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Recommendations for Nuclear Medicine Technologists Drawn from an Analysis of Errors on Australian Radiation Incident Registers

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Recommendations for Nuclear Medicine Technologists Drawn from an Analysis of Errors on Australian Radiation Incident Registers

Abstract

When adverse radiation incidents occur in nuclear medicine in Australia they are reported to the relevant state or territory authorities who investigate the incident and report their findings to the Australian Radiation Protection and Nuclear Safety Agency. The data is then compiled and included in the Australian Radiation Incident Register. The only information that has been circulated from the Australian Radiation Incident Register are the annual summary reports available on the Australian Radiation Protection and Nuclear Safety Agency website. The aims of this study was to analyse the radiation incidents included in Australian Radiation Incident Register together with the state and territory registers that are available to the public, identify the reoccurring themes in Nuclear Medicine incidents and make recommendations to minimise future incidents. **Method:** All radiation incidents recorded on the Australian Radiation Incident Register as well as state and territory registers that occurred in nuclear medicine, radiation therapy and diagnostic radiography between 2003 and 2015 were analysed by a multidisciplinary team comprising of a nuclear medicine technologist, radiographer and radiation therapist. The nuclear medicine technology incidents were placed into one of 19 categories. Each category was then examined in greater detail to determine any reoccurring causes within them. By utilising this information, recommendations were able to be drawn to help prevent adverse incidents being repeated. **Results:** 209 nuclear medicine incidents from the Australian Radiation Incident Register and the state government registers of New South Wales, Victoria, South Australia and Western Australia were analysed. The primary cause of

adverse radiation incidents in nuclear medicine in Australia was failure to comply with time-out protocols, accounting for 85.6% of all incidents. **Conclusion:** By analysing both the cause and rate of radiation incidents from the Australian national radiation incident register and state authority registers we have produced recommendations to prevent repeats of adverse events that have already occurred.

Key Words: adverse events; incident reporting; patient safety; radiation safety

Introduction

Two articles published in 2000 paved the way for worldwide change regarding quality in healthcare, bringing forward the notion that identifying and reporting errors will lead to improved overall patient safety and efficiency (*1,2*).

There is evidence of increased rates of radiation induced cancer in patients receiving cumulative doses above 100mSv,(*3*) so It is the responsibility of the nuclear medicine profession to not become complacent about trying to minimise incidents and keeping patient doses as low as reasonably achievable. The potential risks associated with increased radiation exposure highlight the importance of identifying, reporting and analysing errors that occur within the profession (*4*).

A radiation incident is classified as an event which results in or has the potential to result in unplanned radiation exposure when using an ionising radiation apparatus or radioactive substances (*5*). When adverse radiation incidents occur in Australia they are reported to the relevant state or territory authorities who investigate the incident and report their findings to the Australian Radiation Protection and Nuclear Safety Agency. The data is then compiled and included in the Australian Radiation Incident Register.

The objectives of the Australian Radiation Incident Register are; to highlight the sources or causes of potential hazards, to provide information on incidents and accidents that occur in Australia, provide guidance and feedback to users of radiation to limit/prevent radiation accidents and to provide data for other regulatory and advisory bodies. The only information that has been circulated from the Australian Radiation Incident Register are the annual summary reports available on the Australian Radiation Protection and Nuclear Safety Agency website (*6*). Australian Radiation Protection and Nuclear Safety Agency intend on including more information on post-incident follow-up and the lessons learned in the future (*7*).

This article is part of a larger research project involving researchers from all three strands of the Medical Radiation Science profession (nuclear medicine technology, diagnostic radiography and radiation therapy) to determine what lessons can be learned from the errors that have been reported to state and territory radiation protection authorities.

Despite errors in nuclear medicine being well documented (*8–10*), little is known about the lessons that can be learned from the errors that have been reported and made available on radiation incident registers throughout Australia. By analysing the information available on publicly available radiation incident registers future errors can be reduced. The aims of this study was to analyse the radiation incidents included in Australian Radiation Incident Register together with the state and territory registers that are available to the public, identify the reoccurring themes in Nuclear Medicine incidents and make recommendations to minimise future incidents.

Method

All radiation incidents recorded on the Australian Radiation Incident Register as well as state and territory registers that occurred in nuclear medicine, diagnostic radiography and radiation therapy between 2003 and 2015 were analysed by a multidisciplinary team comprising of a nuclear medicine technologist, radiographer and radiation therapist. Ethics approval was not required as only registers containing anonymised data that were available to the public were examined in this study.

This study utilised an error classification type taxonomy (*11*). Incidents that were deemed beyond the control of the medical radiation practitioner (nuclear medicine technologist, diagnostic radiographer or radiation therapist) were excluded from the study along with incidents that did not contain enough information to decipher the exact cause of the adverse event. All the incidents were organised into Medical Radiation Science professions and examined by the multidisciplinary team. Each member of the research team ascertained the cause of every incident, when differing causes were determined the

group discussed the incident in depth to derive a consensus. The 2012 and 2013 Australian Radiation Incident Register annual summary reports documented approximately 70% of incidents were due to human error (*12,13*). While it can be argued that all incidents are caused by human error, this study aimed to provide a more in depth analysis to draw specific recommendations so the incidents were broken down into a greater number of categories. The nuclear medicine technology incidents were placed into one of 19 categories (see table 1). Each category was then examined in greater detail to determine any reoccurring causes within them. By utilising this information, recommendations were able to be drawn to help prevent adverse incidents being repeated.

Results

The New South Wales incident register included incidents from 2003 until 2013, (*14*) the Western Australia register 2004 until 2012, (*15*) the Victorian register 2007 until 2014, (*16*) the South Australian register 2004 until 2015 (*17*) and the Tasmania register the 2013 – 2014 financial year (*18*) included within the annual reports of the New South Wales Environment Protection Authority, Western Australian Radiological Council, Victorian Department of Health, South Australian Environmental Protection Authority and Tasmanian Department of Health and Human Services respectively.

Of the 573 incidents between all three Medical Radiation Science professional bodies 43 incidents were duplicated in the Australian Radiation Incident Register and state radiation registers leaving 530 incidents to be analysed. The incidents were broken down into professional groups and totalled 209 (39%) from nuclear medicine, 243 (46%) from diagnostic radiography and 78 (15%) from radiation therapy. The classification of the adverse nuclear medicine events by determined cause is detailed in table 1 and a full breakdown of each adverse event is detailed in table 2. There was no trend observed in the number of reported incidents per year.

As shown in table 2, the primary cause of adverse radiation incidents in nuclear medicine in Australia was failure to comply with time-out protocols (TOP), accounting for 85.6% of all incidents. This included both patient interview TOP (12.4%) and procedural TOP (73.2%). Errors associated with booking procedures resulted in 4.3% of all incidents and the remainder 10.0% of incidents were classified as other. These were errors that did not pertain to the other categories.

Nuclear medicine and radiation therapy had a higher percentage of procedural TOP errors compared to diagnostic radiography. Diagnostic radiography had higher percentage of booking procedure errors and patient interview TOP than both nuclear medicine and radiation therapy.

Discussion

Failure to comply with TOP, specifically Procedural TOP accounted for 73.2% of all the incidents in this study. Two of the most significant contributors to this figure were incorrect radiopharmaceutical (36.4%) and incorrect dosage (7.2%). When combined accounting for 43.6% of all incidents. These results are comparable with results from a study by Martin et al. in 2005 which found 47% of radiation incidents in nuclear medicine were due to the incorrect radiopharmaceutical or incorrect dosage (*19*). They had examined incident reporting and investigation systems in Scotland over a 10-year period. Hence, despite the advances in technology, incidents due to the administration of the incorrect radiopharmaceutical or dosage have not changed over the last two decades. We believe these issues can be prevented firstly with extensive radiopharmacy laboratory training to be mandatory for all new staff members and delivered by experienced technologists. Secondly, the implementation of an integrated computerised radiopharmacy management software package can reduce the risk of reconstituting incorrectly or dispensing an incorrect patient dosage. Software computer packages connect directly to an ionising chamber (dose calibrator) and bar code reader. Enabling complete traceability of every activity that occurs in the radiopharmacy laboratory, from pharmaceutical inventory receiving to the recording of

each patient dosage dispensed. However, if the overall issue of incorrect radiopharmaceutical/dosage administration is to be suitably addressed a coordinated approach by the entire profession including nuclear medicine societies, Australian Radiation Protection and Nuclear Safety Agency, Universities and management is required.

2 incidents were due to technologists dispensing an incorrect dosage for paediatrics because the incorrect weight was obtained. Weight estimation is utilised in emergency settings where obtaining a child's weight due to trauma or pain is not possible and active resuscitation is required. The formula is used by the Advanced Paediatric Life Support course throughout Europe, South Africa, Australia and New Zealand. The Advanced Paediatric Life Support formula is weight(kg) =3(age) +7 and we recommend this formula be familiar to technologists (*20*). We also recommend that paediatric doses should be calculated using the European Association of Nuclear Medicine Dosage card (*21*) or Society of Nuclear Medicine and Molecular Imaging Procedure Standards (*22*).

7.2% of incidents were due to procedural TOP, non-compliance. These incidents would have been prevented if protocols were adhered to. We recommend all procedures performed in a nuclear medicine department should have written protocols or local procedures readily accessible to all staff. Staff should be educated on all procedures and protocols during initial orientation and be involved in regular reviews and updates. Quality improvement projects such as regular protocol reviews can be used to keep abreast of new technologies and techniques being implemented throughout the international nuclear medicine profession. Continuing professional development is a requirement of registration and the time and effort involved in protocol reviews contributes to continual professional development and the overall expertise of a nuclear medicine technologist.

Remarkably over 12% of errors were due to non-compliance of patient interview TOP. The incident registers specifically stated that the nuclear medicine technologist did not perform the

pregnancy/breastfeeding check or Correct Patient, Correct Site, Correct Procedure protocol. The Correct Patient, Correct Site, Correct Procedure protocol (*23*) is designed to provide a nationally consistent method for ensuring the intended procedure is performed on the correct patient (*24*). The Correct Patient, Correct Site, Correct Procedure protocols in radiology, nuclear medicine and radiation therapy were released in 2008 but unlike those produced for operating theatres they were not mandated by Health Ministers. Patient identification and procedure matching is part of the National Safety and Quality Health Service Standards which are a critical component of the Australian Health Services Safety and Quality Scheme endorsed by the Australian Health Ministers in November 2010 (*25*). A study published in 2011 by Danaher et al. reviewed the validity of implementing a patient identification procedure in radiology departments and found significant system improvements could be achieved. The authors acknowledged improvements in staff performance may be attributed to the Hawthorne effect (*26*). The Hawthorne effect is a term that refers to the tendency of subjects to improve their behaviour due to their awareness of being observed (*27*). We recommend staff should be well educated on Correct Patient, Correct Site and Correct Procedure protocols followed by auditing and observations undertaken by department management.

Inadequate student and new graduate supervision lead to 2.9% of all the incidents in this study. The incidents are easily prevented as all nuclear medicine technologists should be aware of their professional responsibilities and the potential repercussions that can result from complacency. It is the responsibility of the radiation licenced nuclear medicine technologist to supervise students at all times.

Research performed in this article identified several state radiation registers available to the public apart from the Australian Radiation Incident Register. The Western Australia and Victorian incident registers contained far more detailed information than the information contained with the Australian Radiation Incident Register annual summary reports. The New South Wales register generally contained more

information than the Australian Radiation Incident Register annual summary report. The more information made available to determine the cause of an incident can be beneficial when attempting to learn from past mistakes, so changes to way the information is presented in ARIR annual reports may be warranted.

While this study deals with reported errors, underreporting is an inherent issue in nuclear medicine (*10,28*) as it is in the whole field of medicine (*29*). It has been suggested that nuclear medicine departments located in NSW with medical physicists who have served on the New South Wales Radiation Advisory Council would have a greater probability of reporting radiation incidents due to their greater understanding of the regulatory process. The regulatory process contributes to underreporting due to varying reporting requirements in various Australian jurisdictions (*28*). Nuclear medicine departments worldwide have to create a culture of safety if the profession is to lift the rate of reporting errors and near misses that can greatly improve the learning data available to prevent future radiation incidents (*30*). The disincentives of error reporting, like punitive reporting systems, must first be removed if this is ever to be achieved (*31*).

Table 3 provides a summary of recommendations.

Conclusion

Regulatory requirements should always be adhered to within all areas of medical radiation science but it is also the responsibility of the individual professional for establishing a radiation safe ethos in their workplace. This can be achieved by fostering positive change and creating a culture of safely for all staff and patients. By analysing both the cause and rate of radiation incidents from the Australian national radiation incident register and state authority registers we have produced recommendations to prevent repeats of adverse events that have already occurred. These recommendations, or system

improvements, can be implemented by all nuclear medicine departments irrespective of their size or geographical location.

Conflict of Interest

The authors declare no conflict of interest.

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Classification	Definition
Failure to comply with TOP:	Any error that occurs that would reasonably be expected to be detected and thwarted by carrying out a correctly performed 'correct patient, correct site & correct procedure' time-out protocol and pregnancy/breastfeeding check.
- **Patient Interview TOP**	Any error that involves a procedure performed on the incorrect patient (or foetus) that would reasonably be detected by a time-out protocol.
➢ Closed questions	Due to closed questions being asked when identifying a patient.
➢ Non compliance	Failure to ask Correct Patient, Correct Site, Correct Procedure protocol.
➢ Request error	Due to incorrect patient details on the request/prescription form that would be reasonably detected by a time-out protocol (e.g. an incorrect patient sticker).
➢ Pregnancy/breastfeeding	Due to a pregnancy/breastfeeding check not being performed.
- **Procedural TOP**	Any error that involves the incorrect procedure being performed that would reasonably be detected by a time-out protocol.
➢ Handover	When an incorrect procedure is performed due to handover from one staff member to another where incorrect and or inadequate information is passed on or the new staff member fails to make the appropriate checks before proceeding with the procedure.
➢ Human error	Any error that occurs when the incorrect procedure is performed and no other category applies (e.g. radiographer is distracted and forgets to connect pressure injector to patient's cannula).
➢ Internal systems	Due to procedures or systems within the practice that contributed to the incorrect procedure being performed.
➢ Non compliance	Due to the procedure not being checked on the request/prescription or matched to patient presentation.
➢ Incorrect dosage	When a patient is administered the correct radiopharmaceutical but the incorrect dosage that should be detected by a time-out protocol.
➢ Incorrect radiopharmaceutical	When a patient is administered the incorrect radiopharmaceutical that should have been

	avoided if correct protocols were followed.
➢ Intravenous access	Due to the intravenous access not being checked that would be detected by a time-out protocol.
➢ Request form ambiguity	When the incorrect procedure is performed due to ambiguity of the request/prescription.
➢ Quality control	When the incorrect procedure is performed due to failure to correctly perform quality control checks.
Booking Procedures:	Errors that occur due to the systems in place to request (or cancel) a procedure.
- Internal systems	These errors occur before reaching the MRS professional. They occur either externally to the department (e.g. electronic x-ray requests) or within (e.g. department reception) and would not likely be detected during a correctly performed time-out procedure.
- Non original request form	Errors that occur due to the use of any type of duplicate or non-original referral/prescription form.
Other:	
Inadequate student/new graduate supervision	Errors performed by students or PDY interns under the supervision of qualified MRS personnel.
Inadequate training	Due to unfamiliarity of software, equipment or procedures.
Unintentional radiation exposure to staff or public	The unintentional irradiation of staff or members of the public.
Spillage of a radiopharmaceutical	The unintentional spill of a radiopharmaceutical.

Table 1: The classification of adverse events by determined cause. Each adverse event was allocated into one of 19 categories or sub-categories (shaded in blue).

Category	Total Incidents
Failure to comply with time-out protocol:	**179 (85.6%)**
- **Patient interview TOP**	**26 (12.4%)**
➢ Closed questions	2 (1.0%)
➢ Non compliance	17 (8.1%)
➢ Request error	5 (2.4%)
➢ Pregnancy/breastfeeding	2 (1.0%)
- **Procedural TOP**	**153 (73.2%)**
➢ Handover	4 (1.9%)
➢ Human error	14 (6.7%)
➢ Internal systems	3 (1.4%)
➢ Non compliance	15 (7.2 %)
➢ Incorrect dose	15 (7.2%)
➢ Incorrect radiopharmaceutical	76 (36.4%)
➢ Intravenous access	19 (9.1%)
➢ Request form ambiguity	3 (1.4%)
➢ Quality control	4 (1.9%)
Booking Procedures:	**9 (4.3%)**
- Internal systems	5 (2.4%)
- Non original request form	4 (1.9%)
Other:	**21 (10.0%)**
Inadequate student/new graduate supervision	6 (2.9%)
Inadequate training	4 (1.9%)
Unintentional radiation exposure to staff or public	1 (0.5%)
Spillage of a radiopharmaceutical	10 (4.8%)
TOTAL:	**209**

Table 2: Breakdown of incidents classified by determined cause.

Recommendations to prevent radiation incidents
➢ Extensive radiopharmacy training for all new staff members
➢ Implementation of an integrated computerised radiopharmacy management software package
➢ Co-ordinated approach by the entire nuclear medicine profession to address the issue of incorrect dosage and radiopharmaceutical administration
➢ Utilisation of correct paediatric dose calculators and weight estimation formula
➢ Written protocols or local procedures readily accessible
➢ Departmental protocols should be regularly updated
➢ Correct patient, correct site, correct procedure protocol education followed by departmental auditing
➢ Improved student and new graduate supervision
➢ Disincentives of error reporting must be removed
➢ Create a culture of safety in nuclear medicine departments

Table 3: Summary of recommendations to prevent radiation incidents in nuclear medicine