Entrance skin air kerma from National Lung Screening Trial chest x-ray exams

Philip F. Judy[1] *, Randell Kruger[2] , Chris Cagnon[3] , Anthony Seibert[4], Michael Flynn[5] for NLST Physicists, (1) Brigham & Women's Hospital, Boston, MA,(2) Marshfield Clinic, Marshfield, WI , (3) UCLA, Los Angeles, CA, (4) UC Davis Medical Center, Sacramento , CA (5) Henry Ford Health System, Detroit, MI

Abstract

Purpose: The National Lung Screening Trial (NLST) was designed to compare lung cancer specific mortality between groups of subjects randomized to receive low-dose CT and PA chest x-ray exams. The entrance skin air kerma (ESAK) of NLST participants' chest x-ray exams was estimated.

Methods and Materials: During the NLST screening period of 2002-2007, acquisition parameters were available on 68,810 exams of the 73,733 chest x-ray exams. Acquisition parameters included the tube potential, exposure time-current product (mAs value), and detector system (screen-film, photo-stimulable phosphor, and flat-panel receptors). Yearly measurements of source-image distance, radiation output (mR/mAs), and half-value layer for the nominal kVp of the chest x-ray were performed on the x-ray systems used at each of the 33 Trial sites. The ESAK was calculated for each exam and summaries of ESAK were compared to the NEXT 2001 Survey of PA chest exams.

Results: The facilities average ESAK (0.22 mGy) was two times the NEXT value. The facilities coefficient of variation (73%) was comparable to NEXT 2001 Survey. The ESAK of photo-stimulable phosphor system, which constituted 38% of the detector systems, was 0.32 mGy. The average height of NLST participants was 1.73 m and their average weight was 83.6 kg, the phantom used in the NEXT study was intended to represent a patient with a height of 1.7 m. and weight of 74 kg.

Conclusions: Average entrance skin air kerma was twice that reported by the NEXT. Some of this difference was attributed to increased use of photo-stimulable phosphor detectors that were set up with an average sensitivity less than screen-film detectors.

Background

The primary objective of the National Lung Screening Trial (NLST) is to determine if lung cancer mortality in individuals with substantial smoking history can be reduced by screening with multi-detector chest CT as compared to a single view (PA) chest x-ray. Between 2002 and 2007, 73,733 chest x-ray exams were performed in the NLST. The Trial participants ranged in age from 55 to 74 years old, and each had a substantial smoking history. They were randomly assigned to receive either screening CT scans or screening chest x-rays. They agreed to a baseline imaging procedure plus two annual follow-ups. The purpose of this study was to estimate the entrance skin air kerma (ESAK) of the PA chest exams. Ultimately, ESAK will be used to estimate the effective doses of the PA chest exams.

Methods

Collection of acquisition parameters of all chest exams was specified in the NLST protocol. Acquisition parameters collected included the site specific x-ray machine identifier, the tube potential, the tube current, exposure time, the tube current-exposure time product (mAs), and the detector system (screen-film, photo-stimulable phosphor, and flat-panel receptors). During enrollment, the participants' self-reported heights and weights were collected.

The exam ESAK was calculated as the product of the mAs and the average x-ray tube output measured annually by the NLST site physicist. Since, the output was measured at distance of 100 cm from the focal spot; the ESAK included an inverse square law correction. This method has been shown to predict 98% of the variation in measured skin dose (1).

*A portion of the NLST was administered by the America College of Radiology Imaging Network (ACRIN) ACRIN receives funding from the National Cancer Institute through the grants U01 CA079778 and U01 CA080098.

BRIGHAM AND WOMEN'S HOSPITAL

Methods – Continued

Acquisition parameters necessary to calculate the mAs were available from 68,810 exams acquired during the NLST screening period of 2002-2007. Two sites were technically unable to access the x-ray machine parameters necessary to calculate mAs. These two sites accounted for 4897 exams without the acquisition parameters necessary to calculate the mAs. Annual measurements of source-image distance, radiation output [mR/mAs], and half-value layer for the nominal tube potential of the chest x-ray were performed on the x-ray systems used at each of the sites.

A unique Trial resource ID was linked with site specific x-ray machine identifier and the x-ray machine identifier in the site physicist's report. As a quality assurance, the mAs was plotted as function of exam date and/or participant body mass index each size for each resource ID . Figure 1 is an example of the mAs as function of the date of the exam at a single site. This plot indicated the site switched from a screen-film to photo-stimulable phosphor receptors. The plot also indicates anomalously high mAs values. These anomalously high mAs values were observed at most sites. These anomalously high mAs values did not seem to be associated with large participants. Figure 2 is an example of the mAs as function of body mass index from another site. Anomalously high mAs values occurred at all body mass indices. We concluded these high mAs values were valid.

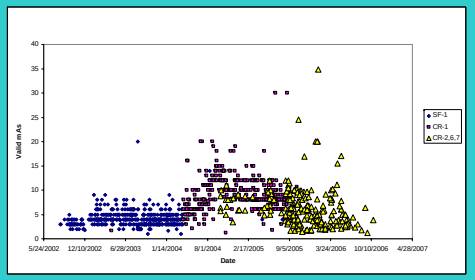

Figure 1 – Exam mAs as function of the exam date

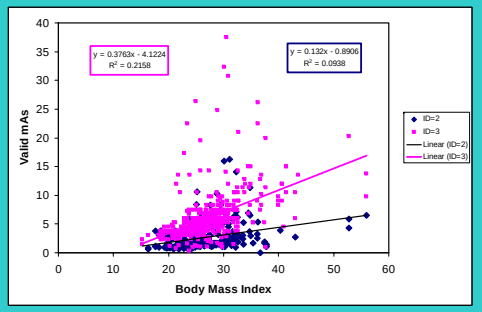

Figure 2 – Exam mAs as function of participant body mass index

Results

The facilities average ESAK was 0.22 mGy; the facilities ESAK standard deviation was 0.16 mGy; the median ESAK was 0.18 mGy. A facility is defined a unique resource, i.e., a x-ray tube with a specific receptor design. There were 91 facilities in NLST.

Results – Continued

The histogram metrics of the mAs values (Table 1) and the cumulative frequency distribution of mAs values (Figure 3) indicate that distribution of NLST exam mAs values were not normal.

Table 1 – Exam mAs histogram metrics

Average	4.49
Stdev	5.50
Median	3.10
Skew	28.25
Kurt	1955.20

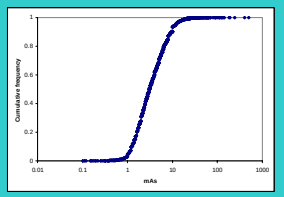

Figure 3 – Cumulative distribution of exam mAs values

While the variation of the facilities ESAK was substantial, facilities ESAK stratified by receptor (Table 2) and plotted as function of tube potential (Figure 4) suggested that ESAK using the photo-stimulable phosphor receptors (CR) was greater than the ESAK using the screen film (SF) or the flat-panel receptors (DR). This suggestion was confirmed by a t-tests (Table 3).

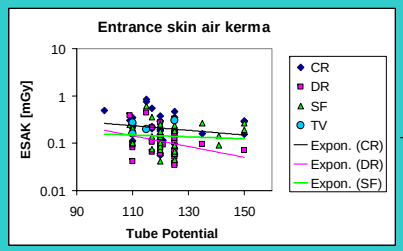

Figure 4 – ESAK stratified by receptor design

Table 2 – ESAK - mGy

Receptor	Average	StDev
CR	0.316	0.278
DR	0.144	0.277
SF	0.176	0.240

Table 3 – Test of ESAK differences

	t test results
CR-DR	0.0007
CR-SF	0.0150
SF-DR	0.2058

There was no evidence that the receptor design confounded the ESAK stratified by receptor design (Figure 4). The x-ray tube outputs [mR at 40 inches/mAs] stratified by receptor plotted as function of tube potential are similar (Figure 5).

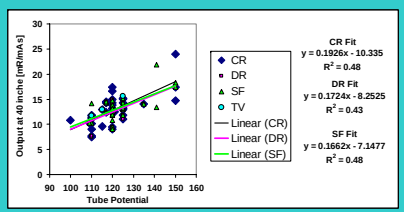

Figure 5– X-ray tube outputs stratified by receptor design

Conclusions

The variation of exam ESAK was dominated by the exam mAs variation. Interestingly, only 10%-20% of that variation could be attributed to variation in participant size.

The facilities average NLST entrance skin air kerma was twice that reported by the NEXT 2001 (2). This difference was attributed to increased use of photo-stimulable phosphor detectors that were set up with an average sensitivity less than screen-film detectors. NLST results are based on patient measurements, while NEXT 2001 were exposures to a phantom that represented the typical patient. The average height of NLST participants was 1.73 m and their average weight was 83.6 kg, the phantom used in the NEXT study was intended to represent a patient with a height of 1.7 m. and weight of 74 kg. Consequently, some of the higher ESAK could be attributed to the larger size of the NLST patient as compared to NEXT 2001 phantom. However, some of this difference should be attributed to increased use of photo-stimulable phosphor detectors that were set up with an average sensitivity less than screen-film receptors and flat-panel receptors.

References

(1) Judy P, Nawfel R, Ababneh Z. Chest Radiography Surface Doses. Med Phys 2003;30:1422-1423. (Abstract of oral presentation)

(2) NATIONWIDE EVALUATION OF X-RAY TRENDS (NEXT) TABULATION AND GRAPHICAL SUMMARY OF2001 SURVEY OF ADULT CHEST RADIOGRAPHY, CRCPD Publication E-05-2, Available Online at No Charge (www.crcpd.org), September 2005.