Acta Med. Okayama, 2009
Vol. 63, No. 1, pp. 43-47


Acta Medica Okayama
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*Original Article*

# Risks of Chest X-ray Examination for Students

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**Chest X-ray (CXR) examination is considered essential for health checkups of students; thus, it is important to objectively assess the CXR for a better understanding of the appropriate X-ray exposure dose, and the risks such an examination entails. Accordingly, we performed a multi-institutional study regarding students' CXR exposure, during a 6-year-period from 2002 (partially including 2001) to 2007, with the collaboration of national, municipal, and private universities and colleges in Japan. A glass badge was worn by the students at the time of CXR screening examination. These glass badges were collected, and their X-ray exposure doses were measured. The results indicated a tendency of decreasing exposure dose over the 6 years, though the difference was not significant. In a comparison of the chest X-ray systems within institutions (own X-ray equipment = inside systems) with those outside the institution (mobile X-ray equipment = outside systems), the average exposure dose with the outside systems exceeded that of the inside systems. Both inside and outside systems included a few X-ray machines with which the exposure was more than 1 mSv. Based on these facts, individuals in charge of student health checkups should be aware of the exposure dose of each chest fluorographic system at their institution.**

**Key words**: health checkup for student, fluorography examination, X-ray exposure dose, risk and benefit, institution's equipment

Measures for infectious diseases in Japan include the "Law for Infectious Disease Prevention and Medical Treatment for Patients with Infectious Disease" (abbreviated as "Infectious Disease Law") enacted in 1998 as a general law regarding infectious disease, due to the onset of new and recurring infectious diseases. The Japanese Ministry of Welfare and Labor drew up a bill for a partial revision of the tuberculosis prevention law, which was approved in June 2004, and included provisions for 1) regular health checkups, with a change from a uniformly aggregated method to a case-by-case method for considering the risk, 2) the abolition of the tuberculin test and BCG vaccinations for babies 6 months old or younger, and 3) the establishment of a basic guideline for tuberculosis prevention by government agencies, and the drawing up of prevention plans by prefectures. As a result, substantial measures became effective on April 1, 2005, which stated that periodical health checkups for high school level or higher students

Received July 1, 2008; accepted October 3, 2008.
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should be done only upon the student's initial admission to the school. However, at medical schools, a tuberculosis examination will be performed every year as previously done, because such students have a high risk of suffering from the infection [1].

Even though CXR is generally regarded as the harmful, the information obtained through CXR images includes not only clues for detecting of tuberculosis, but also clues for detecting other diseases, such as spontaneous pneumothorax, chest tumor, and cardiac disease [2]. Although the risks and benefits of school CXR examinations should be clarified with regard to this information, reports of this type of research have not been published to date. While benefits of the CXR examination are difficult to express numerically, the risks can be expressed numerically by measuring the exposure dose during CXR examination. Thus, we investigated X-ray exposure dose at health checkups for the purpose of reducing the risks.

Using a glass badge, which was originally designed for environmental radiation exposure measurement, we conceived a new method to measure CXR exposure doses at health checkups, defining the exposure dose to the skin as the effective exposure dose. As part of our preliminary analysis [3], we reported at the 39th National Health Administration Research Assembly that if the dose due to CXR exposure was less than 0.5 mSv, the benefit exceeded the risk [4, 5]. So, we indicated that CXR examinations for periodic health screening of students should at least follow the recommendations of the ICRP's exposure limit for the public, *i.e.*, 1 mSv/year [6]. We measured CXR exposure doses of students at periodic health checkups in collaboration with multiple Japanese institutions (including national, municipal, and private universities and colleges) from the years 2002 (partially including 2001) to 2007, collected the data, and assessed the results.

## Materials and Methods

Subjects included about 10 male or 10 female students from each institution; all signed informed consent statements. Each subject wore an identical glass badge (size; 22 × 62 × 10 mm, Chiyoda Technol Co., Tokyo, Japan) above the posterior process of the thoracic vertebrae 11-12 (*i.e.*, near the diaphragm location at deep breath) at the time of the CXR for periodic health check-up (Fig. 1). The badges were collected after the examination, and sent to Chiyoda Technol Co., for measurement of the exposure dose. Average exposure doses (= effective dose) were calculated per person and per CXR system, by dividing the measured data of each glass badge by the number of students.

With the collaboration of each institution, data for a total of 10,226 students (6,173 males and 4,053 females) from a total of 1,006 CXR systems were gathered from 2002 (partially including 2001) to 2007. The glass badge did not interfere with the interpretation of the X-ray film, as shown in Fig. 1. The time involved in putting on and removing the badge caused no noticeable interruption in the examination process.

Statistical analyses were done by three-way ANOVA, using the Stat View software program for Windows; then interaction line graphs were created. The yearly trend was analyzed by the Student-Newman-Keuls method.

## Results

The average X-ray exposure dose in our investigation was 0.77 mSv/person. The number of CXR sys-

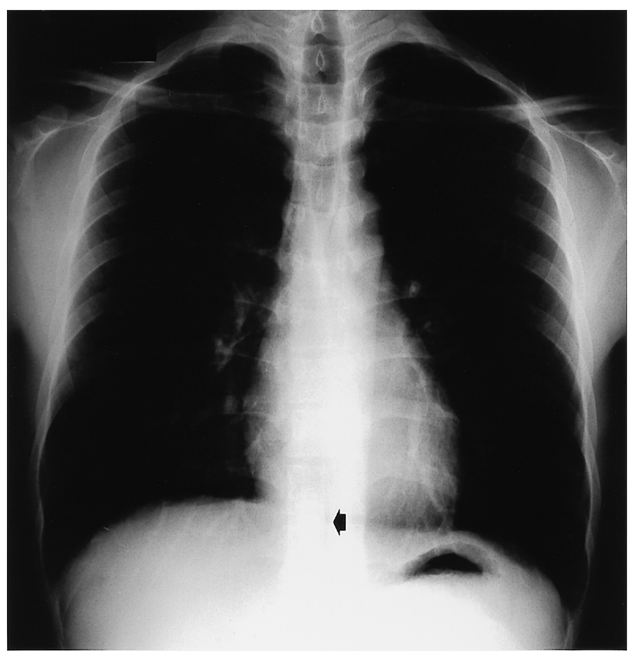

Fig. 1 Glass badge on a X-ray film (arrow)

tems with exposure over 1 mSv/person in the outside systems was 80/801 units, and the inside systems was 9/138 units over the 6-year-period.

Tables 1 and 2 show the measured results. Exposure doses of less than 0.1 mSv/person were excluded as such data were considered impossibly small for a chest fluorography examination, indicating the badge had not been properly positioned.

Table 3 shows the number of CXR exposures exceeding 1 mSv/person. There were no inside systems with exposure over 1 mSv/person since 2004.

Based on the Student-Newman-Keuls analysis, there was a significant difference in the average exposure dose (mean ± SD) per person between the year 2002 (0.774 ± 0.605 mSv/person) and the 2003–2007 period. However, no significant difference was shown among the data from year 2003 to 2007. The overall results show a marked tendency of a decrease in radiation exposure dose, except for the outside systems of chest X-rays, as shown in Figures 2 to 6.

The average exposure dose of female students (0.481 ± 0.058 mSv/person) was significantly less than that of male students (0.676 ± 0.164 mSv/person) ($p < 0.0001$). The average exposure dose of outside systems (0.612 ± 0.012 mSv/person) was significantly higher than that of inside systems (0.536 ± 0.045 mSv/person) ($p = 0.004$), excluding data for which the gender classification was unknown.

## Discussion

The average X-ray exposure dose in our investigation was 0.77 mSv/person, which is less than the ICRP recommendation of 1 mSv as a yearly limit for public exposure. As the general public, except crewman of airplanes, are not usually exposed to radiation from cosmic rays, the total yearly exposure dose of an individual from X-rays is under 1 mSv. Based on our investigation results, if attention is drawn to those CXR systems in which the exposure exceeds 1 mSv (hopefully 0.5 mSv per examination in the future), we can expect a future reduction of X-ray exposure. We

**Table 1** Yearly X-ray exposure dose per person from 2002 to 2004

| Year | 2002* | | 2003 | | 2004 | |
|---|---|---|---|---|---|---|
| | X-ray equipment | mSv per person | X-ray equipment | mSv per person | X-ray equipment | mSv per person |
| Total | 176 | 0.774 | 211 | 0.575 | 192 | 0.579 |
| Male | 103 | 0.874 | 115 | 0.671 | 113 | 0.649 |
| Female | 71 | 0.599 | 84 | 0.472 | 78 | 0.482 |
| Inside System | 49 | 0.684 | 21 | 0.579 | 26 | 0.494 |
| Outside System | 127 | 0.808 | 190 | 0.575 | 166 | 0.592 |
| Number of students | M 1131, F 791 | | M 1296, F 952 | | M 1236, F 859 | |

* Year 2002 includes a part of 2001.

**Table 2** Yearly X-ray exposure dose per person from 2005 to 2007

| Year | 2005 | | 2006 | | 2007 | |
|---|---|---|---|---|---|---|
| | X-ray equipment | mSv per person | X-ray equipment | mSv per person | X-ray equipment | mSv per person |
| Total | 151 | 0.595 | 117 | 0.498 | 92 | 0.518 |
| Male | 92 | 0.682 | 74 | 0.528 | 64 | 0.556 |
| Female | 55 | 0.439 | 41 | 0.445 | 27 | 0.411 |
| Inside System | 20 | 0.410 | 15 | 0.307 | 7 | 0.384 |
| Outside System | 131 | 0.623 | 102 | 0.526 | 85 | 0.529 |
| Number of students | M 992, F 596 | | M 805, F 491 | | M 713, F 364 | |

previously calculated the benefits of the chest X-ray examination, using Waaler's model [7] and the epidemiology of tuberculosis, and the risk using an estimation model [6] and the life expectancy due to lethal

**Table 3** The number of CXRs exceeding 1mSv/person

| Year | Inside system | Outside system |
|---|---|---|
| 2002 | 6 / 49 | 30 / 127 |
| 2003 | 3 / 21 | 15 / 190 |
| 2004 | 0 / 26 | 13 / 166 |
| 2005 | 0 / 20 | 13 / 131 |
| 2006 | 0 / 15 | 7 / 102 |
| 2007 | 0 / 7 | 2 / 85 |

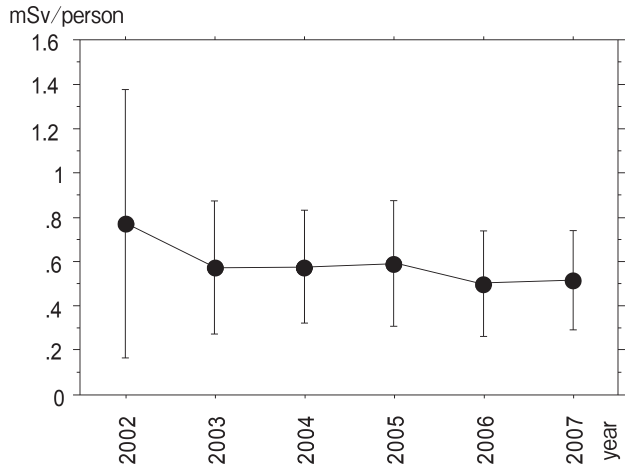


**Fig. 2** Yearly trend of X-ray exposure dose

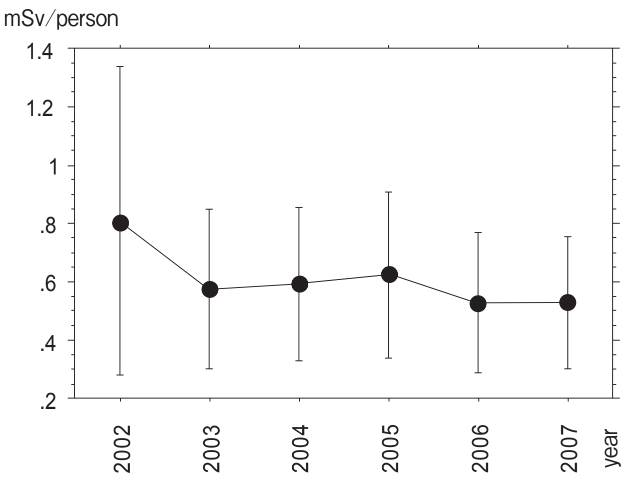


**Fig. 3** Exposure dose of outside systems

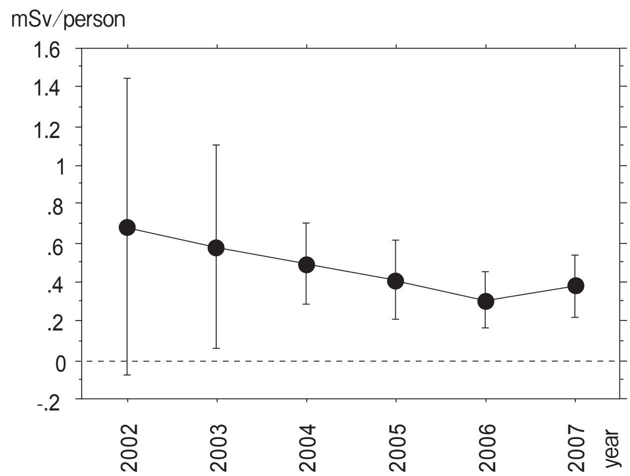


**Fig. 4** Exposure dose of inside systems

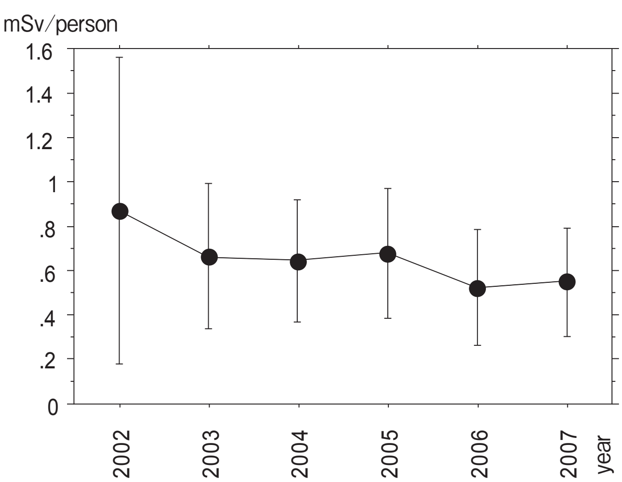


**Fig. 5** Trend of exposure to males

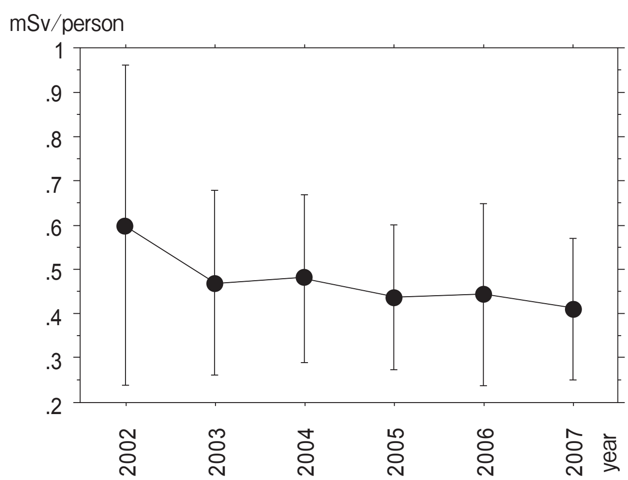


**Fig. 6** Trend of exposure to females

cancer induced by radiation. We concluded that the risks and benefits were almost equal or the benefits surpassed the risks provided the radiation dose of the chest X-ray examination was 0.5 mSv or less [5].

The average value of the CXR outside systems (0.612 ± 0.012 mSv/person) exceeded that of the CXR inside systems (0.536 ± 0.045 mSv/person), and the number of CXR systems with exposure over 1 mSv/person in the outside systems (80/801 units) exceeded that of the inside systems (9/138 units) over the 6-year period. We believe this occurred due to a lack of sufficient maintenance and adjustment of X-ray equipment of the outside systems, since we (the examiners of students' health) cannot adjust or touch such equipment, while with the inside systems have specialists in their institutions for mechanical maintenance. Some CXR inside systems exceeded the 1 mSv/person limit by several fold; in these cases, measures have already been taken to eliminate the issue, such as trading in the CXR system for a new one or commissioning another institution to perform the X-rays. However, corrective measures had not yet been decided for the outside systems; thus, continuation of X-ray exposure dose measurement is considered necessary for a future reduction of X-ray exposure.

The fact that there were significantly higher average X-ray exposure doses for male students than for female students reflects the differences in examination parameters for males and females. Namely, the average thickness of the men's chest is greater than that of women, requiring more exposure, *i.e.*, X-ray tube current multiplied by exposure time (= mA × seconds). For the fluorography examination, data of approximately 0.1 mSv per person or less was taken to indicate erroneous positioning of the glass badge. Therefore, proper positioning of the glass badge should be confirmed when interpreting X-ray images, in future studies.

It is important that the health examiner be aware of the exposure dose at the time of CXR examination, and make efforts to reduce the exposure dose as much as possible. When CXR examinations are commissioned to outside systems, it is necessary to have knowledge of the exposure dose of each X-ray system and request appropriate adjustment of the system when needed. For CXR inside systems, we need to make efforts to reduce X-ray exposure as much as possible through the proper use of equipment.

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