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ORIGINAL RESEARCH

Trauma team radiation exposure: The potential need for dosimetry monitoring

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Abstract

Objectives: Australian radiation regulations require routine monitoring of health-care workers who might receive a whole-body effective radiation dose in excess of 1 mSv/year. In Australian hospitals, routine monitoring with a dosimeter is recommended for levels beyond 300 μSv/year. We aimed to determine the potential radiation exposure to trauma team members and whether routine personal radiation dosimetry should be recommended.

Method: An anthropomorphic mannequin with a radiation detector was placed at five locations around the resuscitation bed. Three sets of standard trauma-series X-rays were performed, and the exposure was measured and averaged at each location. These data were then extrapolated to estimate the potential radiation equivalence at the level of the thyroid gland for staff working in each of the locations over a 1 year period with and without personal protective equipment.

Results: The total dose ranged from 1.2 to 20.5 μSv for a single trauma patient. The highest recorded dose was at the location of the circulation doctor during pelvic X-ray. Based on these data, it would take only 15 trauma patients per year for a team member to be potentially exposed to the level at which routine dosimetry is usually recommended, should no personal protective equipment be used. The use of a lead gown and a lead gown with a thyroid collar reduced exposure by four- and ninefold, respectively.

Conclusions: We have demonstrated the possibility of significant ionizing radiation exposure for unprotected trauma team members. Dosimeter use by trauma team personnel needs to be reviewed based on local protocols and patient numbers.

Key words: *monitoring, radiation, trauma.*

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Introduction

In recent years, in Australia there has been a change in the practice of imaging trauma patients. Where previously all staff stood clear during the trauma series of X-rays (conventionally cervical spine/chest/pelvis), it has become widespread practice for the trauma team to wear lead gowns and to remain around the patient while the X-rays are taken during the resuscitation as part of the primary survey.[1,2] This change has occurred without considering evidence of increased risk to staff associated with this practice, and in our hospital, without the knowledge of the radiation safety officer (RSO).

Trauma centres are, by design, large hospitals, and each typically has a RSO, who is responsible for ensuring that the use of radiation in the hospital meets all the requirements of the NSW Radiation Control Act 1990,[3] and NSW Radiation Control Regulation 2003.[4] The body responsible for overseeing the use of radiation (via the provision of radiation licences) is the Department of Environment and Conservation. The specific requirements vary from state to state, with overall guidances provided by a Commonwealth Government agency, the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA).

The system of radiation protection detailed by ARPANSA deals with exposure to radiation in three classes: occupational, medical and public.[5] Occupational exposures occur principally as a result of working directly with radiation as defined by ARPANSA. Medical exposure is the exposure of patients as part of their medical diagnosis or treatment. Public exposure covers all other exposures. Trauma team members currently fall into this last group,[6–9] because they are not identified as practitioners who are routinely exposed to radiation and therefore do not routinely wear radiation dosimeters. Average background environmental radiation is about 2500 μSv per annum.[10] Effective dose limits for exposure to ionizing radiation in Australia are currently set at 20 000 μSv per year for an occupationally exposed person, and 1000 μSv per year for the public[5] above this background level.

The ARPANSA guidelines recommend that 'Anybody who is likely to be exposed to radiation over a long period of time as a result of their work should be monitored'.[11] In general, the requirement is to monitor all occupationally exposed persons and any staff (not otherwise classified as occupationally exposed) who would receive a radiation dose in excess of 1000 μSv/year. In practice, as a safety margin, workers who might receive a dose exceeding 300 μSv/ year are routinely monitored. Thus, monitoring is recommended for staff who might *potentially* be at risk of high levels of exposure.

A number of studies[12–16] have demonstrated that personal protective equipment (PPE) is effective in the context of the ED resuscitation, where ionizing radiation exposure is likely, but have not examined the need for dosimetry monitoring based on regulatory requirements or potential risk of exposure. A recent Australian study[17] has similarly concluded that the lead gown confers adequate protection from ionizing radiation for the torso.

Two radiation-sensitive organs, the thyroid and eye, are exposed if the full complement of PPE (thyroid-shielding and lead-lined glasses) is not used in addition to the lead gown. There are clear guidelines documenting limits for ocular exposure; however, there are currently no upper or lower dose limits for the thyroid gland. Previous studies have shown a significant under-utilization of thyroid protective equipment by medical staff in non-ED settings.[18,19] Many clinicians have little understanding of the physics of radiation and the potential hazards of occupational exposure. This has previously been illustrated by the failure of doctors to inform patients of radiation exposure risks, as they are themselves unaware of the risks.[20,21]

There have been no studies investigating whether the potential doses received by trauma team members are higher than the limits for workers not classified as occupationally exposed, and thus whether routine dosimetry monitoring should be considered. In this context, we sought to determine:

- The amount of radiation to which trauma team members might potentially be exposed (both in total and at the level of the thyroid) by the use of a hypothetical model
- Whether this potential radiation exposure is at a level which would require ED staff involved in trauma care to routinely wear radiation dosimetry
- What level of PPE is appropriate for protection of staff in this environment

Method

Ethics

As this was an observational study of a hypothetical model, ethics approval was waived by the ethics committee.

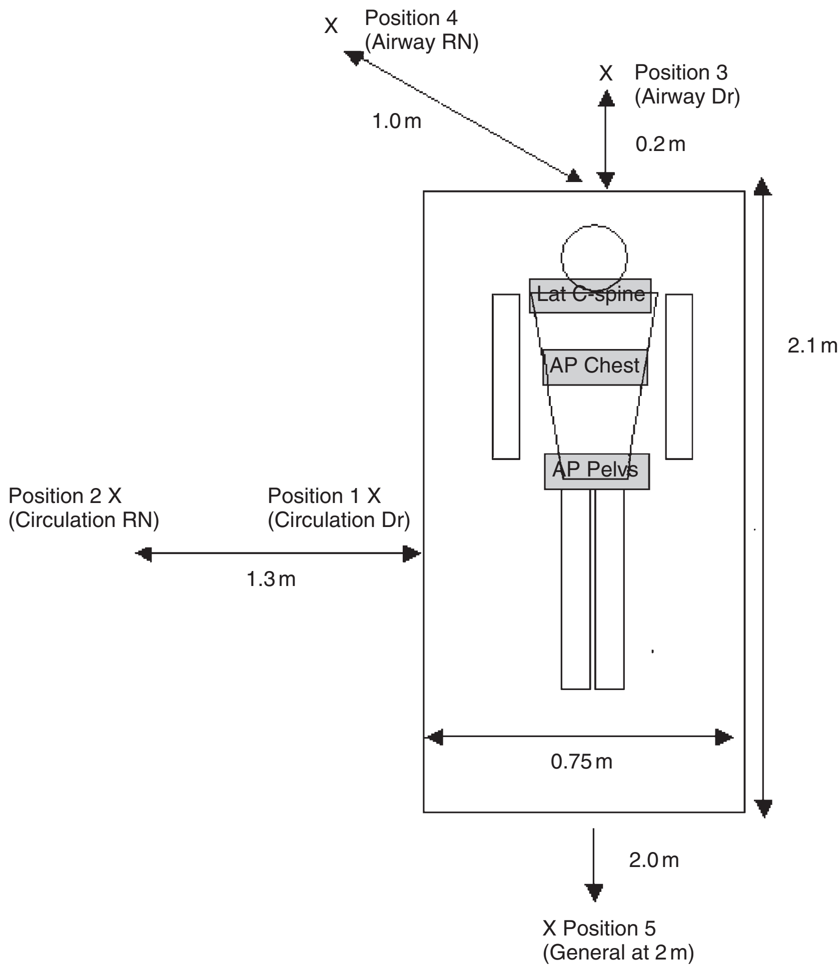

Figure 1. Location of radiation detector (positions 1–5). Position 1: circulation doctor (right lateral aspect of trauma bed, caudal to patient's pelvis); position 2: circulation nurse (at same level as circulation doctor, but at distance of 1.3 m); position 3: airway doctor (at the head of the trauma bed with distance 0.2 m); position 4: airway nurse (distance of 1 m angled at 45 degrees from the head of the bed); position 5: team leader at 2 m from the end of the bed. AP, anteroposterior; Lat-C-spine, lateral cervical spine.

Setting

The study was conducted in the ED of Liverpool Hospital, Liverpool BC, New South Wales, Australia, with more than 50 000 ED attendances and more than 1000 trauma admissions per year. It was performed using an anthropomorphic (Rando Phantom, Phantom Laboratory, Salem, NY, USA) mannequin on a resuscitation bed (Hausted 464APA, Mentor, OH, USA) in a trauma bay of the department.

Study design

A radiation detector (Radcal 2025, Radical Corporation, Monrovia, CA, USA: large-volume chamber for scatter measurements) was placed at five locations around the bed where trauma personnel are usually located. These positions are outlined in Figure 1. The height for all measurements was taken at 1.6 m (the estimated average height of the thyroid). A convenience sample of three sets of standard cervical spine, chest and pelvis trauma X-rays were performed, and exposure was measured at each of the five locations (X-ray unit: Philips Practix 2000, Philips, Amsterdam, the Netherlands), resulting in 45 exposures. The tube–patient distance were standardized based on the local trauma protocol settings, and the following field settings were used: chest 80 kVp, 2.5 mA; pelvis 76 kVp, 30 mA (grid exposure); and lateral cervical spine 85 kVp, 3.5 mA. It was assumed that the exposure for each trauma remains constant, that is, no variability in body habitus.

Measurements

Exposure (mR) at the five locations was calculated and averaged from the three sets of measurements, and the equivalent dose value for each type of X-ray at each location was calculated. This figure equates to the total exposure for an individual staff member at a specific location for a single trauma case. These were then converted to an annual figure (assuming 1000 trauma patients per year) and a 'per staff member' annual figure (assuming 8 h shifts for 5 out of 7 days in 46 weeks – allowing for leave and days off). These data were then extrapolated to estimate the potential radiation dose at the level of the thyroid gland for staff working in each of the locations over a 1 year period. The minimum number of patients required to reach the dose limit was also established.

Using approximate radiological techniques, the exposure was converted to a tissue-related dose measured in Sieverts.[22–24] The dose limit divided by the whole-body effective dose per patient gives the number of patients to be seen for the staff member to reach the specified dose limit. We then applied a weighting factor to estimate the effectiveness of wearing different levels of PPE, specifically a lead gown with or without a thyroid collar, for the same whole-body effective dose. This weighting factor was determined from the sum of tissue weights[25] that were deemed protected or not by the gown and/or collar, and the resulting factor was found to be consistent with previous published values.[26,27]

All testing involving radiation was conducted by the RSO.

Results

Estimated exposure for each staff location following a standard set of trauma X-rays is presented in Table 1. Reproducibility of the readings was typically better than 3%, although the team leader reading at 2 m distance had greater variability due to limited sensitivity of the detector. Based on our underlying assumptions, position 1 (the circulation doctor) could receive an annual dose of 4326 μSv if no PPE is worn. Alternatively, this can be thought of as a 'per patient' dose of 20.6 μSv.

Table 2 summarize the number of patients whom each team member would have to see to reach the ARPANSA dose limits for public exposure and recommended dosimetry monitoring. Without the use of PPE, the 'circulation doctor' might be potentially exposed to 300 μSv (the dose limit at which dosimetry is recommended) after being involved in 15 trauma resuscitations. Forty-nine patients potentially expose the circulation doctor to the maximum recommended limit for the general public. The team leader had the lowest overall exposure, and at a distance of 2 m from the trauma bed, it would take 250 patients before the need for dosimetry would be considered, and 833 patients before the 'public' level of exposure is reached.

Discussion

This hypothetical model has demonstrated the potential for trauma team members to be exposed to levels of ionizing radiation that would require ongoing surveillance. The risk of exposure to ionizing radiation is highest while the pelvic X-ray is being performed, and the team leader is at very low risk of exposure to

Table 1. Estimated exposure for each staff location

Staff member	Dose for X-ray type (mR)			Total per patient (mR)	Total per patient (μSv)	Dose per annum (μSv)†	
	Lateral cervical spine	Chest	Pelvis			Total	Per staff member‡
Circulation Dr	0.029	0.153	1.88	2.06	20.6	20 600	4 326
Circulation RN	0.015	0.030	0.39	0.44	4.4	4 400	924
Airway Dr	0.046	0.139	0.45	0.64	6.4	6 400	1 344
Airway RN	0.016	0.037	0.21	0.26	2.6	2 600	546
Team leader	0.003	0.01	0.11	0.12	1.2	1 200	252

†Assuming 1000 patients/annum and exposure constant for each trauma. ‡Assuming that each staff member works 8 h shifts for 5 out of 7 days in 46 weeks of the year.

Table 2. Dose limit related to number of patients seen

Staff member	Total dose per patient (μSv)	Number of patients/year to exceed limit of					
		1000 μSv (for dosimetry)			300 μSv (public exposure limit)		
		No PPE	Gown	Gown + collar	No PPE	Gown	Gown + collar
Circulation Dr	20.6	15	58	137	49	193	458
Circulation RN	4.4	68	271	643	227	902	2144
Airway Dr	6.4	47	186	442	156	620	1474
Airway RN	2.6	115	458	1089	385	1526	3628
Team leader	1.2	250	992	2358	833	3307	7862

PPE, personal protective equipment.

ionizing radiation. The use of PPE is very effective in limiting exposure, and we have demonstrated the increment benefit of a gown and combined collar and a gown.

There have been many studies measuring the radiation exposure to medical and nursing staff in non-ED settings,[6,8,9,28–33] and a smaller number of studies measuring exposure to trauma personnel[12–17] in the current clinical environment. The 2005 Australian study by Tan and Van Every found a yearly mean effective dose of 6.3 μSv for doctors and 54.3 μSv for nursing staff from a dosimeter worn under PPE.[17] The study does not, however, draw conclusions on requirements for dosimetry, as it assumes that ED staff fall under the mantle of 'occupationally exposed'. The issue of exposure classification has been raised in other medical subspecialties,[6,7,9] but not in relation to emergency personnel. Currently, emergency personnel are not listed by ARPANSA as requiring dosimetry monitoring, because they are not classified as occupationally exposed.

Most other studies have been based in North America and conducted in the 1980s and 1990s. Only one of these studies[12] specifically addressed the issue of the need for ongoing monitoring via dosimetry. This was conducted in the 1980s, when trauma practice was likely to be quite different from current practice, and in an institution where it was mandatory for staff to wear a dosimeter. The study was conducted over a 9 year period and concluded that dosimetry was not required in the ED. Of the five US studies, this was the only one to reach a conclusion about dosimetry. Another study[15] measured exposures equivalent to 16 000 μSv annually for trauma personnel (the highest annual reading of all the studies), but made no comment on the need for dosimetry.

Staff in environments where potential exposure is recognized routinely use protective equipment and wear dosimeters. At our hospital, the measured exposure of most radiographers and cardiologists (measured beneath protective attire) is under 200 μSv per annum (hospital data), and for nuclear medicine technicians, under 3000 μSv per annum. Measurement of waist dose inside protective attire, versus neck dose outside protective attire, within angiography suites yielded dose differences of up to 40-fold in one review.[23]

Staff in environments where potential exposure is not routinely recognized or monitored can be exposed to unacceptable risks, especially if workload or work practices change. The purpose of our study was to measure whether there is a potential risk for trauma personnel given the changes in work practice that have occurred over the past few years.

Evaluation of the risks resulting from exposure to ionizing radiation is a very complex problem. Most estimates have been extrapolated from data obtained on groups of persons receiving relatively high doses (such as uranium miners, and the victims of the Hiroshima and Nagasaki atomic bombs). These estimates are assumed to form a linear dose–effect relationship down to zero, although evidence of harm at low levels cannot be proven.[34]

Occupational limits are set at levels that are regarded as having acceptable risk for long-term harm consistent with other occupations (an exposure of 20 000 μSv is estimated to produce approximately a 1/1000 lifetime risk of fatal cancer).[10,35] This is minimized by the use of protective equipment and monitoring with dosimeters, and regulatory standards enforced in law to ensure compliance. In the present study, although potential exposure exceeded the recommended monitoring limit, the actual dose that staff members receive will be largely mitigated by PPE as evidenced by Tan and Van Every[17] and the present study. However, without ongoing monitoring, there is no way of ensuring that exposure is at a safe level. As current standard practice in Australia is to wear personal dosimeters underneath PPE, these readings will not necessarily indicate actual effective dose, as much of the dose to the dosimeter is attenuated and significant irradiation of non-protected tissue can still occur. As can be seen in Table 1, a person wearing only a gown can still receive one-quarter the effective dose of a person without PPE; yet the personal dosimeter would indicate only a fraction of this dose. These results might indicate a need to reassess the practice of not considering the dose to exposed tissue for estimating a person's annual effective dose.

ED personnel and members of the trauma team encounter a wide variety of risk in association with their workplace.[36] The identification and management of risks is an integral part of any organization. Measures taken to minimize these risks are only one part of the equation. Applying information in a manner that changes behaviour to increase compliance with known safety measures is equally important. With knowledgeable staff and the necessary precautions in place, the utilization of trauma-series X-rays in the critically ill trauma patient can remain both safe to staff and beneficial to the patient.

Limitations

This was an observational study and does not reproduce the dynamic parameters of trauma resuscitation. These include the movement of staff and the characteristics of the patient. Given the spread of personnel around the trauma bed when X-rays are performed, there will be large variations in dose, and so the data generated by the study are only an approximate measure of the magnitude of exposure.

The anthropomorphic phantom, although designed to reproduce the attenuation and scatter properties of a 'human', remains an approximation of the spectrum of ages and sizes that present to the ED. The body habitus of an individual patient is significant for the X-ray field required for radiological studies, and hence the degree and distribution of ionizing radiation (larger patient means more irradiation required and hence more scatter).

Our estimates assumed that team members would remain by the bedside while X-rays were being performed, although in practice, they might often briefly step away from the patient. We also assumed that all patients undergo the three standard films in all cases. Therefore, we have considered the worst-case scenario, whereas both of these factors might be modified to further reduce the potential exposure for team members.

Lastly, there are also significant differences between departments and countries in setting up the radiation field (and hence exposure) generated by X-ray equipment. In addition, the standard exposures for a trauma series of X-rays can vary significantly between hospitals.[24] In clinical practice, the radiographer decides the value of each parameter, dependent on the body habitus of the patient, the body part being X-rayed, the equipment (e.g. use of grid), protocols within the hospital, and the experience of the radiographer.

Conclusions

The possibility of significant ionizing radiation exposure exists in the context of a tertiary urban hospital where trauma teams utilize standard three view (cervical spine, chest and pelvis) radiography at the bedside. Our findings suggest that the need for dosimeter use by staff working in these areas might warrant review. The RSO needs to be aware of current practice in trauma resuscitation and effect a change in practice where appropriate.

Authors contributions

MI 80% (design, methodology, data collection, manuscript preparation), GG 80% (design, data collection, data analysis, manuscript review), AM 40% (design, data collection, manuscript review), AH 30% (design, manuscript preparation).

Competing interests

Anna Holdgate is a section editor for *Emergency Medicine Australasia*; all other authors declare no conflict.

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