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*Research paper*

# Study On Reduction of Exposure Dose through Development of Field Display Devices of Radiation Fluoroscopy

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## Abstract

**Background**: This study was to develop a field-of-view display system for radiographic imaging equipment for the purpose of reducing the exposure dose when using the C-arm fluoroscopy device.
**Methods**: To evaluate its effectiveness, the time was measured and the doses injected into the instrument during the time of exposure to radiation were compared.
**Findings**: As a result, when the developed field device was installed, the radiation exposure time for finding the target organ was 23.90±3.30 sec before installation, 8.22±1.90 sec after installation, and 66% of radiation exposure time was decreased. It was found that the dose was reduced by 62% from 16.57±1.28 mGy to 6.27±1.36 mGy after installation.
**Improvement**: It was confirmed that the irradiation field display device of the fluoroscopic device developed through this study can reduce the radiation exposure time by visually displaying the radiation exposure area, thereby effectively reducing the exposure dose.

**Keywords**: *C-arm X-Ray, radiation field indicator, exposure dose, fluoroscopy, dosimetry.*

## 1. Introduction

The C-arm fluoroscopic device among the devices for diagnosing disease using radiation has been increasingly used due to the advantages of in real-time identifying the anatomical structure of the patient as well as shortening the operation time by improving the diagnostic accuracy [1]. As the use of C-arm increases, the exposure by the fluoroscopy of the practitioners has increased in proportion to the exposure of patients, resulting in the high radiation dose to the body directly exposed to the radiation as well as the organ close to the X-ray tube [2-6].

To reduce the radiation exposure, the International Commission on Radiological Protection (ICRP) has proposed shortened exposure time, increased distance to the source, and the use of a shield material [7]. However, because the patient is placed between the X-ray tube and the detector of the C-arm device, controlling the distance is an insignificant measure, and the practitioner who performs medical treatment beside the patient would have limited benefit from the distance-based approach. Furthermore, despite its shielding effect on a part of the body, the use of assistive devices for shielding has the disadvantage that causes an inconvenience and degraded efficiency. As a result, the most contributing factor for reducing the exposure dose would be the exposure time in the C-arm fluoroscopy [8].

The collimator enables to visually confirm the target area through the light field and to perform the scanning in using the diagnostic radiation generators. Thus, the exposure dose can be reduced by shortening the unnecessary radiation exposure time for identifying the target area, as in the fluoroscopy, and further lowering the chances of rescanning [9]. However, because the C-arm device as one of the fluoroscopic devices is used without the light field and the radiation is invisible with bare human eyes, the radiation is applied to identify the exact position of the fluoroscopic images during the medical treatment, and the target area should be confirmed by moving the positions of the X-ray tube or changing the positions of a patient. It is necessary to identify the scanning position due to the change of the attitude of the photographer. Thus, unnecessary scanning during C-arm fluoroscopy for identifying the exact location of a target organ would raise the radiation exposure time, resulting in the increase in the exposure dose [10-12]. Furthermore, because the radiographic site cannot be visually examined, the radiation safety awareness has become reduced, resulting in an increase in the exposure dose of patients and practitioners in the C-arm operating room [13,14].

The present study fabricated an X-ray display device for C-arm that enables a practitioner to identify the region having the high exposure does in the radiographic site of the patient by utilizing the function of the light field in the X-ray irradiated area in using the C-arm fluoroscopic device. Thus, this study is aimed to evaluate the method that can reduce the radiation exposure of the patients and practitioners due to the fluoroscopy in a completely new manner.

## 2. Materials and Methods

The collimator used in the diagnostic radiation generator is composed of a metal blade adjusting the X-ray irradiation field and a light field device inside the system. According to the Ministry of Food and Drug Safety, the referential average illuminance of the variable light field collimator as performance standard of light field is 100 Lux or higher at a distance of 1 m between the radiation source and the image [10].

Although the blade adjusting the X-ray irradiation field is installed inside the X-ray head of the C-arm fluoroscopic device, the C-arm fluoroscopic device includes no light field device. Thus, this study fabricated a new concept of a light field device outside the X-ray head to display the X-ray irradiation area in using the X-ray generator for C-arm as shown figure 1 and further used a LED chip(2000 Lm) as a light source [Figure 1].

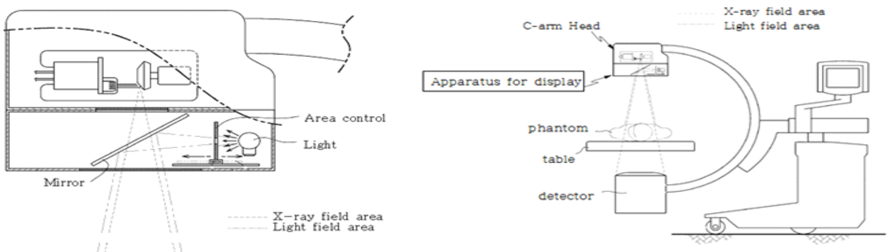


**Figure 1:**.Schematic diagram of C-arm X-ray field display

As shown in figure 2 describing the experimental methods, the humanoid phantom(model name: Ph-3/Ph-1; S/N: 13C-06; manufacturer: Kyoto Kagaku; country of manufacture: Japan) was placed on the surgery table in the supine position by combining the Ph-3 head phantom and the Ph-1 chest phantom, while setting the C-arm device on the over-tube mode. The fluoroscopic conditions of the C-arm X-ray unit(model name: PROSTA; S/N: H040717D051; manufacture: DK medical system; country of manufacture: South Korea) were measured through a radiation dose meter(model name: Unfors Xi R/F; S/N: 166981; manufacturer: Fluke; country of manufacture: Sweden) under the automatic brightness control of 40 to 110kVp and 0.5 to 4.9mA, and the calibration error was 0.6% (calibration date: February 2018) [Figure 2].

**Figure 2:**.Photograph of C-arm X-ray field display

Ten radiologists with experience of using C-arm equipment for 5 or more years were allowed to use the C-arm fluoroscopic device for selecting three random sites of the target organ(RtShouder, Thoracic spine, Lt Shoulder) on the phantom, matching the radiographic center on the centers of the target organ, and further performing the scanning. In this manner, three measurements were obtained before and after the use of the developed X-ray display device, respectively to compare the average time. To measure the exposure dose proportional to the radiation exposure time without affecting the movement of the C-arm, a radiation dose meter was installed at an arbitrary specified point of the C-arm detector for simultaneously measuring the exposure dose as shown in figure 3. [Figure 3].

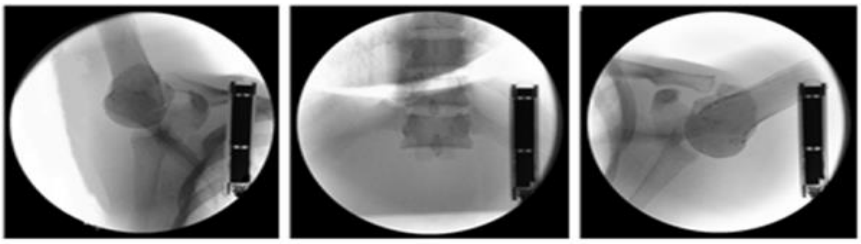

**Figure 3:**.Phantom exposure area

## 3. Results and Discussion

The radiation exposure time was measured according to the presence or absence of the X-ray display device developed under the same the fluoroscopic conditions. To obtain the measurements on the three sites of the target organ, the C-arm was aligned to the edge of the table where the phantom was placed, and the fluoroscopy was performed at the center of each organ in the order of Rt Shoulder, Thoracic Spine $12^{th}$, and Lt Shoulder. The exposure time of all 10 subjects was reduced by 37 to 78% when the developed X-ray display device for C-arm, as shown in Table 1. The average exposure time was 23.90±3.30 sec before installing the developed X-ray display device, and 8.22±1.90 sec after installing the developed X-ray display device, showing the reduction in the radiation exposure time by approximately 60% [Table 1].

**Table 1:**.Objective long-term tracking coincidence time

| No | Pre C-arm Collimator (Sec) | Post C-arm Collimator (Sec) |
|---|---|---|
| 1 | 24.67 ± 1.53 | 7.87 ± 1.90 |
| 2 | 23.67 ± 1.53 | 6.63 ± 0.21 |
| 3 | 26.00 ± 1.00 | 5.47 ± 0.21 |
| 4 | 30.67 ± 2.08 | 7.27 ± 0.15 |
| 5 | 24.67 ± 1.53 | 9.43 ± 1.27 |
| 6 | 21.33 ± 0.58 | 7.73 ± 0.21 |
| 7 | 24.33 ± 1.53 | 8.83 ± 0.32 |
| 8 | 22.67 ± 0.58 | 6.77 ± 0.31 |
| 9 | 18.33 ± 1.53 | 11.47 ± 1.12 |
| 10 | 22.67 ± 1.53 | 10.77 ± 0.76 |
| Total | 23.90 ± 3.30 | 8.22 ± 1.90 |

To minimize the external influence on the incident radiation dose during the fluoroscopy, a radiation dose meter was installed at an arbitrary specified point of the C-arm detector, and the radiation dose was measured according to the presence or absence of the developed X-ray display device for C-arm. The accumulative radiation dose was measured for the incident radiation from the beginning to the end of the measurement. The radiation exposure dose of all 10 subjects was reduced by 47 to 74% when the developed X-ray display device, as shown in Table 2. The average exposure dose decreased from 16.57±1.28 mGy before the installation to 6.27±1.36 mGy after the installation, showing the reduction in the incident radiation dose by approximately 62% [Table 2].

**Table 2:** Measured dose before and after installation of developed C-arm collimator

| No | Pre C-arm Collimator (mGy) | Post C-arm Collimator (mGy) |
|---|---|---|
| 1 | 17.33±1.53 | 6.60±0.44 |
| 2 | 16.33±1.53 | 4.50±0.17 |
| 3 | 16.33±0.58 | 4.57±0.32 |
| 4 | 15.67±1.15 | 5.80±0.26 |
| 5 | 16.67±0.58 | 7.07±0.15 |
| 6 | 17.33±1.53 | 6.73±0.31 |
| 7 | 17.33±1.54 | 7.03±0.25 |
| 8 | 17.00±1.73 | 4.47±0.21 |
| 9 | 16.33±1.53 | 8.53±0.35 |
| 10 | 15.33±1.15 | 7.37±0.12 |
| Total | 16.57±1.28 | 6.27±1.36 |

Although the medical use of radiation is not limited to the certain radiation dose in terms of the patient's own benefits and defensive behavior optimization, the use of radiation should be reasonably minimized. Nevertheless, the use of a C-arm type fluoroscopy device resulted in the occurrence of the exposure to patients as subject directly exposed to the radiation, as well as the increased likelihood of cancer for practitioners due to continuous occupational exposures [6,8]

During the medical treatments using the C-arm for the fluoroscopy, the radiation exposure significantly increases within the radiographic light field. Thus, due to the inconvenience and degraded efficiency of utilizing a shielding device in using a C-arm type of fluoroscopy device for minimizing the radiation exposure [3,14], additional efforts to reduce the exposure of patients and practitioners are required despite it minimal effect. As factors that contribute to the increase of the exposure dose in the use of the C-arm fluoroscopy device, the fluoroscopic time is the most crucial among various factors including the distance between a patient and an x-ray tube, the angle of the tube, the use of collimation, and the posture of the patient [15].

The C-arm type fluoroscopic devices are divided into an over-tube type where the X-ray tube is placed above the location of the patient, and an under-tube type where the X-ray tube is placed below the location of the patient. Studies have shown that the long-term radiation exposure in both types is high to the body organs of the patients and practitioners, which are close to the X-ray tube [2-5]. To reduce the radiation exposure time of patients and practitioners, a commercially available display device indicating the radiographic position can be installed in the detector for the under-tube system. Related studies have revealed that the time for determining the radiographic position was reduced by 40 to 71% [16]. However, in the over-tube system commonly used in the operating room, conventionally available display devices cannot be used in considering the actual range of the radiation propagating in a conical form. Thus, this study developed a new concept of X-ray display device for C-arm to show the area exposed to the radiation by installing this X-ray display device in the over-tube system, which is a method widely used in clinical practice to secure the space for surgery as well as facilitating the successful surgery. The developed X-ray display device for C-arm can be installed on the C-arm tube without any modification of the existing equipment, and despite the varying distance between the patient and the X-ray tube, this X-ray display device can visualize the range of the radiation propagating in a conical form, and further provide the benefit for practitioners to actively avoid the exposure area. Thus, the exposure dose has increased in the conventional fluoroscopy because the scanning time increased in searching the radiographic target due to the exposure area that are not displayed. Moreover, the exposure dose has increased more due to the X-rays increased by the autonomous exposure control when hands of a practitioner or operational tools are present within the irradiation field [17]. However, the use of the developed X-ray display device could result in decrease in radiation exposure time for searching the target organ by enabling the practitioner to monitor the exposure area of the radiographic site in real-time. By moving the hands or surgical instruments outside the exposure area, the practitioner can reduce the radiation exposure time. This study has further revealed that the exposure time by applying the developed X-ray display device to the C-arm type fluoroscopic device was reduced by approximately 66% from 23.90±3.30 sec to 8.22±1.90 sec, and the radiation dose was reduced by approximately 62% from 16.57±1.28 mGy to 6.27±1.36 mGy.

## 4. Conclusion

The present study is aimed to reduce the radiation exposure dose in using the C-arm type fluoroscopic device. In this respect, this study applied the light field function as in the collimator of a diagnostic radiation generator to the C-arm for visualizing the radiographic area to develop a new concept of X-ray display device. Furthermore, this study showed that the developed X-ray reduces the radiation exposure dose of patients and practitioners by reducing the radiation exposure time for searching the radiographic area through real-time display of the radiographic area. Furthermore, despite the same amount of time exposed to the radiation, because the practitioner can monitor the exposure area in real-time, the practitioner can actively avoid the exposure, which could lead to further reduction in exposure dose due to the use of the C-arm type fluoroscopic device. As the limitations of this study, because the phantom represents the fixed posture of the patient to measure the radiation exposure time, this study results do not reflect the actual variation in postures of the patients. Moreover, because the exposure dose was measured on the detector surface of the C-arm, this study result does not reflect the actual exposure dose. For these reasons, further studies are required to measure the exact exposure dose in the various fluoroscopic environments.

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