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Australian Radiation Protection and Nuclear Safety Agency

arpansa

Australian Radiation Incident Register

Annual Report

Report covering incidents occurring in 2021

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ARPANSA
619 Lower Plenty Road
YALLAMBIE VIC 3085
Tel: 1800 022 333 (Freecall) or +61 3 9433 2211

Email: info@arpansa.gov.au
Website: www.arpansa.gov.au

Preface

The Australian Radiation Incident Register (ARIR) is a repository of radiation incident information from Commonwealth, state and territory radiation regulators. It is intended to raise awareness of radiation safety and to facilitate the sharing of lessons learnt from radiation incidents across Australia.

The National Directory for Radiation Protection (2nd Edition, 2021) in schedule 4 specifies the types of incidents that must be reported to the Australian Radiation Protection and Nuclear Safety Agency (ARPANSA) for compilation in the ARIR. These reporting arrangements are agreed to by all jurisdictions through the Radiation Health Committee (RHC) and the *National Directory for Radiation Protection* (NDRP), endorsed by Australian Health Ministers. Reporting of other radiation incidents is encouraged, including minor events, near misses and other opportunities which could lead to valuable learnings. More information on the RHC and ARIR can be found on the ARPANSA website: arpansa.gov.au.

This report was approved for publication in October 2024 following consultation with professional bodies and state and territory regulators.

Purpose and scope

This report is a summary of data submitted to the ARIR for incidents that occurred in 2021.

The purpose of the ARIR is to raise awareness of the risks associated with common tasks involving radiation, share the learnings identified as a result of incidents, and assist in the identification of topical areas where safety efforts may be focused to improve radiation protection.

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

Source of the incident reports

Incidents are reported to regulators by users of radiation in their jurisdiction. The regulator submits incidents to the ARIR based on the user reports received. While the specific requirements for incident reporting vary between jurisdictions, the NDRP outlines the common requirements for reporting of incidents to the ARIR. Due to the differences in state legislation and differing levels of promotion for reporting of incidents to the ARIR, some jurisdictions report more than others. For example, some jurisdictions do not regulate certain types of non-ionising radiation and so do not receive incident reports related to these types of sources.

Incidents are typically investigated by the reporting organisation and where applicable the local regulator. The reports identify the direct cause and contributing factors that led to the incident, as well as recommendations or preventative actions implemented to avoid recurrence. No additional investigation is undertaken as part of the preparation of this report. However, additional information may be requested to help categorise incidents and to ensure learnings can be shared.

In some instances, individual incidents that occurred in 2021 are summarised and highlighted. These provide insight into the circumstances of the incident and include the lessons to be learnt, which are typically identified by the reporter or in some instances by the submitting regulator. As such the learnings may not necessarily represent the views of ARPANSA and may not be appropriate for all situations. Similarly, the reporter-estimated effective/absorbed doses are based either on calculated individual dose or, where unavailable, on typical doses for that procedure.

While ARPANSA has performed basic quality assurance on the data, the information presented is based on the reports submitted to ARPANSA and may contain inaccuracies and may be amended from time to time.

Contents

Summary of incidents occurring in 2021

Radiation is routinely used across Australia by more than 50,000 licensed users who perform millions of individual tasks each year. The incidents that occur and the nature of the resulting outcomes show that the use of radiation in Australia is generally very safe. However, unexpected events occasionally occur even with safety controls in place. Where such events meet the criteria in the *National Directory for Radiation Protection* (NDRP) they are required to be reported to the relevant regulator, and subsequently to the Australian Radiation Incident Register (ARIR). The register is managed by ARPANSA, who analyse submitted incidents and publish the results to raise awareness of common hazards and to identify and promote practices that could prevent future incidents.

There were 829 incidents reported in 2021, which is a 3% increase from the previous year. The majority of incidents were related to medical imaging, especially computed tomography (CT), projection X-ray and nuclear medicine. Human error was the primary cause of most incidents, followed by equipment malfunction.

The estimated additional effective doses received by patient or workers as a result of incidents was categorised as 'very low'[1], i.e. below 10 mSv, in 93% of incidents.

An incident will often have several contributing factors, such as not following procedures, quality control errors, or order/referral interpretation issues. However, these factors are not always reported to the ARIR. Preventative measures are the actions reported to avoid recurrence of similar incidents including reinforcing procedures, improving communication, or conducting regular quality checks.

This year is the first of the short format reports. ARPANSA intends to work with specialists to produce deeper analysis and findings periodically. The annual summary report provides a snapshot of the incidents that occurred and highlights where significant incidents have been flagged for inclusion.

[1] United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), 2012 Report to the UN General Assembly, Annex A - Attributing health effects to ionizing radiation exposure and inferring risks, UNSCEAR 2012 report.

Overall statistics

Number of incidents reported

The number of incidents reported to the register for 2021 is 829, which is similar to the 2020 figure of 803. After publication an additional 51 incidents were submitted for 2020, bringing the total for 2020 to 854 incidents. Figure 1 shows the number of incidents reported for each year from 2016.

The overall trend of increased reporting numbers is indicative of increased awareness and positive reporting cultures. ARPANSA has been raising awareness of the register and promoting its potential since 2012. This includes upgrades to the database and introduction of a web portal for regulators in 2016. ARPANSA is currently engaging in further projects to encourage increased reporting including an enhanced national reporting system for radiation oncology. Detailed national trend analysis for incidents and events is not possible without stable and consistent reporting practices from all states and territories.

Late submissions are any submissions received after the cut-off period for the reporting cycle, at least 6 months after the end of the calendar year in which the incidents occurred or when the report is prepared.

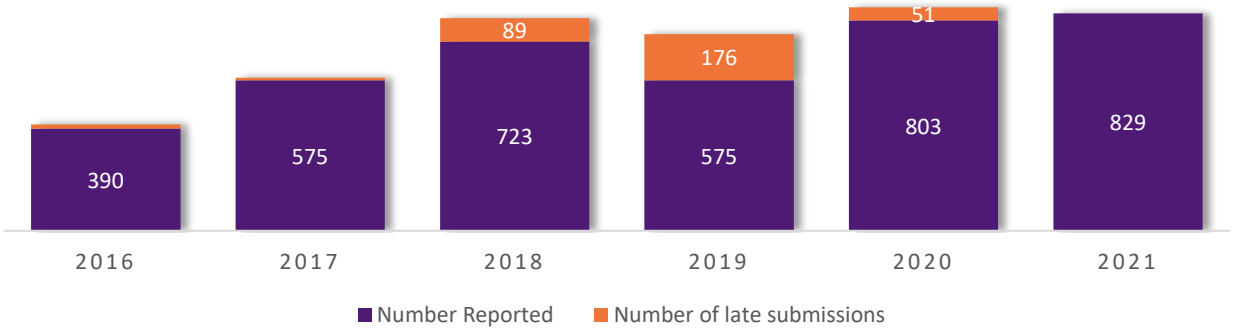

Figure 1: Number of incidents reported to the register over time

Estimated doses received as a result of incidents

Exposure to radiation is reported in terms of the effective dose in millisievert (mSv) where possible. This is a risk-related radiation protection quantity which accounts for the radiation quality and the contributions of organ sensitivity to overall risk of disease later in life after an exposure averaged over the whole body (typically of a patient)[2].

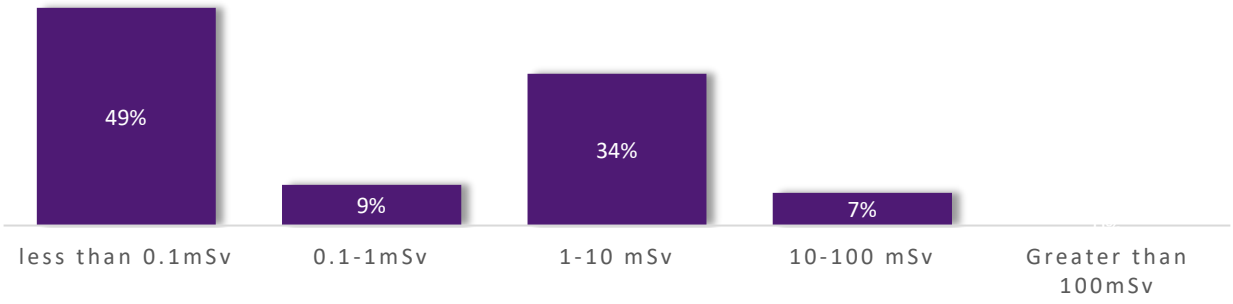

Figure 2: Distribution of effective dose as the result of incidents reported in 2021

Figure 2 illustrates the distribution of effective doses across the incidents reported for 2021. All estimated effective doses were below 100 mSv, the threshold for what is generally referred to as 'low' doses[1]. In addition, 93% of effective doses were 'very low', i.e. below 10 mSv. Risks for disease later in life at such exposures are generally inferred from models and any health effect later in life could not be unequivocally attributed to the specific exposure event. For all events recorded in 2021, inferred risk for future health effects would be low.

Where exposure is to an organ or specific region, absorbed dose in gray (Gy) is used. Localised tissue reactions may occur after exposures of several Gy. Such exposure levels can be reached for instance following a spill of high-activity radiopharmaceuticals, in interventional procedures, and in radiation therapy.

Doses are presented as reported, including doses calculated for an individual patient, or estimated based on the procedure. Incidents are reviewed by the regulatory agencies and ARPANSA for quality control. However, doses reported to the register are typically not independently verified, this includes when no dose information is supplied in which case a best estimate based on typical doses for the type of exposure may be used.

[2] For a discussion on dose and risk, see Publication 147 of the International Commission on Radiological Protection (ICRP) Publications, Use of dose quantities in radiological protection.

Types of incidents reported

Table 1 shows the number of incidents by category over the previous 5 years. The largest category continues to be medical imaging. This is to be expected as more than 16 million diagnostic medical imaging procedures involving radiation were carried out in 2021 in Australia, according to Medicare Benefits Schedule (MBS) information.

Table 1: Overall ARIR statistics for 2021 compared with previous 4 years

	2021		2020		2019		2018		2017	
Incident category	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**
Medical (All)	817	99%	786	98%	556	97%	708	98%	553	96%
Computed tomography (CT)	312	38%	295	37%	208	36%	264	37%	212	37%
Plain Film X-ray/ conventional radiography	205	25%	234	29%	143	25%	247	34%	164	29%
Diagnostic nuclear medicine	166	20%	157	20%	141	25%	131	18%	114	20%
Interventional / Fluoroscopic imaging	30	4%	46	6%	36	6%	45	6%	34	6%
Dental	26	3%	14	2%	5	1%	4	1%	8	1%
Medical - Radiotherapy	78	9%	40	5%	23	4%	17	2%	21	4%
Other	12	1%	17	2%	19	3%	15	2%	22	4%
Contamination	3	<1%	3	<1%	4	<1%	3	<1%	5	1%
Transport of radiation material	2	<1%	4	<1%	3	<1%	2	<1%	0	0%
Imaging (inc. industrial radiography and XRF)	1	<1%	4	<1%	1	<1%	2	<1%	1	0%
Found/lost/stolen	1	<1%	1	<1%	6	<1%	1	<1%	5	1%
Non-Ionising Radiation (inc. laser and IPL)	3	<1%	1	<1%	2	<1%	1	<1%	1	0%
Other	2	<1%	4	<1%	3	<1%	6	<1%	10	2%
Total	**829**		**803**		**575**		**723**		**575**	

Note: percentages are rounded

About Medicare statistics

Medicare statistics are available online which only includes the number of procedures for which Medicare payments are made. As such, the true number of procedures undertaken is higher than that indicated by Medicare statistics. For example, state operated hospitals receive operational funding to perform imaging services which are not rebated against Medicare, and some private imaging is not covered by Medicare. http://medicarestatistics.humanservices.gov.au/

Cause of incidents

Direct cause

Across 2021, human error was reported as the direct cause in 61% (506) of reported incidents. This is consistent with previous years. The direct or initiating cause should not be seen as being more important than contributing factors. Addressing the contributing factors can be more effective in preventing the incident in future or reducing the consequences of outcomes.

Figure 3: Incidents in 2021 by primary cause

Human error means that something has been done that was not intended, not desired by a set of rules, or that led the task or system outside acceptable limits. Human error does not mean a person is at fault but only that the outcome of human actions was undesirable. For more information on this and on elements that lead to human error see the ARPANSA website and Holistic safety guide.

Equipment malfunction includes software and hardware failures. This can include a range of incidents including breaks, glitches, or power failures. Malfunctions may be caused by human error in the design, manufacturing, operation and maintenance of equipment. In contrast, **equipment deficiency** is where the equipment used was not suitable for the task or failed to perform as expected.

Patient factors outside of operator control include where the patient becomes unwell or suffers anxiety (e.g. claustrophobia) or self-discharges. Incidents involving women who are unknowingly pregnant are also included in this category.

Medical procedure complications can result in a higher than normal dose. For example, during a complex surgery a significant fluoroscopic dose may be delivered if the procedure takes longer than is typical. This is reportable as an incident in most jurisdictions.

Contributing factors

An incident will often have several contributing factors. However, these factors are not always identified in the reports submitted to the ARIR. In some instances, such as medical complications during a procedure or equipment failure, these factors may not be readily apparent. In 12% of incidents no information on contributing factors was provided. Analysis of the contributing factors such as why a procedure was not followed can have a wider benefit in exposing underlying vulnerabilities which could result in unrelated incidents. See the table below for examples of contributing factors.

It is possible that the incidents would not have occurred if one of the contributing factors had been addressed. This is the basis for the 'Swiss cheese' model of safety where an incident or accident occurs only where there is an alignment of vulnerabilities. This demonstrates the value of the 'defence in depth' approach to radiation safety where several independent controls contribute to overall safety. With effective monitoring of these controls, it is possible to detect positive or negative deviations from the expected outcomes. This can lead to issues and improvements being identified, which may result in significant reduction in the likelihood of an incident with significant outcomes occurring.

The most common contributing factor was 'individuals not following procedures', which was identified in 30% of incidents. The next most common contributing factors were errors in quality control and issues related to orders or referrals. This is consistent with the findings of previous years.

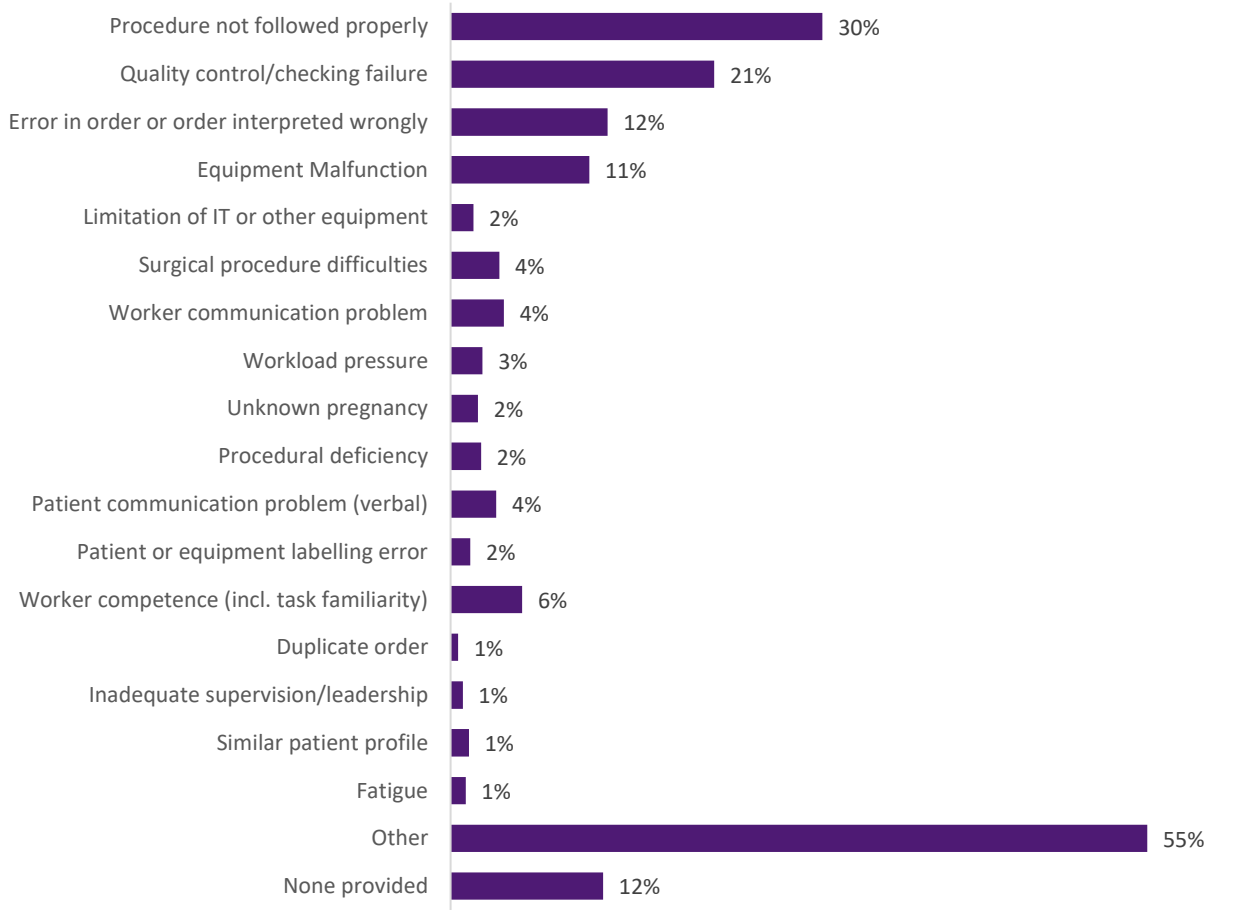

Figure 4: Contributing factors identified in 2021 incidents

Summary of controls and preventative measures implemented

Preventative measures, actions taken to prevent recurrence of similar incidents, were identified in most reports. Examples of incidents where no actions were identified include where equipment faults could not be reproduced, unforeseen patient complications and unknown pregnancies.

Equipment improvements were identified as being made in 26% of reports, most of which involve instances where equipment was serviced or a technician was called out.

The next most common action was reinforcement of procedures which has been the most common action in previous reports. In 2021, such actions were taken in 22% of incidents. However, this remedial action is unlikely to be effective in the long term if used in isolation, especially if they are in relation to lapse or slip errors.

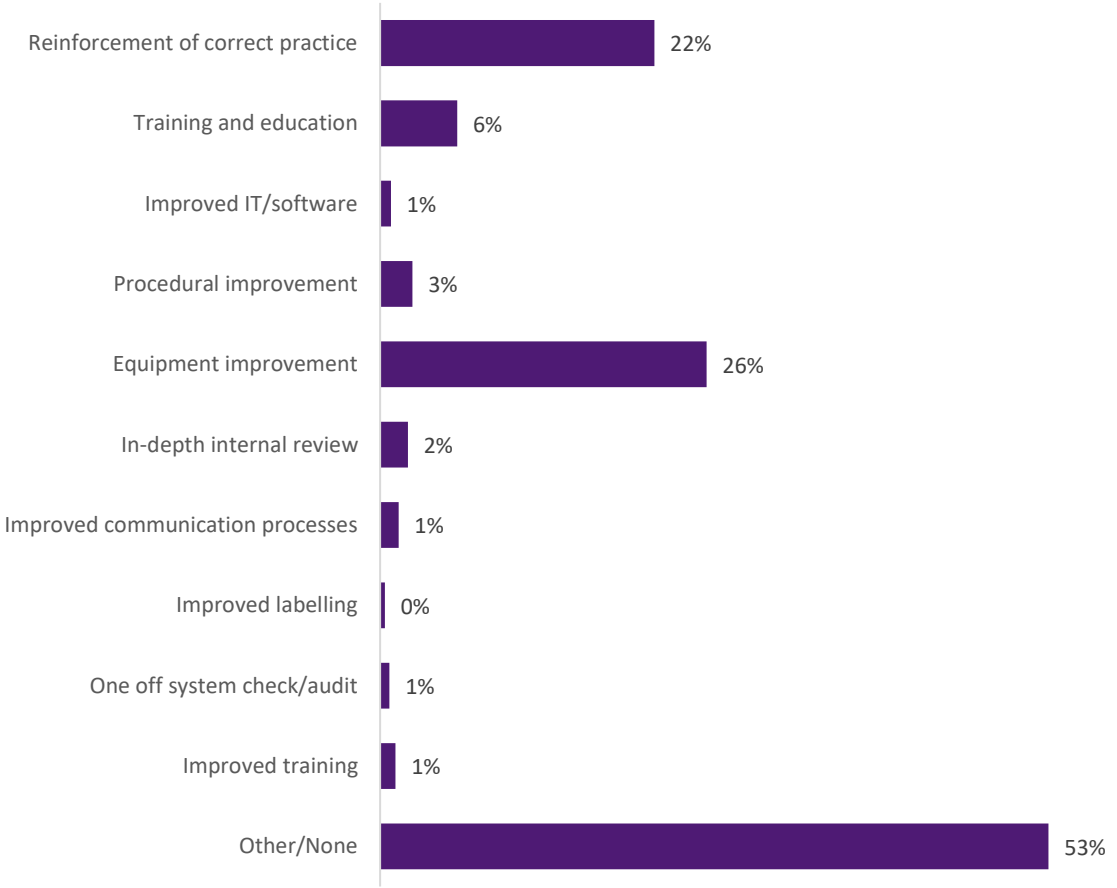

Figure 5: Remedial actions taken to prevent recurrence in 2021

The ARIR Annual Report for incidents in 2020 included nuclear medicine workflows, which provides some examples of where a more holistic approach is undertaken.

Examples of contributing factors and actions or learnings

Example case:	*Factors identified*	*Learnings/Actions*
A patient received a referral for a nuclear medicine scan and a CT scan of the lumbar spine. Upon attending a booking to complete the nuclear medicine scan the radiographer also conducted a CT scan as no record of a lumbar spine CT scan had been captured in the electronic imaging storage system. However, the radiologist identified that the patient had already received the relevant CT scan the week prior at another location of the practice. *The CT scan resulted in unnecessary effective dose of 12 mSv to the patient.*	• **Procedure not followed properly** • **Worker communication** • **Limitation of IT systems**	**Procedures Improvement**: Adequate record keeping protocols and procedures should be reinforced to ensure relevant patient medical data is current, up-to-date, and available to relevant practitioners.
A patient due to undergo a sentinel node lymphoscintigraphy scan was incorrectly injected with Tc-99m labelled Mebrofenin (4 x 80 MBq) rather than Tc-99m labelled Nanoscan. Once the error was identified during the scan, a lower than normal dose of Tc-99m labelled Nanoscan was administered and the study was completed. The patient and referring medical officer were notified of the event. The cause of the incident was deemed to be "inattention to detail when selecting the agent vial prior to reconstitution". Both agent vials had a similar "blue popoff cap" and had labels of different shades of blue. The vials were not properly inspected prior to use and it was speculated that colour may have been used for identification of the radio-pharmaceutical rather than the actual words and name. *The patient received a total effective dose of 5.1 mSv.*	• **Procedure not followed properly** • **Quality control/checking failure** • **Patient or equipment labelling**	**Reinforcement of correct practice:** staff were reminded of the importance of visual inspection. This should be based on direct confirmation of the radiopharmaceutical's identity rather than indirect. **Equipment Improvement**: a new hot lab management system that was being implemented at the time of the incident report is anticipated to reduce the risk of this type of accident.
A doctor requested a CT scan of a patient's lower right leg from the knee down to where the leg had been amputated. The patient's left leg, which had also been amputated, could be seen by the radiographer, but the right leg was hidden under blankets. The radiographer thought the doctor had asked for a scan of the wrong leg and scanned the left leg instead. *The patient received an additional effective dose of about 2.5 mSv.*	• **Procedure not followed properly** • **Error in order or order interpreted incorrectly**	**Reinforcement of correct practice:** the radiographer was reminded to seek advice in cases of uncertainty. Assumptions regarding the intent and accuracy of orders/requests should not be acted upon by staff without adequately consulting the issuing Doctor first.

Summary of incidents

Medical

This category covers medical use including imaging performed using X-ray apparatus and nuclear medicine imaging using radiopharmaceuticals. Dental imaging is also included in this category.

Table 3: Overall statistics for medical incidents by modality

Modality	Number of incidents reported	% of all medical incidents	Effective dose per incident (mSv) Note: does not include skin or critical organ doses.		
			Average	Min	Max
Computed tomography (CT)	312	38%	3.9	0.0	67.0
General X-ray	205	25%	0.3	0.0	5.0
Nuclear medicine	166	20%	3.8	0.0	26.0
Fluoroscopic/interventional	30	4%	N/A	-	-
Dental	26	3%	0.0	0.0	0.7
Radiotherapy	78	10%	N/A	-	-
Non-ionising	1	<1%	N/A	-	-
Total	**818**				

Table 4: Overall statistics for 2021 medical incidents by description

Type	Number of incidents reported	Percentage of all medical incidents	Effective dose per incident (mSv) Note: does not include skin or critical organ doses.		
			Average	Min	Max
Unnecessary scans or scans not as intended	524	64%	2.5	0.0	32.0
Equipment failure	151	18%	3.0	0.0	34.0
Medical procedure complications	34	4%	0.9	0.0	9.3
Unknown pregnancy	26	3%	7.7	0.0	67.0
Spills/Extravasation	31	4%	2.1	0.0	14.1
Other	52	6%	2.7	0.0	15.0
Total/average	**818**				

Unnecessary imaging or exposures not as intended

The most common type of incidents in the medical category were procedures that were not carried out as intended by the referrer. This includes errors in the referral or during imaging leading to the wrong patient being imaged, the wrong procedure, wrong site, or an unnecessarily repeated imaging. These were discussed in detail in the feature topic of the ARIR Annual Report for incidents in 2017. Many of these incidents identify the lack of a timeout – an immediate pause by the healthcare team to confirm details such as the correct patient, procedure, and site – as an important factor. The role of the referrer and the system of referral are also highlighted in a number of incidents.

Equipment Failure

The next most common type of incident was where equipment failure was a primary factor. This is typically equipment malfunction but can include other limitations of the equipment. Equipment related incidents was the feature topic in the ARIR Annual Report for incidents in 2019.

Radiotherapy

Radiotherapy is the use of radiation as treatment, often for cancer. This was the feature topic of the ARIR report for incidents in 2018. The ARIR Development Committee are currently working on enhancements to the system for reporting to improve the quantity and quality of information received about such incidents.

> **Doses in therapy**
> Radiotherapy doses are different from those used in diagnostic imaging. A large dose is delivered to a very specific area for a clinical benefit. Other surrounding areas receive a smaller dose. Rarely the high dose might not be delivered to the correct site. As the absorbed dose (measured in Gy) is concentrated on a specific area this is difficult to compare with an effective dose (Sv) for the whole body.

Table 5: Radiotherapy incident statistics in 2021

Category	Number of reports	Comment	Dose variation (excess/underdose)
Planning/Imaging	45	Pre-treatment imaging dose is low compared to prescribed treatment dose	<20mSv
Incorrect treatment site	10	Often for approximately a third of fractions (e.g. 1 of 3, or 2 of 5)	1-16 Gy
Incorrect treatment dose	5	Includes over- and under-dosing typically for/by one fraction, but sometimes for a whole treatment plan	1-1.5 Gy
Equipment malfunction	14	These incidents required pre-treatment imaging to be repeated, no other impacts on dose were reported	<20mSv
Other	4	Includes unknown pregnancies and administrative error	
Total	**78**		

Other incidents

Category	Number of reports	Maximum Effective Dose (mSv)
Contamination (non-medical, e.g. laboratory)	3	10
Non-ionising (Beauty Services)	1	N/A
Non-ionising (laser)	1	N/A
Radiation Gauges (including Portable Density / Moisture Gauges)	1	<0.1
Sources Found/Lost/Stolen	1	1.6
Transport of radioactive material	2	<0.1
Veterinary Services	1	10
Other	2	3.7
Total	**10**	**10.0**

Transport

The transport of radioactive material is routinely carried out across Australia, mostly without incident. Unlike on-site movement, transport can involve material moving through areas that are not under the direct control of a licence holder.

What are the transport requirements?
All transport must be conducted in accordance with the *Code for the Safe Transport of Radioactive Material 2019*, RPS C-2. This code sets out requirements such as signage and permitted container types. Under the code, different requirements apply depending on the type of material ranging from exempt and low-level material to shipments of high-activity radioactive material.

Example case: Transport

A vehicle being used to transport a portable moisture / density gauge was involved in an accident when the vehicle rolled over. The gauge was secured inside a metal transport container which was bolted to the vehicle tray and further protected with a "roll bar". Police, fire services and ambulance attended. The Radiation Safety Officer (RSO) for the source owner also attended the scene of the accident and determined from a radiation survey and visual inspection that the gauge was intact and undamaged. The RSO then transported the gauge back to the site.

Learnings:

As fatigue may have been a contributing factor in the accident, the company has amended the travel arrangements to permit additional rest periods for technicians involved in transporting the gauges.

Non-ionising radiation

Only incidents that are covered by radiation protection legislation in a particular jurisdiction are reported to the ARIR. This may include the use of cosmetic lasers and industrial applications of lasers.

Example case: Laser

A student was replacing a rubidium vapor cell on an optical bench that has a high-powered laser. While replacing the vapor cell, the lid slid through the laser beam causing the laser to reflect into the student's right eye. The laboratory had appropriate Personal Protective Equipment (PPE) including laser safety goggles available for use. It was confirmed that the affected student was inducted into the workplace and the induction contained information about wearing safety goggles while working the particular lasers. However, the student was not wearing the safety goggles while replacing the vapor cell. Fatigue was also identified as a risk factor due to the length of time the student had been working.

Example case: Laser
The student was tested after the flash and underwent a retinal scan the next day. The retinal scans confirmed 'no abnormalities' which was consistent with their previous retinal scan.
Learnings: *This incident highlights how the design of equipment and carrying out required non-routine tasks contributes to incidents and demonstrates the importance of understanding and following risk assessments and procedures (including the use of PPE).*

Contamination with radioactive material

Radioactive materials are frequently used in research laboratories and for industrial purposes across Australia without incident. However, contamination with radioactive material can and does occur.

Example Case: Contamination during Maintenance
A technician conducting visual inspection and maintenance of a water purification system inadvertently broke the process fluid barrier of a valve due to improper understanding of the valve's design. This was partly due to it being a uniquely designed valve which was not the same as similar valves in operation. The technician subsequently experienced contamination of the hands with tritiated water due to spray emanating from the valve. The airborne tritiated water further exposed the technician and exposed an engineer accompanying the technician. The resulting effective doses were estimated to be 250 µSv and 25 µSv to the technician and engineer respectively.
Learnings: *This incident highlights the importance, during maintenance, of adequate prior training and clear guidance on the scope and risks of a task prior to its commencement, as well as the consistent use of appropriate PPE (such as gloves). In this instance it was deemed that a lack of guidance on what constitutes a visual inspection and how to manage the specific risks associated with this valve were the main causes of the incident.*

Radiation gauges

Fixed and portable radiation gauges have widespread use across various industries in Australia and are routinely used without incident. Where requirements and guidelines are not followed the risk of an incident can be increased.

Example Case: Damage of Radiation Gauge
A portable density/moisture gauge was being used on a construction site in close proximity to an excavator and was left unattended by the operator when they left the gauge to speak to the site foreman. The excavator driver checked the gauge operator was not in their path before driving, but failed to see the gauge was still on the ground and proceeded to drive over it. The gauge case and handle were damaged, however the radioactive source was undamaged and remained inside the shielded gauge housing. The gauge was sent to the supplier for repair.
Learnings: *Ensure gauges are not left unattended in the field and ensure that signage is erected around a gauge in use, as defined in Annex A of the safety guide for Portable Density/Moisture Gauges Containing Radioactive Sources (RPS5).*