	M	84.8	4	0.7	31.6	8.9	1.94
16	83	F	52.5	4.9	0.7	25.5	6.1	1.51
17	80	M	60	3.7	0.5	21.3	6.3	1.32
18	81	F	63	3.7	-	23.6	-	1.13
19	85	F	66	3.1	1.4	11.7	4.7	0.78
20	86	M	47	2.2	1	4.5	4	0.4

M: Male; F: Female

the tube voltage and tube current in the current study were 67 kV to 97 kV and 0.9 mA to 2.5 mA, respectively, and it is conceivable that the radiation dose was higher in the actual clinic than in the phantom study. However, this dose is significantly lower compared with doses received during many other common radiological procedures such as endoscopic retrograde cholangiopancreatography [22] and barium swallows [17]. However, because some patients undergo VFSS multiple times, and the age range is wide, each patient's dose should be monitored carefully [18,23].

Screening time in this study depended on the patient's condition [3]. Table 2 summaries the comparisons between Patients 2 and 3. Patient 2 had an additional 3 minutes of exposure time compared to patient 3, with X-ray tube voltages of 73 kV for Patient 2 and 80 kV for patient 3. Patient 3 may have had a higher exposure when the cervical spine constituted the majority of the region of interest in the lateral position *vs.* patient 2, resulting in increased fluoroscopic conditions. Similar findings were found when comparing patients 1 and 13.

Our results showed that VFSS can be performed using minimal radiation doses. Our findings also showed that the potential risk from radiation exposure in VFSS is lower compared with other common radiological investigative methods. However, in accordance with the principle of ALARA, every effort should be made to reduce radiation exposure.

To our knowledge, this is the first study reporting ESD in patients undergoing VFSS, and our technique helps evaluate the more efficiently. We showed that the dose received by patients was significantly lower; therefore, we propose that VFSS can be used as a low-risk diagnostic method.

In conclusion, instead of estimating a patient's dose in VFSS, we used a dosimeter directly attached to the patient's skin to measure the ESD. From these results, we estimated the ED, in this study. Using our method, it was possible to measure the exposure dose more accurately than in previous studies.

The main limitations of our study are that we analyzed data from a single hospital, and the small sample size of 20 patients may not reflect exposure in all patients. Further studies with a larger population are needed to evaluate the influence of the radiation exposure risk. The measured ESD in this study were very low, and it may be that small differences in exposure dose could have large effects on statistical results.

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