Australian Government
Australian Radiation Protection and Nuclear Safety Agency

Australian Radiation Incident Register

SUMMARY OF RADIATION INCIDENTS
1 January 2013 to 31 December 2013

1. Introduction

The Australian Radiation Incidents Register (ARIR or Register) is a repository of radiation incident information from Commonwealth, State and Territory radiation regulators. It is intended to raise awareness of radiation safety across Australia.

This report is a summary and analysis of data submitted to the Register for incidents which occurred in 2013.

Further information on the ARIR can be found on the ARPANSA website.

2. Purpose and Scope

The purpose of this report is to assist in the identification of topical areas in which safety effort may be focussed and identify any practices which may be either adopted or avoided to improve radiation protection. To achieve this purpose focus is directed at the causes of incidents.

Schedule 13 of Radiation Protection Series No.6 (RPS6), *National Directory for Radiation Protection (NDRP)* specifies the types of incidents that must be reported to ARPANSA for compilation in the ARIR. Reporting arrangements are agreed by the ARPANSA Radiation Health Committee (RHC) which includes representatives from radiation regulators of each Australian jurisdiction. ARPANSA has no control over the completeness and depth of information included in incident reports outside of the Commonwealth jurisdiction. Uncertainty over reporting practices and the often limited information contained within the ARIR reports makes it problematic to draw definitive conclusions on trends without additional information that is not available to the Register (e.g. levels of actual reporting or number of medical procedures undertaken).

Geographical or personal data that may lead to the identification of individuals or organisations is not included in an incident report and does not form part of this analysis.

3. Overall Statistics

The total number of reports the Register received in 2013 was 201. These reports were distributed amongst 18 of the 32 groups used to categorise incidents. The table below provides the number of incidents from each group together with numbers from the previous four years for comparison.

Incident Category	2013		2012		2011		2010		2009		Average 2009-13	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Diagnostic Radiology	112	56	65	58	57	48	57	49	43	42	67	51
Nuclear Medicine	51	25	28	25	33	28	28	24	27	26	33	26
Radiotherapy	9	4	6	5	10	8	11	9	13	13	10	8
Borehole Logging	5	2	1	1	4	3	5	4	4	4	4	3
External Exposure (non-medical)	4	2	2	2	0	0	0	0	0	0	1	1
Contamination	3	1	2	2	0	0	0	0	0	0	1	1
Transport	3	1	1	1	1	1	1	1	0	0	1	1
Dental	2	1	1	1	0	0	0	0	0	0	1	0
Laboratory	2	1	1	1	0	0	1	1	0	0	1	1
Portable Density/Moisture Gauge	2	1	0	0	3	3	1	1	1	1	1	1
High Recorded Dose	1	0	0	0	1	1	2	2	3	3	1	1
Industrial Radiography	1	0	0	0	2	2	1	1	3	3	1	1
Mining	1	0	0	0	0	0	0	0	0	0	0	0
Nuclear Safety	1	0	0	0	0	0	0	0	0	0	0	0
Radiation Gauge	1	0	0	0	1	1	2	2	2	2	1	1
Sources Found	1	0	0	0	0	0	0	0	1	1	0	0
Theft of Sources	1	0	0	0	1	1	0	0	2	2	1	1
Unauthorised Disposal of Source	1	0	2	2	0	0	1	1	0	0	1	1
Cabinet X-Ray	0	0	**0**	0	1	1	1	1	1	1	1	0
Consumer Products	0	0	0	0	0	0	0	0	0	0	0	0
Deliberate or Malevolent Act	0	0	0	0	0	0	2	2	0	0	0	0
Industrial Linac	0	0	0	0	0	0	0	0	0	0	0	0
Irradiator	0	0	0	0	0	0	0	0	0	0	0	0
Laser	0	0	2	2	1	1	0	0	2	2	1	1
Luminising/Luminous Device	0	0	0	0	0	0	0	0	0	0	0	0
Radiofrequency	0	0	0	0	1	1	0	0	0	0	0	0
Sources Lost	0	0	0	0	2	2	3	3	0	0	1	1
Static Eliminators	0	0	0	0	0	0	0	0	0	0	0	0
Ultraviolet	0	0	0	0	0	0	0	0	0	0	0	0
Unauthorised Possession of Source	0	0	0	0	0	0	0	0	0	0	0	0
X-Ray Analysis	0	0	0	0	0	0	0	0	0	0	0	0
XRF Source	0	0	1	1	0	0	0	0	0	0	0	0
TOTALS	**201**		**112**		**118**		**116**		**102**		**130**	

Table 1: Overall Register statistics for 2013 and the prior four years. Note percentages rounded.

The number of incidents reported to the register in 2013 was higher than in previous years. ARPANSA has actively promoted the benefit of good reporting practices during this reporting period. Improved reporting is considered a more likely reason for the increased number of reported incidents rather than an actual increase in the number of incidents that have occurred.

Three trends are clear in Table 1. Over the past four years, the proportion of reported:

- Diagnostic Radiology incidents have increased.
- Nuclear Medicine incidents have remained relatively stable.
- Radiotherapy incidents have decreased as a proportion of overall incidents.

The interpretation of these trends is ongoing, and additional analysis of the information contained in ARIR reports is planned.

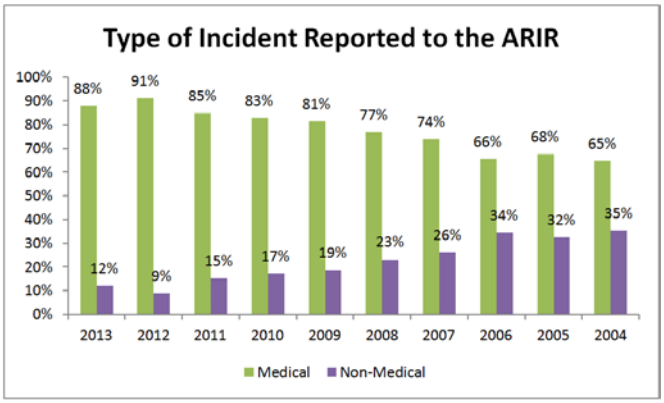

Figure 1: Types of incidents reported to the Register since 2004 as a percentage of total incidents for the year.

Overall medical radiation incidents continue to dominate the incidents reported and accounted for 88% of all incidents reported to the Register in 2013. Data from Figure 1 shows that the proportion of medical incidents reported to the Register has remained within the range of about 80% to 90% over the past five years.

4. Primary Causes

4.1. Overview of Incidents and Preventative Measures

The largest primary cause of all reported incidents was human error accounting for 138 (69%) incidents. It was not possible to determine the primary cause of a further 33 (16%) incidents but it is possible that these are also be related to human error. The full spread of primary causes for all 2013 incidents is:

- Human Error: 138 (69%) incidents
- Unclear: 33 (16%) incidents
- Patient error or factors beyond control[1]: 9 (4%) incidents
- Equipment malfunction: 11 (5%) incidents
- Complicated medical procedure[2] or complications: 7 (3%) incidents
- Equipment deficiency: 3 (1%) incidents

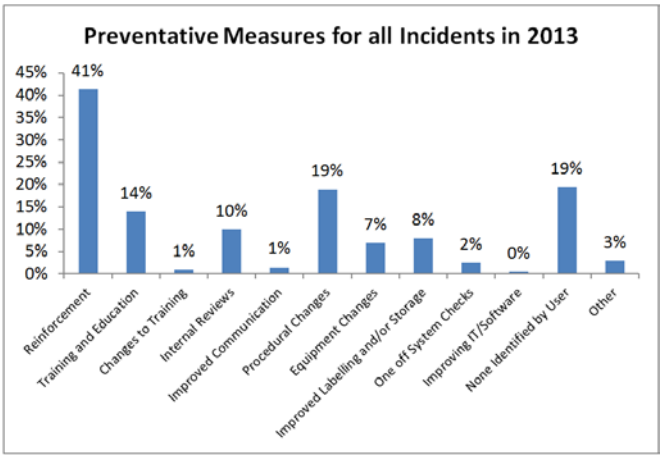

Figure 2: Preventative measures used by an operator/user for all incidents during 2013. All values are expressed as a percentage of the total number of incidents in the year.

[1] Examples of "patient error or factors beyond control" cover a range of circumstances. Examples include undeclared pregnancy, patients discharging themselves part way through treatment, and patients becoming ill during their treatment.
[2] Incidents of complicated medical procedures are typically those where the patient's condition is more complex than anticipated leading a longer surgical procedure and increased radiation exposure.

The nature of these causes are elaborated on in Section 5 of this report.

The prevalence of human error as the primary cause was more apparent in medical incidents compared with non-medical incidents (72% and 46% respectively). However, when the proportion of incidents in which the primary cause is unclear is added to the human error incidents the proportions are similar as seen in Figures 3 and 4 (i.e. 84% for medical incidents and 92% for non-medical incidents).

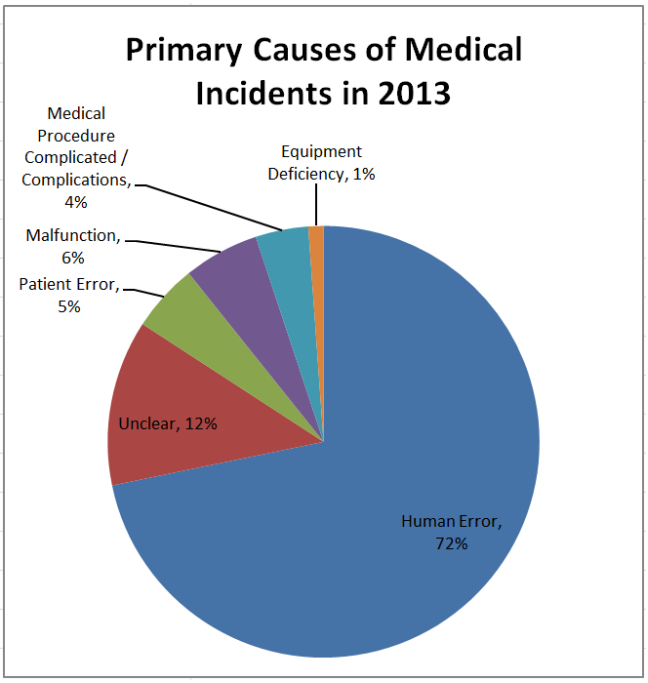

Figure 3: Primary causes of medical incidents in 2013 as a percentage of medical incidents.

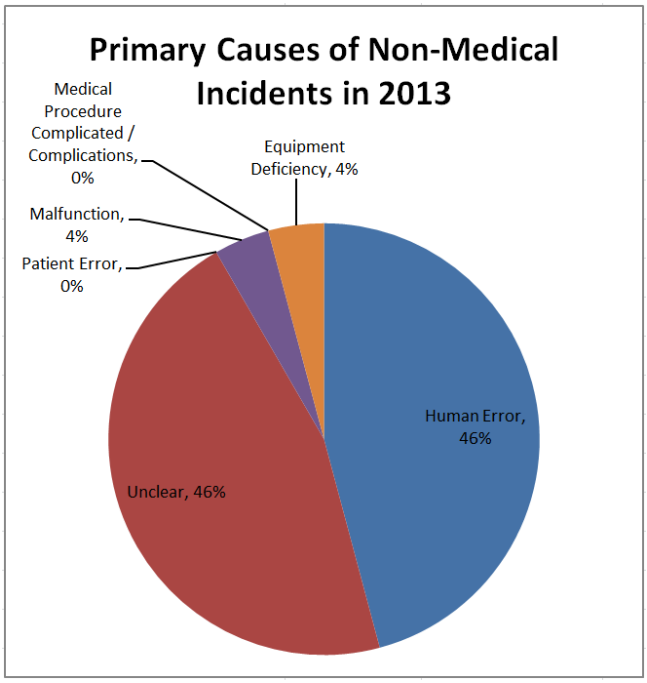

Figure 4: Primary causes of non-medical incidents in 2013 as a percentage of non-medical incidents.

In addition to the primary causes of medical and non-medical incidents, the significant contributing causes of the incident and the significant preventative measures actioned by the user/operator during 2013 can be seen below in Figures 5 to 8. In addition these figures also show that many ARIR reports don't describe any contributing causes or preventative measures. This is an area where reporting practices can be improved.

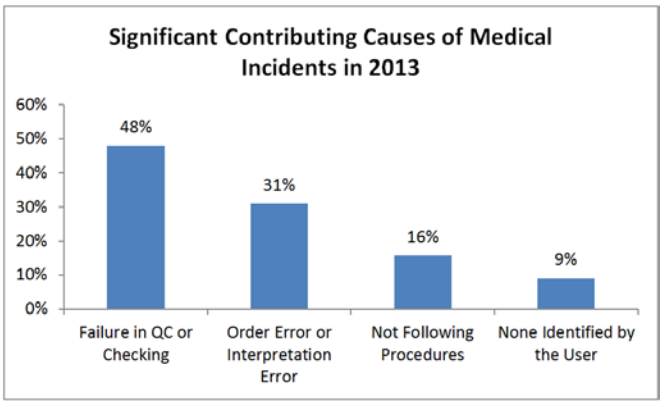

Figure 5: Significant contributing causes of medical incidents in 2013 as a percentage of all medical incidents in the year.

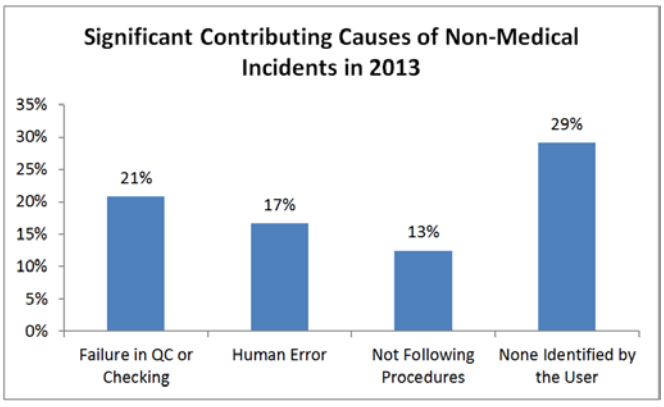

Figure 6: Significant contributing causes of non-medical incidents in 2013 as a percentage of all non-medical incidents in the year.

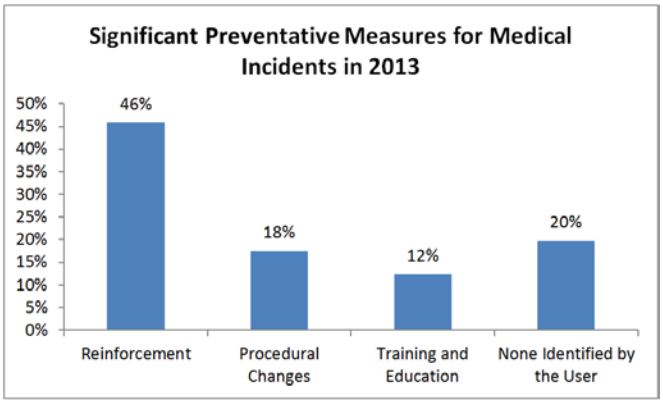

Figure 7: Significant preventive measures for medical incidents in 2013 as a percentage of all medical incidents in the year.

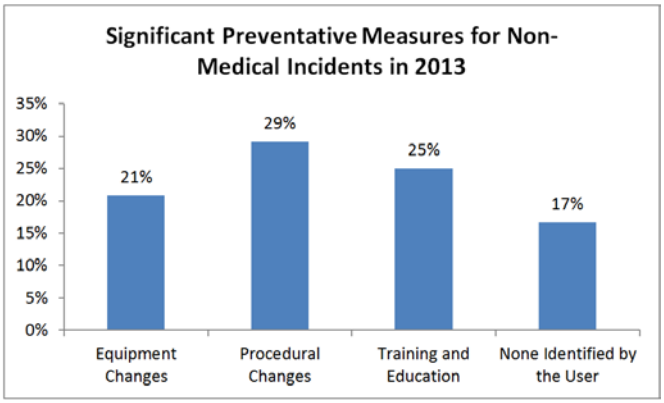

Figure 8: Significant preventative measures for non-medical incidents in 2013 as a percentage of all non-medical incidents in the year.

4.2. Human Error

Incident reports stated human error as the primary cause in 69% of all the 2013 incidents. The cause of a further 16% of all incidents was not specified in the incident report but it is possible that the majority of these were also caused by human error.

Analysis of the reports does not always permit the determination of contributing factors that led to the human error. 11% of all the incident reports didn't contain sufficient information to determine a contributing cause. Where apparent, the largest contributing causes as a percentage of all the incident reports are a failure in quality checks and quality control (45%), errors in orders or in the interpretation of order instructions (27%), not following procedures (15%), general human errors (11%), and poor patient verbal communication for medical incidents (5%). Production pressures were listed as a contributing cause in only 6% of human errors incidents, a relatively low number which may provide a positive indication of safety culture.

In roughly 89% of all the incidents that provided some insight on contributing causes, it is apparent that there were multiple failures associated with the incident. In these cases it is quite possible that the incident may not have occurred if some of the contributing causes had been prevented.

A review of the 138 incidents where human error was the primary cause indicates that the focus of preventative measures is directed at reinforcement/reminders of good practice to staff (58% of the 138 incidents), procedural changes (23%) and training and education (20%). In a few cases reinforcement/reminders were escalated and formal warnings were issued. About 1% of these reports suggested improving the IT/software systems and internal reviews were reported to have been conducted in only 9% of cases where human error was the primary cause.

Human Factors improvements were implemented after some incidents. Many of these were relatively simple to implement. Examples include; improved labelling; rationalised storage of sources, and improvements in communications protocols and procedures.

In 7% of incident reports where human error was the primary cause there was no preventative measures indicated to prevent repeat incidents.

4.3. Unclear

There was insufficient data contained in 33 (16%) incident reports received by the Register in 2013 to determine a primary cause of the incident. Information provided to the Register is processed beforehand by the Commonwealth, State and Territory regulators to remove any identifying information. An inability to determine the cause from the Register data does not imply that an incident has not been properly investigated within its own Commonwealth, State or Territory jurisdiction.

ARPANSA, in conjunction with the Radiation Health Committee (RHC) is currently reviewing reporting requirements with the aim of capturing more information to aid cross jurisdictional learning. This will include improvements on root cause analysis of incidents.

4.4. Patient Error or Factors Beyond Control

There were ten instances reported of medical procedures to patients who were unknowingly pregnant at the time. From information provided in the reports there was no clinical error made in performing the procedures. Only in one of these incidents was the patient not asked if she was pregnant.

One incident involved a nuclear medicine patient that collapsed and became incontinent while in the hot waiting room of a nuclear medicine department. The patient had been injected with a radiopharmaceutical one hour earlier. This resulted in contamination of the patient's clothing, a chair, the floor, a bed and responder's foot ware. Following this incident decontamination and isolation occurred with all contaminated items returning to background radiation levels after one day. The dose to the patient was unknown and no preventative measures were identified.

4.5. Equipment Malfunction

The reported incidence of equipment malfunction leading to a radiation incident was low at 5% of all incidents in 2013 with about 91% of these incidents relating to medical incidents. No common failure of equipment was identified in the data submitted to the Register.

The types of causes of a malfunction or breakdown resulting in a medical radiation incident can be seen in Figure 9.
For computed tomography (CT) related causes the malfunctions were related to, for example, an electronic communication error occurring between the patient bed and the CT scanner, and the CT scanner unexpectedly stopped working. For x-ray system related causes the malfunctions were related to failure of the: (1) automatic exposure control (one incident), (2) equipment or software which resulted in the scan image being lost (one incident), (3) generator (one incident), (4) digitiser (one incident), and (5) equipment to adjust correctly the exposure parameters for the size of the patient (one incident). The Register also reported an incident where a hospital's power supply was disrupted which caused

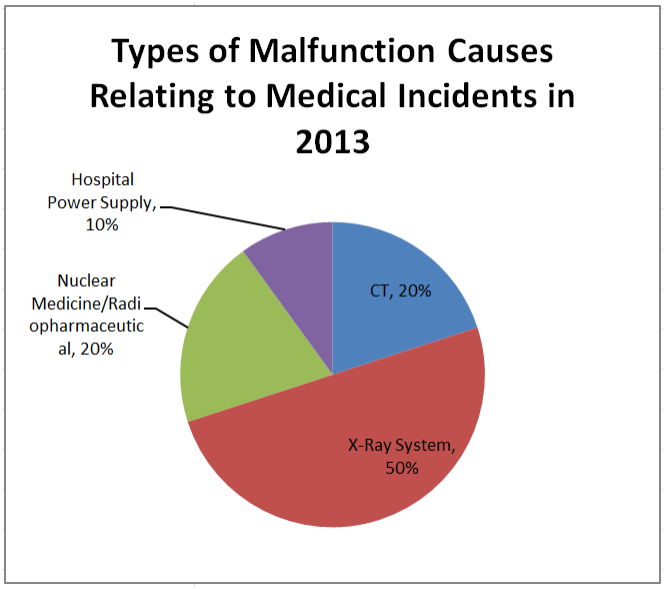

Figure 9: Types of malfunction causes that relate to medical incidents in 2013 as a percentage of all malfunction primary cause incidents in the year.

disruption to a patient's renal scan resulting in the scan data being unrecoverable and requiring the scan to be repeated.

Outside of the medical industry there was one incident where, during the production process, a radioactive gas leaked from a cyclotron research facility. The gas passed through a hot cell exhaust and into the outside environment. No radioactive material was leaked into the facility. The total activity released into the outside environment was estimated to be 25 GBq and the maximum activity concentration was estimated to be 500 MBq/m^3 which was released over a period not exceeding 5 minutes. Lower activity levels were measured over approximately 30 minutes. An estimate of the effective dose a person remaining in the vicinity at the ground level for several hours was negligible at 0.04 µSv (micro Sieverts). This operator undertook an internal review and actioned preventative measures to improve safety such as including modifying procedures, and changing the production process and equipment to reduce the amount of radioactive gas that can be released to the environment.

4.6. Medical Procedure was Complicated or Complications

During 2013 there were seven medical incidents (or 4% of all medical incidents) where the primary cause was attributed to the medical procedure being complicated or there were clinical complications during the procedure. Each resulted in the patient receiving a higher than expected skin dose in the range of 7 to 31 Gy (Gray). Of these incidents, only one mentioned that acute skin effects (or erythema[3]) were observed. Two incident reports described that no acute skin effects were observed and the remainder didn't state whether acute skin effects were observed. No preventative measures were described for any of these incidents.

4.7. Equipment Deficiency

Of the three incidents (or 1% of all incidents) where the primary cause was attributed to equipment deficiency, one was related to non-medical and two related to medical incidents.

The one non-medical incident was caused by a failure in the design of a programmable logic controller (PLC) panel to adequately filter out electric noise signals. This design failure resulted in radiation shielding at a facility (which is controlled by a PLC) to be removed which caused the local radiation area monitors to alarm. When the monitors alarmed the area was evacuated which resulted in only one person receiving a dose of 1 µSv while all other people received zero. To improve safety the facility operator conducted an internal review and upgraded the equipment.

The two medical incidents were caused by failed batches of radiopharmaceuticals. It was reported that one of these batches was withdrawn from clinical use. The supplier was contacted to investigate these failures. A failure in quality control and/or checking was reported to have been a contributing cause in one incident. However the incident reports didn't include detailed information on the findings of the supplier or for the contributing causes.

5. Incidents by Category

This section reviews category specific data for incidents reported in 2013. Most incidents reported were medical incidents with causes associated with a range of medical practice that are not specific to radiation incidents.

[3] Further information on erythema caused by medical use of radiation can be found at the IAEA website.

Descriptions of incidents within the various sub-categories are provided if the radiation exposure or lessons learnt are considered significant.

5.1. Diagnostic Radiology: 112 Incidents

Of the 112 reported incidents in diagnostic radiology, 60 involved CT scans, 42 involved x-ray scans and ten surgical procedures with x-ray. The average effective doses of non-surgical CT and x-ray scans were about 9 mSv and 0.4 mSv respectively. The highest individual absorbed dose was a 31 Gy skin dose received due to complications during a complex coronary angiographic procedure. No skin changes were observed suggesting that the dose was not concentrated to a small area of skin. Sub-categorisations of diagnostic radiology incidents for 2013 are shown in Figure 10.

In regard to Figure 10, all sub-categories are typical of general clinical environments, i.e. they are causes which can be seen across many medical practices and are not restricted to medical procedures involving radiation. The 'Other' sub-category primarily included incidents during surgical procedures with x-rays.

Further details regarding non-surgical CT and x-ray incidents that resulted in the highest exposures are described below.

A hospital patient was booked for a CT scan of the abdominal aorta. The scan was initially attempted, and this did not produce an adequate result. A further two attempts to perform the scan were made, neither of which were diagnostically viable. The total effective dose to the patient as a result of the three failed scans was estimated to be approximately 125 mSv. In response to the incident, the hospital's radiation team initiated an investigation leading to disciplinary actions due to concerns about over-ranging and radiation protection.

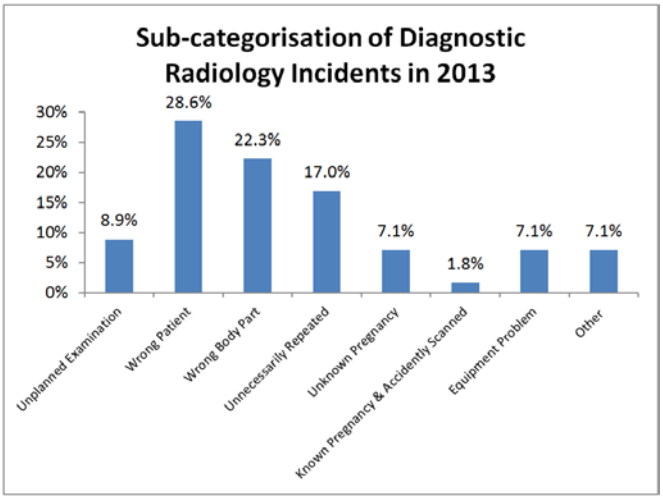

Figure 10: Sub-categorisation of Diagnostic Radiology incidents in 2013. Values expressed as a percentage of the total number of Diagnostic Radiology incidents in the year.

A patient presented for a lumbar spine series at a medical imaging practice. All requisite identification and pregnancy checks were carried out including the date of the last menstrual period (LMP). The LMP was about two weeks prior to the date of the examination. About three weeks after the examination, the practice was notified by the patient's obstetrician that the patient had been pregnant at the time of the examination. The dose to the foetus was approximately 3.73 mSv. A written contextual risk assessment was provided to the patient's obstetrician. The primary cause of this incident is unclear due to insufficient information in the incident report. However, a contributing cause is likely to be unknown pregnancy. No preventative measures were recommended by this operator in the incident report.

5.2. Nuclear Medicine: 51 Incidents

The average effective dose received by patients in reported incidents involving nuclear medicine was approximately 5.4 mSv. The reported primary cause in the majority of incidents was human error (33 incidents). Where identified

the largest contributing causes was a failure of quality control or checking (21 incidents) and the largest preventative measure was reinforcement (13 incidents). Incidents within different sub-categories are shown in Table 2.

Nuclear Medicine Sub-category	% of Nuclear Medicine Incidents (rounded)
Incorrect Diagnostic Scanning Agent/Radiopharmaceutical Given	25 %
Unnecessary Administration of a Radiopharmaceutical	22 %
Radiopharmaceutical Preparation or Supply Error	10 %
Radiopharmaceutical Delivery Error (e.g. extravasated, subcutaneous delivery, cannula disconnected)	10 %
Equipment Malfunction	6 %
Incorrect Scanning Procedure Performed	6 %
Scanning Agent/Radiopharmaceutical Administered But Scan Not performed	6 %
Wrong Dose / incorrect Activity	2 %
Wrong Patient	2 %
Unnecessary Repeat Scan	2 %
Unknown Pregnancy	2 %
Patient was Administered a Scanning Agent/Radiopharmaceutical But it Resulted in a Poor Image	2 %
Patient was Administered a Scanning Agent/Radiopharmaceutical and Subsequently Breastfed her Child Resulting in the Child Receiving a Radiation Dose	2 %
Patient and Medical Staff were Contaminated with a Radiopharmaceutical when the Patient became Incontinent	2 %
Cyclotron Operated without Operational Cyclotron/Vault Safety Interlocks. However No Dose to People.	2 %

Table 2: Sub-categorisation of nuclear medicine incidents in 2013.

A causal analysis of the first three sub-categories in Table 2 identified that:

- Human error was the primary cause in all three sub-categories (a total of 23 incidents).
- The most common contributing causes was a failure in quality control or checking (17 incidents), order error or interpretation error (6 incidents), and production pressure (5 incidents).
- The most common preventative measures was reinforcement (10 incidents), internal reviews (6 incidents), and procedural changes (6 incidents).

Further analysis of the sub-category incorrect diagnostic scanning agent/radiopharmaceutical given, identified that:

- Maladministration of radiopharmaceuticals containing Tc-99m (Technetium 99m)[4] accounted for all but one incident. The other incident involved maladministration of Tl-201 (Thallium 201).
- An incident or error was detected usually when medical personnel viewed the images of the scan and realised that the images weren't what they expected.
- Where a patient is administered the incorrect radiopharmaceutical, labelling errors are frequently reported as contributing factors. These errors can occur by the radio pharmacist, nuclear medicine technologist or physician. The similarity of labels and packaging may also be contributing to errors, for example a report described HDP and Sestamibi being contained in identical syringes with only the details marked on the labels

[4] Tc-99m is the most common radioisotope used in medicine. Further information can be seen here and here.

used to distinguish the two products. Quality control or checking was a common theme and included one case where the name of the unit dose was not checked against the labelled vial prior to dispensing the unit dose.

- One case involved the failure of the MDP cold kit product. However the cause of the failure wasn't described in the report.
- One incident involved a patient being incorrectly administered Tl-201 Thallous Chloride because the radiopharmaceutical had been incorrectly logged against the patient in the schedule by a nuclear medicine technologist.
- Reinforcement remained the most common preventative measure followed by improved labelling and/or storage, and training and education.

5.3. Radiotherapy: 9 Incidents

There were nine incidents reported for radiotherapy. The primary cause of eight of these was human error. The other one was unclear due to insufficient information in the report. Sub-categories of diagnostic radiology incidents in 2013 are shown in Figure 11. Further details on the sub-categories incorrect dose and wrong region for the 2013 year are described below.

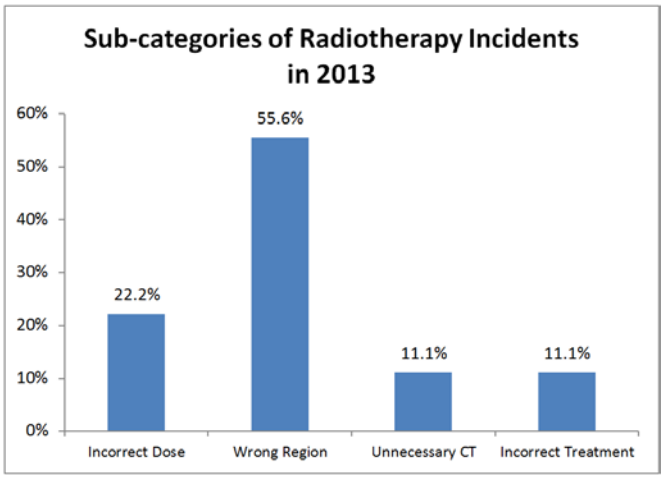

Figure 11: Sub-categories of Radiotherapy incidents in 2013. Values for each sub-category are expressed as a percentage of the total number of Radiotherapy incidents in the year.

One incident was caused when the patient identity protocol wasn't followed which resulted in the wrong patient receiving a dose of 5.22 Gy. In this case the operator used reinforcement as the primary tool to improve work practices.

Another case of incorrect dose involved a patient undergoing brachytherapy and who was prescribed a non-standard treatment. During the second fraction of a three fraction treatment, the prescribed treatment plan was not checked and the patient received a standard treatment instead incurring an additional dose of 1.5 Gy. This case was primarily caused by human error with a number of contributing causes, such as failure in following and checking the order, and new software and display information. Following this incident the operator conducted an internal review, changed procedures and improved labelling to prevent further incidents.

Regarding the wrong area sub-category, human error was the primary cause for all incidents. Common contributing causes included failure in checking treatment orders and settings, understaffing, collective/individual skill levels not sufficient, lack of task familiarity, wrong tattoos being used, and production pressures (including because the patient was anxious and/or in pain). Examples of these incidents are described below.

A patient receiving treatment for breast cancer inadvertently received treatment to the wrong breast. Contributing causes were a failure of standard checks, less task familiarity (since senior staff had left the department placing a higher burden on junior staff), work load pressures due to a public holiday, and incorrect documentation was used. Preventative measures included the operator requesting that more senior staff are employed, protocol changes, an automated system introduced so that the bed movement will occur directly from the treatment plan, and new treatments will not commence on the weekend.

A patient incorrectly received treatment in the wrong region of the spine for one fraction with a dose of 4 Gy. During the treatment there was a bed interlock that didn't clear so supervisory staff were distracted in resolving this issue. As a result a student therapist incorrectly input the treatment field region that was verbally read out by a supervisory staff. The field region parameters weren't checked by the supervisory staff. This error wasn't noticed until setting the field for the second treatment area. This case highlighted task familiarity and student supervision as contributing causes. No preventative measures were described in this report.

5.4. Borehole Logging: 5 Incidents

Four of the five incidents involved a source being stuck in an offshore well that was unable to be recovered.

The fifth incident involved a neutron generating borehole logging tool that wasn't shielded properly during use. However, since the operator had a 9 metre (30 foot) exclusion zone, barriers, a verbal announcement over a public address system, radiation monitor and personal dosimeters for staff, the dose to staff from this incident was negligible. The incident was caused by human error since a field personnel failed to identify the correct position of the source. The operator subsequently conducted an internal review and updated procedures to improve work practices.

5.5. External Exposure (non-medical): 4 Incidents

An incident occurred at an industrial processing facility where workers may have been exposed to a radiation detector/gauge. The facility had been in the process of changing some aging gauges when a worker saw that a gauge had already been removed from its location and was sitting on the ground. The area was cleared and a gamma radiation survey was conducted to ensure the gauge shutter was functioning properly. The removed gauge was then transported to the secure gauge store. The report didn't state if any workers received a radiation dose. Human error is considered the primary cause of this incident with a lack of task familiarity a potential contributing cause. The operator is planning to improve the training of key personnel to prevent further incidents.

One incident occurred at a research facility when an area radiation monitor alarmed. Upon investigation it was identified that an electrically controlled radiation shield was in the open position when it should've been closed. No personnel were significantly exposed to radiation. An investigator did record a dose of 1 µSv on their personal dosimeter while conducting the investigation. The operator concluded that the design of the electrical control system was inadequate. The primary cause was the electric noise in the control circuits. Recommendations for improvement of the design and an appropriate immediate remedy have been implemented.

Two incidents occurred at separate metal recycler/dealers. The first incident involved personnel cutting off the ballast ring of a washing machine that contained Th-232 (Thorium 232) as ballast following radiation monitors previously alarming. The second incident occurred when the radiation monitor was alarmed by an object in a shipping container. The object was on old aviation meter that contained Ra-226 (Radium 226) paint. Following both of these incidents the radioactive material or object was taken to an interim storage facility. The reports didn't state whether personnel received a radiation dose and no preventative measures were recommended.

5.6. Contamination: 3 Incidents

An incident occurred at a research facility when there was an accidental release of short-lived (half-life 20 min) C-11 on the form of carbon dioxide and carbon monoxide gases to the outdoor environment. During the production process, some of this material leaked out of the system and was drawn up through the exhaust, and out of the top of the building. The primary reason of this leakage is currently unknown, but is considered to be equipment failure or malfunction and not human error. No radioactive material was released within the research facility building. The total activity released to the environment was approximately 25 GBq. The maximum activity concentration was estimated to be 500 MBq/m^3 over a period of no more than 5 minutes. Lower levels were measured over approximately 30 minutes. An estimate of the effective dose a person could receive at the ground level if they remained in the plume for several hours is a maximum of 0.04 µSv (which is a very small dose). Following this incident the operator conducted a review and recommended a number of changes including using new equipment, a different process, using a delay loop to reduce the activity of the radioactive material prior to any discharge and updating procedures.

Note: Two further contamination incidents within a laboratory environment are described under the Laboratory category in section 5.8.

5.7. Dental: 2 Incidents

One incident involved a patient that was ordered two different types of x-ray scans. However, it was later determined that one of these scans was unnecessary. The effective dose to the patient was 10 µSv. The other incident occurred when a patient who was unknowingly pregnant received an x-ray scan. The dental clinic followed all standard procedures and the patient denied they were pregnant prior to the scan. The dose to the foetus was estimated to be less than 0.01 mGy.

5.8. Laboratory: 2 Incidents

While undertaking quality control testing at a research facility, a worker became contaminated with a liquid radioactive material. The incident occurred whilst the person handled and then accidently dropped a syringe containing the liquid radioactive material onto their hand. The worker's hands, some clothing and personal items were inadvertently contaminated with this material. The operator's analysis of dose implications from this incident estimated that the person received an extremity/skin dose of 355 mSv to their hands[5]. This incident was also assessed by the operator as a near miss for an accident with a potential extremity dose of 7.1 Sv. The primary cause of this incident was human error. A number of contributing causes were identified, including: failure to adequately identify and assess the hazards and risks associated with the process; failure to follow work procedures and limits of approvals; failure to perform routine contamination checks of hands and gloves; reduction in the frequency of health physics surveys; facility staff lacking knowledge of authorised limits; lessons already learnt in other parts of the organisation were not transferred to this facility; and the change control process wasn't followed. The operator completed an investigation of this incident, and identified amongst many findings, that the latex gloves worn by the exposed worker may not have been the most appropriate material when working with organic solvents. Further analysis will be undertaken by the operator to determine the best gloves and whether double-gloving will be used. Following the incident, some improvements to the workplace were undertaken to improve human factors, including

[5] The annual equivalent dose limit to the skin is 500 mSv for occupational exposure (Schedule 1 of Radiation Protection Series No. 6 *National Directory for Radiation Protection* (republished February 2014)).

the installation of a wall mounted contamination monitor, changes in layout of the laboratory for locations of specific equipment, and better signage and work practices.

The second contamination incident occurred following approximately 13 GBq of liquid iodine-131 being spilt on a laboratory floor and contaminating an area of approximately 1 m^2 within a designated radiation area. The spill was contained with absorbent materials and shielded with lead bricks pending further assessment and decontamination. The primary cause was unclear since the pot containing the radioactive source cannot be closely examined until the contamination decays to a safe level. Initial findings suggest that there may have been a mechanical failure of the tungsten pot or that the lid was not correctly screwed on. A number of preventative measures have been identified including radiation safety training to workers, radiation monitors with non-SI units will be replaced, electronic dosimeters will be available on site, tungsten pots with handles attached to the lid will be replaced, and personnel must verify that the lid is correctly closed before shipment.

5.9. Portable Density/Moisture Gauge: 2 Incidents

Both incidents occurred because a gauge was run over or hit by a vehicle. Damage was to the apparatus only and not to the shielding or source. Human error was the primary cause in both cases with inexperienced personnel a factor in one incident. One of the preventative measures included additional training for all technicians on the importance of controlling the work area (including the appropriate use of signage).

5.10. Transport: 3 Incidents

An incident occurred when a vehicle driven by an intoxicated driver crashed into a parked vehicle which was carrying a radiation moisture gauge. This incident occurred in a suburban area. The gauge was checked for damage and taken to a laboratory for further testing. No damage was reported to the gauge.

Another incident occurred when one disused 44 gallon drum that was labelled Radioactive LSA (Low Specific Activity) was found in the scrub about 800 metres from a road. This type of drum is usually used for the transport of uranium ores and concentrates. Radiation surveys were conducted and it was confirmed that no radioactive material was found in the drum. However, the area was cordoned off because uranium ore could have leached in to the soil. The drum was traced back to a local mine operator who conducted an investigation. The investigation concluded that the drums were disposed of several years ago when a different type of drum was introduced. These drums never contained radioactive material. This incident was caused by human error due to not removing the radioactive label from a drum that didn't contain radioactive material prior to safe disposal.

5.11. High Recorded Dose: 1 Incident

An incident occurred at a hospital when two radiopharmaceutical radiation workers exceeded their monthly extremity dose limit. The extremity dose was estimated to be 73.57 mSv. The primary cause could not be determined from the report.

5.12. Industrial Radiography: 1 Incident

The unshielded lid was found to be on the source holder of a non-destructive testing kit used for testing radiation shielding. The unshielded lid should not be used when the source is in the container which it was in this instance.

The shielded lid was then immediately attached. Both shielded and unshielded lids are the same colour but labelled with different coloured stickers. Due to low occupancy of the area the estimated dose to people was estimated to be very small. This incident was primarily caused by human error since a worker didn't follow the procedures for safe work practices. The operator has since spray painted the unshielded lid in an obvious colour to distinguish it from the shielded lid. All workers were notified of this change and told to be vigilant when storing the source holder.

5.13. Mining: 1 Incident

Up to 1.5 million litres of radioactive slurry (a mixture of mud, water, uranium ore and acid) spilled when a leaching tank split open. Workers were evacuated and production shut down. The tank lost its contents within half an hour. No workers were reported to have received a radiation dose. An investigation into the cause of this incident was ongoing when this incident report was submitted. Therefore the primary cause is currently not reported.

5.14. Nuclear Safety: 1 Incident

Unauthorised material was found in a restricted area in a facility. The material was packaging from spare parts and whilst it had no actual consequence on this occasion, it was considered to be a nuclear safety risk. This human error resulted when procedures weren't followed and there was a failure to check the area for unauthorised items. Preventative measures included removing the material from the area, reinforcement of work procedures to staff and induction refresher training. It is planned to phase out the use of packaging material at the facility.

5.15. Radiation Gauge: 1 Incident

A radiation gauge containing a caesium-137 sealed source was found stored at an industrial facility and later safely disposed overseas. Due to a lack of information in the incident report the primary cause is unknown.

5.16. Sources Found: 1 Incident

A person found a vial containing radium underneath a relative's house. The local regulator was contacted and they placed the vial into a shielded lead container and took it into possession. The estimated exposure to a person was 0.01 mSv. The primary cause is unknown due to insufficient information within the incident report.

5.17. Theft of Sources: 1 Incident

Local Police notified the local regulator that a member of the public had discovered two empty boxes labelled "Radioactive Material" at a park. The boxes were used to transport radiopharmaceuticals and had been were stolen from where they were left outside a hospital whilst awaiting collection by the supplier. The boxes and the area where they were found were monitored for radioactive contamination and were found to be uncontaminated. The boxes were later returned to the radiopharmaceutical supplier. No preventative measures were described in the incident report.

5.18. Unauthorised Disposal of Source: 1 Incident

A company disposed to landfill a fixed radiation gauge containing a 22 GBq americium-241 sealed source without approval from the local regulator. Instead of seeking approval from the local regulator, the company mistakenly sought approval from the local landfill operator. The landfill operator used a radiation survey meter to assess the

radiation gauge and measured a dose rate of less than 5 µSv/h and deemed the gauge to be acceptable for landfill. The landfill operator erroneously indicated that its standard operating procedure states that an item with a radiation dose rate at the surface of less than 5 µSv/h can be accepted for landfill. The radiation gauge went to landfill and had at least two metres of coverage. The local regulator conducted an investigation and determined that the radiation gauge had to be recovered from the landfill and returned to the company for correct disposal by an organisation that is authorised to dispose of radioactive sources. The incident was primarily caused by human error and not following procedures. No preventative measures were identified in the report.

6. Comments and Conclusions

The number of incidents reported in 2013 increased substantially from previous years. ARPANSA has actively promoted the benefits of reporting all incidents, including low level and near-miss events. Recent increases are considered to be likely due to an increase in reporting rates rather than an increase in incidents.

The health and environmental impact of individual incidents is not derivable from reports submitted to the register. ARPANSA, State and Territory Radiation regulators base radiation protection practices on the recommendations of the International Commission on Radiological Protection (ICRP). To assess the risk of harm, in particular cancer later in life, the ICRP use a linear no-threshold model (LNT) for the purpose of radiological protection, where the risk of biological damage from ionising radiation is assumed to be directly proportional to the dose. Under this model the risk of harm rises from zero dose, i.e. even small amounts of radiation carry a risk of harm. However, in general, health effects of radiation in a population do not become statistically evident until an effective dose approaching 100 mSv is received, although for absorbed doses to specific organs, diseases in such organs may become discernible in defined and sufficiently large sub-groups of the population at exposures corresponding to a few tens of mGy. For acute tissue reactions (or 'deterministic effects') to be observed, much higher exposures are required. This implies that the majority of incidents reported to the register, for example from diagnostic radiology, will have no observable health impact. Radiotherapy and nuclear medicine procedures do have a higher risk of harm even when correctly administered due to 'collateral' harm to adjacent tissues. Maladministration during such procedures can cause significant damage to healthy tissue.

These principles of risk, and the identification of mitigation methods, underpin the value of good reporting to the register for both high impact radiation practices (e.g. radiotherapy and nuclear medicine) and more common but lower impact practices (e.g. conventional x-ray and CT).

Analysis of incident causes indicates that many had multiple contributing causes and it is quite possible that the incident would not have occurred if one of the contributing causes had been prevented. This is the basis for the 'Swiss Cheese' model of safety described by Prof James Reason (*Human Error, Reason J, Cambridge University Press. 1990)* , where an incident or accident occurs only where there is an alignment of vulnerabilities. Shoring up vulnerabilities or adding additional controls can block a pathway leading to the incident and often small changes to operating environments can bring about a meaningful reduction in the number of incidents and accidents that occur.

The majority of reported incidents cite human error as the primary cause. Analysis of contributing causes and preventative measures suggests that there is high reliance on actions taken by individuals rather than other passive or active systems (e.g. processes, procedures, physical or engineered barriers). Whilst this is to be expected in many applications of radiation use, the information in incident reports suggests that many of the contributing causes could be identified beforehand. In the majority of occurrences, similar incidents have been reported previously to the Register. Examples include failures in quality control processes, particularly cross checking of information, problems

with labelling and ordering systems and more general communication issues. Many of these contributing causes are associated with skill and rule based human performance. Reinforcement of correct processes or practices, improving procedures, and training and education were the most common three preventative measures in the 2013 incident reports. Task analysis can assist in matching processes and instructions to the strengths and weaknesses in skill and rule based human performance and may lead to long lasting improvements. Surprisingly internal reviews were reported to have been conducted in only 9% of incidents where human error was the primary cause. Organisations often gain deeper knowledge on the root cause and contributing causes of an incident following an internal review and therefore can implement improvements that directly aid in preventing similar occurrences.