Personal Dosimeter Use In Australian Nuclear Medicine Practice

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Citation

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Abstract

Introduction: Anecdotally, Australian Nuclear Medicine staff wear a single thermoluminescent dosimeter (TLD) for monitoring purposes and tend to wear their TLD in a variety of body positions including but not limited to the chest, waist and shoulder. There is a paucity of published data directly relating to the effect of placement of the TLD on whole body dose measurements.

Methodology: A survey was undertaken of current protocol and procedures employed for personal radiation monitoring of occupationally exposed staff in Nuclear Medicine departments across Australia. The study design utilised a self-administered questionnaire to provide participant confidentiality. The experimental study utilised a quasi-experimental, repeated measure (within subjects) design of eight Nuclear Medicine staff volunteers. TLD data was collected for two consecutive monitoring periods of two months duration each. All participants wore two TLDs simultaneously, one positioned on the chest and the second positioned at the waist.

Results: The position for the primary TLD of staff was predominantly at the waist (92.8%) with the remainder (7.2%) placing their primary TLD at the chest. A further 34.8% use a second TLD on the chest, 15.9% on the finger, 5.8% on the collar and 1.4% each for the pocket, umbilicus and under the apron. The mean x-ray / gamma ray dose for TLDs positioned at the chest was 287.5 µSv while the corresponding waist dose records had a mean of 178.8 µSv. The matched pairs t test demonstrated a statistically significant difference between matched pairs (P = 0.001) with a mean decrease in recorded doses for the waist of 108.8 µSv (95% CI of 50.2 to 167.3 µSv).

Conclusion: Comparing occupational radiation doses within Nuclear Medicine departments and amongst Nuclear Medicine departments is fraught with danger. There is a need for the development of uniform policy and practice in relationship to TLD position.

INTRODUCTION

There are many occupations that routinely expose employees to varying types of radiation. Medical occupational radiation exposure covers both diagnostic and therapeutic exposures to both humans and animals ([1]). Occupational radiation studies have been an important topic since the early 1940's ([2]) with an increase in mortality from leukaemia and other cancers being noted in a range of occupationally exposed groups ([2,3,4,5,6]). The current estimate of the probability of induction of a fatal cancer for radiation workers exposed to low levels of ionising radiation (within occupational standards) is four cancers per hundred persons exposed per Sievert ([7]).

A person working in a Nuclear Medicine department on average receives an annual effective dose of about 2.0 mSv, which may be increased to around 3.0 mSv if they work in a positron emission tomography (PET) facility ([1]). Over a working lifetime (assuming 2.0 mSv per year) the average risk per year is calculated at 0.8 in 10000, equivalent to a total lifetime risk of 3.7 in 1000 ([8,9]). These figures can be converted to a loss of life expectancy (LLE) of 17 days ([9]). This compares favourably to a pilot travelling 400000 kilometres over a period of 40 years with a LLE of 64 days and unemployment with a LLE of 500 days ([8,9]). Smoking 20 cigarettes per day or being overweight by 15% produces a LLE of six years and two years respectively ([10]).

The first and perhaps most obvious objective of personal (or personnel) monitoring is to provide information of external

radiation exposures of the individual working with radioactive materials and / or radioactive devices ([1],[11],[12]). This information then assists in work planning and rostering of staff allowing control of the workplace as well as providing exposure information relating to accidental exposures, changes in practice and changes in dosage types ([1],[11],[12],[13]). Personal radiation monitoring and dose assessment also enables optimisation of procedure and protocol ([13]).

Anecdotally, Australian Nuclear Medicine staff wear a single thermoluminescent dosimeter (TLD) for monitoring purposes and tend to wear their TLD in a variety of body positions including but not limited to the chest, waist and shoulder. A number of factors may affect the choice of TLD position. Firstly, the employee may consider the radiosensitivity of critical organs and elect to wear their TLD in a place that is representative of radiation burden to these organs. An example could be a dosimeter worn on the waist to provide an approximation of the radiation dose received by the gonads. Secondly, the weight, design and attachment mechanism may favour one body location over others.

The Australian Radiological Protection and Nuclear Safety Authority (ARPANSA) recommends that the TLDs they provide be worn at waist or chest height to determine doses typically received by the body ([1]). Landauer recommends that the TLD should be worn on the chest ([14]). Guidelines for wearing the TLD, however, are usually the responsibility of the institution in which the radiation worker is employed. While the best position for TLD placement tends to be left for individuals to decide, physical principles suggest a variation in TLD position could correspond to a variation in dose recorded.

There is a paucity of published data directly relating to the effect of placement of the TLD on whole body dose measurements. Harbottle et al. ([15]) reported up to 50% variability between TLD measurements worn on the breast pocket compared to the waist. More recently, variations in TLD measurements have been reported between the waist and collar positions ([16]).

Despite guidelines provided by TLD manufacturers, there is no universally accepted consensus on TLD positioning. Moreover, there is anecdotal evidence to suggest inter and intra departmental variability in TLD placement. This investigation may contribute to the collective knowledge of industry, providing justification or impetus to develop universal strategies for TLD use, reducing variability and error in radiation monitoring and, thus, providing a more accurate and effective planning instrument.

METHODOLOGY

INDUSTRY SURVEY

The study was a survey of current protocol and procedures employed for personal radiation monitoring of occupationally exposed staff in Nuclear Medicine departments across Australia. The study design utilised a self-administered questionnaire to provide participant confidentiality. A structured questionnaire was employed in order to collect unambiguous answers for quantitative evaluation.

In August 2006, 122 questionnaires were sent to the Chief Technologists of each Nuclear Medicine department in the sampling frame. The sampling frame included all Australian departments accredited by the Australia and New Zealand Society of Nuclear Medicine (ANZSNM) in addition to those departments identified under a ‘nuclear medicine' search query of the online telephone directory. A reply paid envelope was included for the return of the completed questionnaire. Department identity remained anonymous since the questionnaire contained insufficient information to identify individual departments.

POSITION EXPERIMENTATION

The experiment utilised a quasi-experimental, repeated measure (within subjects) design. A total of eight volunteers participated with a mean age of 33 years. All participants were current employees of the Nuclear Medicine section of the Medical Imaging department at the Canberra Hospital. Data was collected for two consecutive monitoring periods of two months duration each and, thus, data collection occurred between June and November in 2006. The participants were either Nuclear Medicine technologists or worked in the Nuclear Medicine radiopharmacy laboratory. For the four-month duration of data collection, each participant was supplied with two ARPANSA TLDs to be worn during the normal course of their daily duties. One positioned on the chest and the second positioned at the waist. The dose results were provided in μSv (micro-Sieverts) and accounted for both X and (gamma) rays. The sum total of the radiation exposure to the participants was equal to that they were ordinarily exposed during normal work practices.

STATISTICAL ANALYSIS

A P value less than 0.05 was considered significant. The

difference between independent means and proportions was calculated with a 95% confidence interval (CI). CIs without an overlap and / or those that did not include zero were considered to support a statistically significant difference while confidence intervals with an overlap and/or included zero represented differences for which chance could not be excluded as the cause.

The study was granted institutional ethics and radiation safety approval.

RESULTS

INDUSTRY SURVEY

At the completion of the data collection period, 69 of the 122 questionnaires had been returned completed. Another four questionnaires were returned unopened with a postal notation that the addressee was unknown. Thus, a minimum compliance rate of 58.5% (69/118) was determined. Responder compliance for this self-administered postal questionnaire was considered to have an excellent response. Responders comprised 65.2% private and 34.8% public departments. While all Australian states and territories were represented, NSW (43.5%) and Victoria (17.4%) made up the bulk of respondents.

The mean number of staff per department that are issued with TLDs was 12 (median of 10) with a range of one to 45. No statistically significant difference was noted in the mean number of staff per department monitored across states (P = 0.960), which suggests the distribution of various department sizes is similar across states; perhaps just the number of departments varies. There was, however, a statistically significant increase in the mean number of staff monitored per department for department type; from private centres (eight) to public departments (20) (P < 0.001). Table 1 provides a summary of the percentage of departments that use TLD monitoring of different staff types.

Figure 1

Table 1: Monitoring of staff types.

Staff Type	Percentage Monitored
Technologists	100
Doctors	95.7
Nurses	75.4
Physicists	27.5
Secretaries	24.6
Other	20.3

Four suppliers were used by Australian departments for monitoring services including, Landauer (43.5%), ARPANSA (36.3%), Australian Radiation Services (ARS) (11.6%) and Queensland Monitoring Service (QMS) (5.8%) while a further 2.8% of departments employed multiple suppliers. No statistically significant difference was noted for TLD supplier versus the department type (P = 0.391). Not surprisingly, there was a statistically significant difference in TLD supplier versus state (P = 0.003) with NSW departments favouring Landauer and ARPANSA, Queensland departments favouring QMS, South Australia / Western Australia favouring Landauer and Victoria leaning away from Landauer. No statistically significant relationship was noted for TLD supplier versus the mean number of staff monitored per department (P = 0.467). The mean contribution of reasons for departments to chose one supplier over another included the accuracy of the devices (39.4%), cost (23.0%), practice/department policy (22.6%), device design (9.4%) and other reasons (5.7%). Other reasons included continuity of service, service/support and being ‘Australian'. Accuracy showed a statistically higher contribution to decision making (P < 0.001) while device design showed a statistically lower contribution (P < 0.001). Generally there was no statistically significant difference to contribution based on state or department type (public versus private) or the number of staff monitored. Victoria did, however, report a lower contribution of accuracy to the decision process than other states (P = 0.006). Furthermore, the contribution of cost to decision making increased as the number of staff monitored increased (P = 0.127) (Figure 1) and there was a matching decrease in the contribution of accuracy as staff numbers increased (P = 0.151) (Figure 2). Policy had a statistically greater contribution to departments using ARS (P = 0.007) and device design for Landauer users (P = 0.023).

Figure 2

Figure 1: Bivariate fit of the cost contribution to supplier choice by the number of staff issued with TLDs.

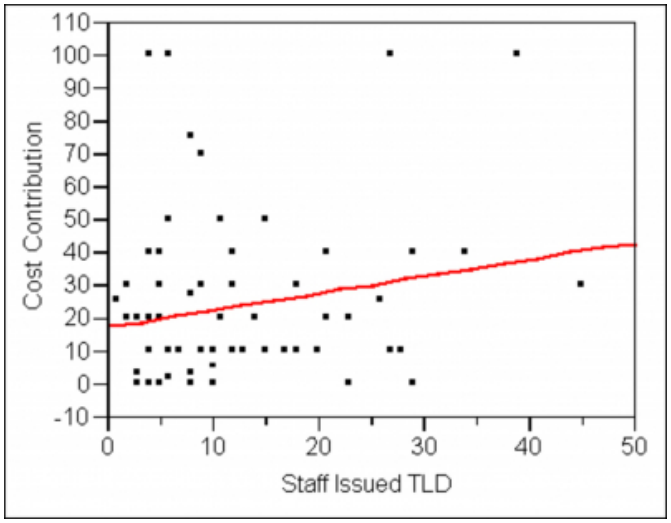
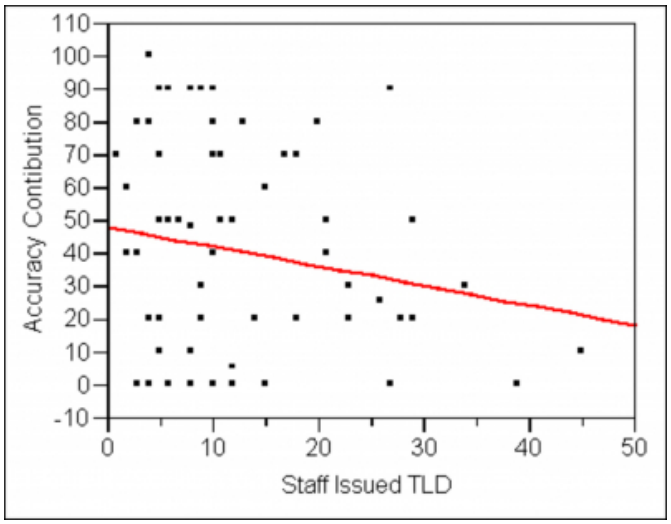


Figure 3

Figure 2: Bivariate fit of the accuracy contribution to supplier choice by the number of staff issued with TLDs.



The position for the primary TLD of staff was predominantly at the waist (92.8%) with the remainder (7.2%) placing their primary TLD at the chest. A further 34.8% use a second TLD on the chest, 15.9% on the finger, 5.8% on the collar and 1.4% each for the pocket, umbilicus and under the apron. The mean contribution of reasons for staff to chose one position over another included convenience (29.1%), representative of gonad dose (24.1%), representative of the whole body dose (14.3%), the department policy (13.6%), manufacturer guidelines (8.6%), device accuracy (5.7%), evidence (3.6%) and other reasons (0.9%). Convenience and representative of gonad dose were reasons with a statistically higher contribution to choice ($P < 0.001$) while evidence and accuracy were reasons with statistically lower contributions to choice ($P < 0.01$). Tradition / habit represented the other reason for position choice. Generally, no statistically significant relationships were noted for reasons for staff choosing TLD position by the state, department type, the number of staff issued with TLDs per department, the TLD supplier or the principle TLD position. There was, however, a statistically higher contribution of the position being reflective of the gonad dose for private centres (30.8%) compared to public departments (1.7%) ($P = 0.014$).

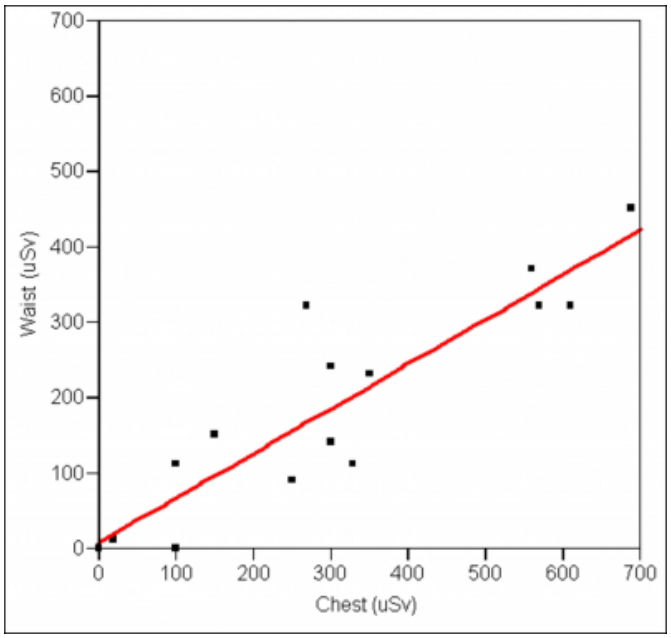
The monitoring period for TLDs ranged from one to three months with a mean of 2.2 months and a median of three months. No statistically significant relationship was noted between the monitoring period and department type ($P = 0.245$), the number of staff monitored ($P = 0.618$) or the supplier used ($P = 0.083$). Surprisingly, there was no statistically significant difference in monitoring period for departments identifying cost as an issue for choosing a supplier over other departments ($P = 0.967$) since a three-month monitoring period reduces overall costs.

POSITION EXPERIMENTATION

TLD reports included both x-ray / gamma ray dose and beta doses. On all records the beta dose was recorded as zero. Both control readings were also reported as zero. The mean x-ray / gamma ray dose for TLDs positioned at the chest was 287.5 µSv with a 95% CI of 168.0 to 407.0 µSv. The corresponding waist dose records had a mean of 178.8 µSv with a 95% CI of 100.9 to 256.6 µSv. No statistically significant difference was noted between the means ($P = 0.071$) and this is supported by the overlap of the 95% CIs. The matched pairs t test, however, demonstrated a statistically significant difference between matched pairs ($P = 0.001$) with a mean decrease in recorded doses for the waist of 108.8 µSv (95% CI of 50.2 to 167.3 µSv). The absence of zero in the 95% CI supports a statistically significant difference between matched pairs. As illustrated in Figure 3, the difference between the two readings increases with an increasing recorded dose.

Figure 4

Figure 3: Bivariate fit of the chest dose by the waist dose.



DISCUSSION / CONCLUSION

The industry survey revealed a number of interesting findings. The majority of staff monitored (92.8%) elected to wear their dosimeter on the waist primarily for reasons of convenience (29.1%) and the representativeness of the dose to the gonads (24.1%). These findings suggest that accuracy of the whole body dose was not a major consideration. For private industry, gonad dose was reported to be of most importance and this may reflect the mean age of those in the private sector or a gender bias, although neither was extracted in the survey.

The questionnaire also revealed that as the number of staff monitored in a department increased, the decision to choose one dosimeter supplier over another varied. The contribution of cost to the decision making process was found to increase while the accuracy contribution of the dosimeter decreased. These findings suggest that in the larger departments, personal monitoring is governed by decisions of cost and convenience, perhaps reflecting a general belief that accuracy of TLDs is fairly uniform across suppliers. Interestingly, there was no statistically significant increase in the monitoring period for departments who indicated that cost was an important factor in choosing a supplier. While cost is important in choosing a supplier, these results suggest that optimal radiation practice is not cost prohibitive. That is, despite increased costs, some departments employ a shorter sampling frame, presumably to offer a better tool for monitoring and controlling exposure.

The accuracy of the dosimeter reading may have a significant impact upon the dose recorded for each employee. This study highlighted a number of factors that contribute to the accuracy of the dosimeter. Primarily, the position that the dosimeter was worn was found to provide variability in the dose results obtained with a mean decrease in waist measurements over chest measurements of 108.8 µSv (40% mean difference). The investigation also showed that as the dose recorded increased so did the difference between chest and waist doses.

It is important to consider that the mean 40% difference may represent an increase in accuracy for the whole body radiation dose of chest TLD placement. If this were correct, current Australian practice to wear dosimeters on the waist would be producing markedly decreased occupational radiation dose estimates. It is not unreasonable to consider that the chest TLD overestimates whole body dose, especially given the nature of some Nuclear Medicine activities that have the chest disproportionately close to the source (e.g. bending forward to inject a patient). Indeed, the chest TLD might gain greater exposure because it has a poorer protective effect of lead glass shielding in the radiopharmacy of some departments; valuable in reflecting eye exposure but not necessarily representative of whole body exposure. Perhaps the choice of TLD position is governed less by the whole body radiation dose it is meant to indicate and more by the perceived ‘critical organ' identified by individuals (gonads versus eyes).

A lack of universal guidelines for dosimeter use means that the responsibility of radiation monitoring lies with each individual. In turn the overall accuracy and effectiveness of personal monitoring as a planning instrument is compromised. Variable TLD positioning within Nuclear Medicine departments and amongst Nuclear Medicine departments is, thus, fraught with danger. There is a need for the development of uniform policy and practice in relationship to TLD position.

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