Australian Government
Australian Radiation Protection and Nuclear Safety Agency

arpansa

Australian Radiation Incident Register

Annual Report

Incidents occurring January to December 2020

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ISSN 0157-1400

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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 (schedule 14 in the previous edition) 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 Australian Health Ministers endorsed NDRP. 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 December 2021 following consultation with professional bodies and state and territory regulators.

Purpose and scope

This report is a summary and analysis of data submitted to the ARIR for incidents that occurred in 2020.

The purpose of this report is to raise awareness of the risks associated with common tasks, share the learnings identified as the result of incidents, and assist in the identification of topical areas where safety efforts may be focused to improve radiation protection. Therefore, the focus of this report is on the causes of incidents and on recommendations or remedial actions taken as a result.

Geographical or personal data that may lead to the identification of individuals or organisations are not included in an incident report and does 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 preventive 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.

Throughout the report individual incidents that occurred in 2020 are summarised and highlighted. These provide an 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 represent the views of ARPANSA and may not be appropriate for all situations. Similarly, the reporter-estimated doses are based either on calculated individual dose or, where unavailable, on typical doses for that procedure.

Contents

Summary of incidents occurring in 2020

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 Australian Radiation Incident Register (ARIR). The register is managed by ARPANSA. We analyse submitted incidents and publish the results to raise awareness of common hazards and to identify and promote practices that could prevent future incidents.

The number of incidents reported in 2020 increased by 40% from the number reported in the previous publication. However, reporting by jurisdictions has been impacted by COVID-19 responses and 166 late submissions were received for 2019. In the short-term, reporting may still be affected; however, in the longer-term we expect a general upward trend to continue. The upward trend is indicative of increased awareness and a positive reporting culture, which ARPANSA have been actively promoting.

Human error was the primary cause (also called initiating cause or trigger) identified in the majority of incidents in 2020, consistent with previous years. However, incidents generally have a number of contributing causes such as time pressures, labelling issues, or specific reasons for not following procedures. Often if one of these contributing factors had not existed the incident would not have occurred. However, reports often do not identify the contributing factors that may have been present.

This year's report includes a focus on nuclear medicine incidents where, in particular, a number of incidents highlighted process or workflow issues as contributing factors.

Lessons that can be learnt from incidents this year include the importance of managing workflows such as:

- Product workflow: Managing the way product moves through processes – such as ensuring only one vial/pharmaceutical is in the workspace at a time
- Patient workflow: Managing how the patient moves through the process– including the appropriate use of time-outs
- Information workflow: Communication of critical information – such as from the request to the practitioner or from planning to treatment phase
- Changes to workflows:
    - Adapting to unusual circumstances – for example when a patient's treatment requirements differ from the standard needs (e.g. a patient's mobility is limited) or when the standard way of doing something is unavailable (e.g. equipment failure). In these circumstances, clinicians can benefit from training and access to instructions that identifies common scenarios and describes considerations or potential actions.
    - Understanding the impact of new procedures and equipment – such as software or equipment changes that can affect workflow.
- Making workflows resilient to slips, 'lapses in memory', such as not performing a necessary check or forgetting protective equipment. This can include procedures that help minimise forgetfulness and quality checks (for example, an independent person checking three-way taps or labels prior to administration).

Overall statistics

Number of incidents reported

There were 803 incidents reported in 2020, which is 40% more than the 575 incidents received in the previous year's reporting period. However, an additional 166 incidents from 2019 were received after the reporting period bringing the total number of incidents occuring in 2019 to 741 and reducing the year-on-year increase to 8%. Figure 1 shows the number of incidents reported each year from 2014 to 2020.

The overall trend of increased reporting numbers is indicative of increased awareness and positive reporting cultures. ARPANSA has been raising awareness and promoting the resource and 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 incident and event trend analysis is not possible without stable and consistent reporting practices from all states and territories.

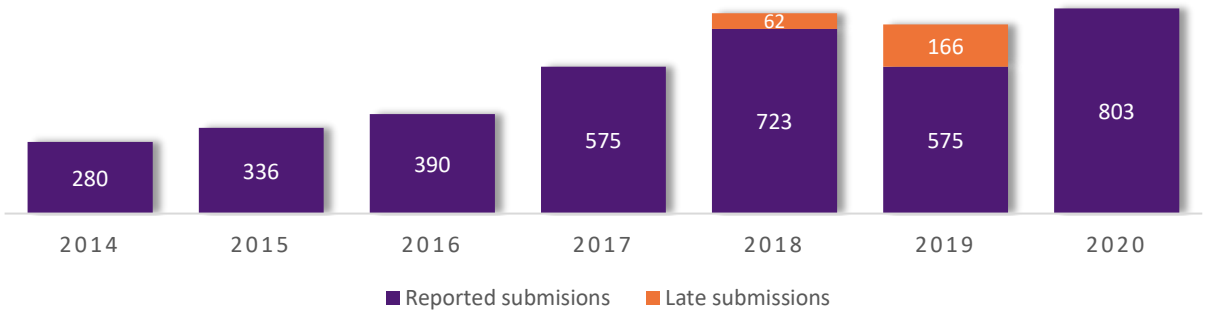


Figure 1: Number of incidents reported to the register over time

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 over-all risk of disease later in life after an exposure averaged over the whole body[1] (typically of a patient). Where exposure is to an organ or specific region, absorbed dose in gray (Gy) is used.

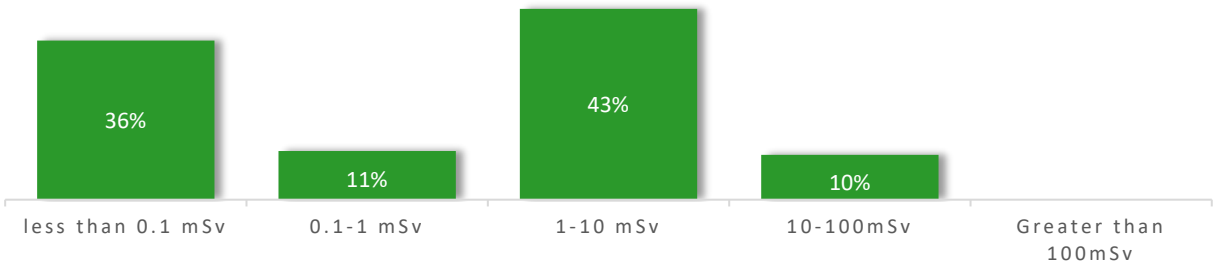


Figure 2: Distribution of effective dose as the result of incidents reported in 2020

Figure 2 illustrates the distribution of effective doses across the incidents reported for 2020. All estimated effective doses were below 100 mSv, the threshold for what is generally referred to as 'low' doses, and 90% were 'very low', i.e., below 10 mSv. Risk for disease later in life at such exposures are generally inferred from models and any health effect later in life would not be possible to unequivocally attribute to the specific exposure event[2]. For all events recorded in 2020, inferred risk for future health effects would be very low.

Localised tissue reactions may occur after exposures of several Gy. Such exposure levels can be reached for instance by 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 and missing information such as skin or organ doses may not be available.

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

[2]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

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 expected as more than 15 million diagnostic medical imaging procedures involving radiation were carried out in 2020 in Australia, according to Medicare Benefits Schedule (MBS) information.

Table 1: Overall ARIR statistics for 2020 compared with previous 4 years

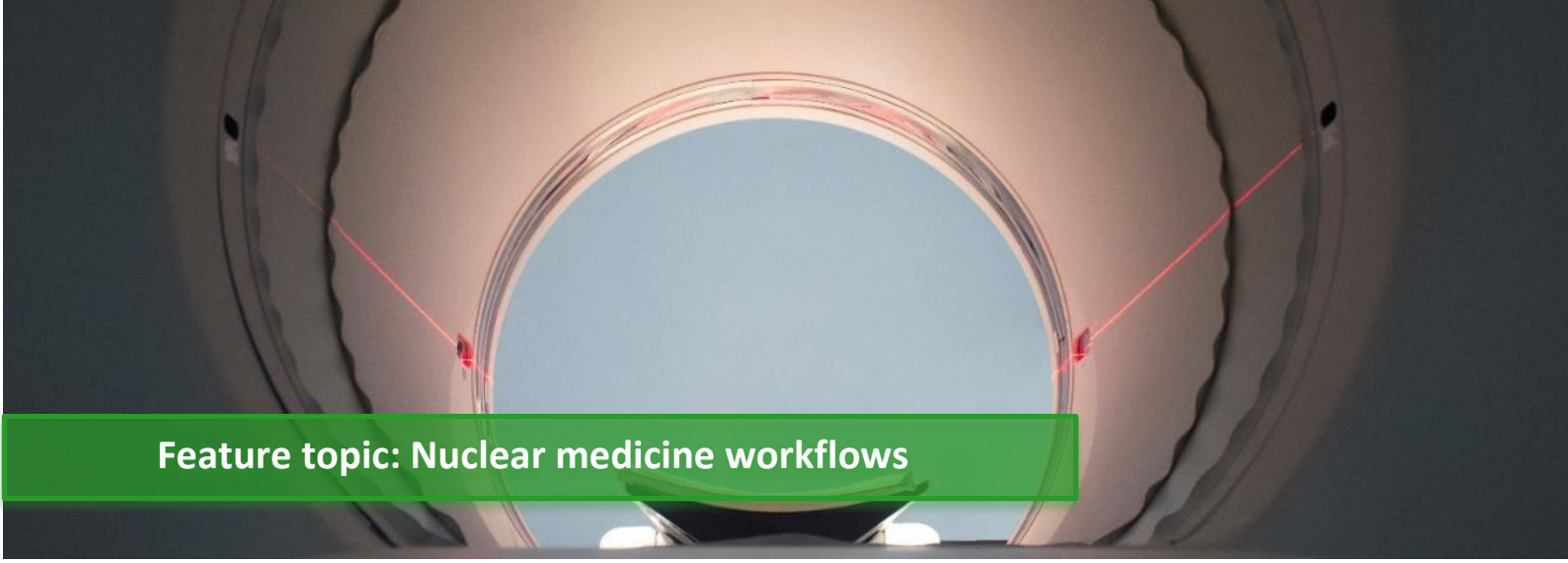
	2020		2019		2018		2017		2016	
Incident category	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**	**No.**	**%**
Medical										
Medical - Diagnostic imaging (All)	746	93%	533	92%	691	96%	532	93%	352	91%
+ Computed tomography (CT)	*(295)*	*(37%)*	*(208)*	*(36%)*	*(264)*	*(37%)*	*(212)*	*(37%)*	*(143)*	*(37%)*
+ Plain Film X-ray/ conventional radiography	*(234)*	*(29%)*	*(143)*	*(25%)*	*(247)*	*(34%)*	*(164)*	*(29%)*	*(110)*	*(28%)*
+ Diagnostic nuclear medicine	*(157)*	*(20%)*	*(141)*	*(24%)*	*(131)*	*(18%)*	*(114)*	*(20%)*	*(73)*	*(19%)*
+ Interventional / Fluoroscopic imaging	*(46)*	*(6%)*	*(36)*	*(6%)*	*(45)*	*(6%)*	*(34)*	*(6%)*	*(22)*	*(6%)*
+ Dental	*(14)*	*(2%)*	*(5)*	*(1%)*	*(4)*	*(1%)*	*(8)*	*(1%)*	*(4)*	*(1%)*
Medical - Radiotherapy	*40*	5%	*23*	*4%*	*17*	2%	21	4%	16	4%
Other										
Contamination	3	<1%	4	<1%	3	<1%	5	<1%	1	<1%
Transport of radiation material	4	<1%	3	<1%	2	<1%	0	<1%	1	<1%
Imaging (inc. industrial radiography and XRF)	4	<1%	1	<1%	2	<1%	1	<1%	3	1%
Found/lost/stolen	1	<1%	6	<1%	1	<1%	4	<1%	15	4%
Non-Ionising Radiation (inc. laser and IPL)	1	<1%	2	<1%	1	<1%	1	<1%	1	<1%
Other	4	<1%	3	<1%	6	1%	10	2%	0	0%
Total	**803**		**575***		**723**		**575**		**390**	

Note: percentages are rounded

* an additional 166 incidents that occurred in 2019 were submitted in 2021.

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/]



Feature topic: Nuclear medicine workflows

Summary of nuclear medicine related incidents

There were 157 incidents identified in nuclear medicine imaging. This accounts for 20% of all reported incidents, which is consistent with the 5-year data.

Table 2: Nuclear medicine related incident statistics 2020

Incident Type	Number	Average effective dose (mSv)	Range (mSv)
Equipment malfunction	28	6.8	0-30
Extravasation of radiopharmaceutical and intravenous (IV) administration failures	26	3.7	Dose can be difficult to determine due to uncertainty in percentage administered and uptake
Radiopharmaceutical administered but scan not performed	24	9.5	0 – 30
Incorrect type of radiopharmaceutical injected	20	5.0	0.5 – 17
Incorrect scanning procedure	13	5.4	0 – 16
Radiopharmaceutical spill/leak	11	2.9	0 – 20
Incorrect activity of radiopharmaceutical injected	10	3.5	1.4 – 10
Unknown pregnancy or unintended exposure of pregnant staff	6	1.2	0 – 7
Patient factors	5	5.3	0 – 16
Defective batches of radiopharmaceuticals	4	6.9	1.6 – 12
Other	10	3.5	0 – 6
TOTAL	157	5.4 mSv	0-30 mSv

The workflow in nuclear medicine is critically important to ensure the right radiopharmaceutical is administered to the right patient to achieve the desired clinical outcomes.

Nuclear medicine workflow
Before images can be produced several steps have to occur. A radiopharmaceutical is prepared from radioactive material (this is what the cameras pick up), and the pharmaceutical agent that determines where in the body the radioactive material will go (uptake organ). This is injected into the patient who can then be placed in the scanner that produces the images.

Supply	The radioactive material generally originates in a reactor or accelerator that is offsite. The pharmaceutical agent is usually supplied in the form of a 'cold kit' to which the radioactive material is added.
Preparation	The combination can take place within the nuclear medicine department or at a dedicated lab. The final radiopharmaceutical is commonly referred to as 'a dose' and has an activity measured in becquerels (Bq). This indicates how much radioactive material is present, which varies for each patient depending on their size and needs.
Administration	The radiopharmaceutical is adminstered (e.g. injected) into the patient, after a final check to ensure that the details on the labels match the referral and patient information. This can be made more difficult due to shielding around the syringe, which is also labelled. Depending on the type of scan injection can occur many hours before the scan.
Scanning	The patient is scanned using a camera that can 'see' where the radiopharmaceutical went. In hybrid imaging a CT scan is also performed to create a combined image of functional and anatomical information, such as organs and bones. Both processes result in exposure to radiation which is measured in millisieverts (mSv) effective dose.

Supply – transport of nuclear medicine

The short half-life of the isotopes typically used in nuclear medicine means the material needs to get where it will be used promptly. As such, the transport of nuclear medicine radionuclides is typically performed by specialised couriers or by employees. In complex destinations such as hospitals, it is important that the delivery is received by the right people to ensure it can be placed in safe and secure storage.

Example case: Transport of nuclear medicine

A package containing the radioactive material (nuclear medicine) was delivered by the courier and left unattended at the hospital department's reception desk as nobody was around to receive the package. In this case the source was promptly discovered and transferred to medical physics hot lab, the designated destination.

(No increased occupational dose)

Learnings:

- *Ensure couriers are aware of the delivery requirements, i.e. be delivered to the correct location and received by the right person (such as directly to a medical physicist or nuclear medicine technologist), and what to do if they cannot find the right person.*
- *Ensure the recipient, including reception staff, are aware of the incoming shipment, and the delivery requirements or who to contact.*

Ensuring correct labelling of all transport packaging including the correct radionuclide was also highlighted in incidents this year. This is important as the type of radiation may have safety implications particularly if the package is damaged in transit.

Example case: Labelling

A package had transport labelling indicating iodine-131 was present but on opening the package it was found that the package contained iodine-123 (as ordered). The package was a UN 2915 Type A package being delivered to a nuclear medicine hot lab in a hospital and was otherwise labelled appropriately.

Preparation

While human error (e.g. not following a standard protocol / procedure) is often the proximal cause of an incident the underlying contributing factors in the working environment increase the potential for human error. Human error can be broken down into different error types with different strategies being effective for addressing the different kinds of error.

Lapses

A memory lapse, or a 'slip of action' is considered a skills-based error because they happen when someone is already familiar and experienced with a task. This is where one or more steps within a task are omitted unintentionally. For example, missing a patient identification step, getting the order of steps wrong, or writing down the wrong radionuclide. Lapses and slips occur when someone is very experienced, completes tasks automatically, tasks are complex with multiple steps, or tasks very similar to other tasks.

Lapses can generally not be solved with training or reinforcing existing practice. Effective strategies for addressing this type of error can be physical workplace design, automation, use of checklists, and reducing interruptions.

Example case: Spills

A nuclear medicine technologist (NMT) at a medical imaging practice accidentally threw an eluate vial of ^{99m}Tc - pertechnetate into the hot waste sharps container. The technologist extracted the vial from the container using tongs but then dropped the vial. It smashed and spilled 10 GBq ^{99m}Tc onto the hot lab floor. The technologist cleaned up the liquid and glass, placed absorbent pads on the floor and sealed the hot lab.

(Occupational effective doses were less than 1 mSv)

Example case: Incorrect radiopharmaceutical or incorrect activity administered

A radiochemist selected the incorrect vial from the lab fridge which resulted in a patient being injected with 183 MBq of ^{99m}Tc MAG3 (mercaptoacetyltriglycine) instead of the prescribed ^{99m}Tc MAA (macroaggregated albumin).

The syringe and 'dose slip' were labelled with MAA and the patient's correct details. An investigation found that the MAG3 and MAA vials look similar and are kept on the same shelf in the refrigerator; the radiochemist thought the MAA vial was where the MAG3 vials were. The misadministration was noticed when the radiopharmaceutical was found to be in the kidneys rather than the lungs.

(Effective dose 1.3 mSv)

Two patients were administered with ^{99m}Tc pertechnetate (TcO4) instead of ^{99m}Tc -MIBI (sestamibi).

The NMT drew up the radiopharmaceutical in error from the pertechnetate pot (green colour) instead of the MIBI pot (green with red dot). The NMT did not doublecheck the radiopharmaceutical by looking at the compound label on the pot. The activity concentration of the pertechnetate was very similar to the MIBI concentration and so was not flagged as unusual when measured using the dose calibrator.

(Effective doses to two patients 6 mSv)

Example case: Incorrect radiopharmaceutical or incorrect activity administered
A patient was injected with 767 MBq pertechnetate instead of HMPAO (hexamethylpropyleneamine oxime). *More than one vial was present on the workspace which resulted in the injection of the incorrect isotope. The workspace contained a vial of HMPAO along with the pertechnetate. Once the patient was cannulated and ready to have the brain scan, the dose was drawn from the incorrect vial.* *(Effective dose 9.7 mSv)*
A NMT inadvertently injected a patient with 900 MBq of ^{99m}Tc pertechnetate instead of ^{99m}Tc -HDP (oxidronate). *The NMT set the patient up for a bone scan of the knees and injected a dose prepared by anther technologist. The pertechnetate injection was labelled correctly however it was sitting amongst ^{99m}Tc-HDP injections which were also labelled correctly.* *(Effective dose 10 mSv)*
A patient was booked for a nuclear medicine renal scan with ^{99m}Tc - DMSA (dimercaptosuccinic acid) but was injected with 180 MBq DTPA (diethylene-triamine-pentaacetate). *The NMT responsible assumed that the DTPA kit in the hot lab fridge was DMSA.* *(Effective dose 1.2 mSv)*
Two vials were behind the L-block (operator shielding) and the wrong dose was drawn up and given to a patient. *(Effective dose 2.5 mSv)*
The background level on the dose calibrator was set incorrectly with a dose inside the well. This resulted in the patient being injected with 1050 MBq where the maximum activity normally given is 850 MBq. *(Effective additional dose 1.4 mSv)*
Learnings: • *The workplace should be arranged such that radiopharmaceutical vials are not mixed e.g. only one pharmaceutical at a time.* • *The position of vials that look similar should be separated in the fridge to avoid selection error. Ways to discriminate between vials (labelling, colour, location, accessibility, touch) should be explored where possible.* • *Find opportunities within the work process to check the label of the vial rather than relying on the position or expected content.* • *Users should not assume that instruments are set/reset by the previous user or by the equipment. All dose calibration settings should be checked before measurement.* • *Utilise a barcode/computer based hot lab management system.* *For more information on how to identify and separate radiopharmaceuticals see the safety guide RPS 14.2: Safety Guide for Radiation Protection in Nuclear Medicine (2008)*

Mistakes

Mistakes occur where a planned action or decision is made that does not lead to what is intended. Mistakes can either be rule-based errors (misapplying a rule with the assumption that it will result in a certain outcome but it does not) or knowledge-based errors (an action is taken because the person is lacking knowledge on an aspect of the task; they expect it to turn out a certain way). Mistakes can occur because of time pressure or attempts to make processes more efficient.

Where an expected action is deliberately not taken this is referred to as a violation. These can occur for a variety of reasons such as a usual working scenario, difficult or unreasonable procedures, or the consequences of the violation being minimal to the overall outcome. It is important to understand the reasons to address the issue.

Education about risks and consequences, and training on ‘why’ not just 'how' can be effective in addressing this type of error. Addressing factors in the work environment can also reduce the incidence of mistakes caused by, for example, high workloads, culture, fatigue, interruptions. Other strategies can include approval structures, effective change and risk management activities, and active workforce involvement in the development of rules and procedures that will affect them.

Example case: Skipping quality control

A pregnant female patient (3rd trimester) was referred for a lung scan and was injected with the wrong radiopharmaceutical.

Following the ventilation phase the NMT drew up activity for the perfusion phase. In error, the NMT selected a vial of MAG3 (a renal agent) from the bench instead of MAA. The MAG3 was processed to undergo double-checking by the hot lab management system. However, unknown to staff, the NMT had specified the dose to be drawn using a method that bypassed the normal checking process. While a dose slip that showed that MAG3 was drawn up was produced as usual, the NMT was not alerted to the problem and it was not checked. The error was identified when the scan showed features typical of MAG3 rather than MAA.

(Effective dose 1.3 mSv)

The software systems and how information is recorded can also contribute to these kinds of errors.

Example case: Therapeutic nuclear medicine – incorrect activity

A hospital patient treated with ^{177}Lu-dotatate (lutate) for neuroendocrine cancer received more than intended.

The request form was completed for administration of 8 GBq of lutate. This was registered in the radiology information system, the treatment planner and the electronic medical record (EMR). Pathology estimated glomerular filtration rate results from the day prior to treatment showed impaired renal function in the patient. Consequently, the nuclear medicine consultant and fellow decided to reduce the administration to 6 GBq lutate. This change was made in the EMR, but not updated in either the radiology information system or the treatment planner. The radiopharmacist dispensing the lutate prepared an administration of 8 GBq as per the treatment planner, which was then administered. Following the incident, the EMR was defined to be used as the sole source document for accessing and dispensing of radiopharmaceuticals.

(The kidneys received an additional 1.2 Gy)

Learnings:
Where possible, reduce the number of systems in which medical imaging procedure details are entered. In the short-term provide clarity on the primary source of information (e.g. use the EMR record for dispensing).

Administration (injection) – IV administration failure/extravasation

Injecting into a patient’s tissue instead of into the blood vessel can cause the injection to remain in the underlying tissue, e.g. in the arm. This can produce localised high doses of radiation to the patient. If too much of the radiopharmaceutical remains in the arm instead of where it was intended, the effectiveness of imaging or therapy will also be diminished. Extravasation of most diagnostic radiopharmaceuticals does not result in any reported radiation injuries or skin effects to the patient.

Extravasations occur during routine intravenous procedures and are almost impossible to entirely prevent due to the many factors involved including patient movement. However, the likelihood of occurrence can be reduced through training and practice such as using an IV-catheter that has been flushed, to ensure patency. This can be followed by visually and physically monitoring for swelling occurs and asking the patient if they experienced discomfort during injection. Sharing expertise between clinicians on prevention of extravasation can also benefit teams. For this reason, clinics should monitor for radiopharmaceutical extravasation including trending and reporting.

Example case: Extravasation

A patient presented for a PET scan and following a difficult cannulation extravasation occurred.

After a few attempts at cannulation due to poor venous access a cannula was inserted under ultrasound control. Prior to injection of the tracer the cannula was tested with saline. The patient did not report feeling any discomfort or pain. They then proceeded with injection of 286 MBq of ^{18}F fluorodeoxyglucose (FDG) using an automatic injector. Following injection, the patient complained of pain and the extravasation was then visible due to a swollen arm.

(Skin dose of extravasation is difficult to determine due to uncertainties in uptake)

A hospital patient presented for a whole body 18F FDG scan followed by a CT attenuation correction (CTAC) scan that had to be repeated due to extravasation/leakage.
A NMT connected the patient to the FDG line but did not check the line was connected correctly. As the injector pushed the FDG into the line, some of the FDG leaked out onto the floor; the NMT did not notice this leakage. The patient received an exposure from the FDG during uptake and then had the CTAC scan. The entire procedure had to be repeated.

(1.3 mSv from repeated scans; skin dose of extravasation is difficult to determine due to uncertainties in uptake)

Learnings:

- *The use of a central line port-a-cath, where installed, should be considered for PET radiopharmaceutical infusions, for example by the Nuclear Medicine Physician.*
- *Ensure patency of radiopharmaceutical injection canula. Testing should be done using the same flow rate and pressure as the injection of the tracer (such as using the auto injector where applicable).*

IV administration failure can also result in a spill of radioactive material either at the site of injection or at the source. Small spills can typically be cleaned up without significant dose to persons and is made easier by the relatively short half-life of medical isotopes. However, if contamination is not detected it could lead to exposure to people including from ingestion or inhalation of radioactive material. Material that comes into close contact with the skin can also lead to significant skin dose, particularly material used for PET scanning.

Example case: Spills

A patient presented to the nuclear medicine department of a hospital for a stress and rest myocardial perfusion procedure. During the injection of the stress dose (1.2 GBq of ^{99m}Tc Sestamibi) the 3-way tap was inadvertently left open resulting in the spill of the radiopharmaceutical onto the arm and sides of the patient.

The nuclear medicine registrar immediately attempted decontamination of the patient and electrocardiogram (ECG). Affected linen was immediately removed from the patient and discarded in the linen bag and wipes used in decontamination were discarded in a hot waste rubbish bin. The linen bag and hot waste rubbish bin were then relocated to the radiation waste store.

(Occupational effective doses were less than 1 mSv, skin doses were not estimated)

A hospital patient was treatment with 9.4 GBq of ^{177}Lu octreotate (lutate), which leaked during injection.
At the end of Lutate infusion, the nuclear medicine physician noticed that the connections between the saline flush and 3-way tap had leaked despite it being checked prior to infusion. The leaked lutate was mostly contained in a plastic tray that is always positioned under the infusion set. Contamination was also detected on a stainless steel trolley and the mobile patient shield. All surfaces were decontaminated and waste was placed in a lead box and transferred to the hospital's radioactive waste room. It was estimated that about 8 GBq of lutate had leaked.

(Occupational effective doses were less than 1 mSv)

Learnings:

Checks of the injection lines and taps should be carried out prior to infusion. Independent checks (e.g. a person checking setup performed by another staff member) have been implemented in some hospitals.

Scanning – equipment malfunction/limitation

Malfunction of the scanning equipment occurred in 24 incidents; either where a CT was performed or radioactive material injected without the scan being performed. Failure of ancillary equipment such as injectors accounted for a further 8 incidents. An effective maintenance strategy is one of the key controls for this type of incident.

Equipment choice and method of use can also influence equipment related incidents.

Example case: Power failure

Power went out when the patient was halfway through a PET scan resulting in a loss of data.

The full low dose thighs to vertex CT had already been acquired. Once the power was back up (from generator) and the scanners were tested, the scan was started again. The patient had the low-dose CT repeated from liver to vertex to enable attenuation correction/fusion of the remaining PET acquisition. Scan speed for the PET scan was slowed to account for the additional 2-hour delay in acquisition.

(Effective dose 2.1 mSv)

Learnings:

Hospital backup power infrastructure can reduce the chance and severity of power outages. Uninterruptible power supply (UPS) locally in the department could be used for computers and key infrastructure when external power is lost; this may help to prevent data loss. It should be noted that the benefit and cost may vary between hospitals, and a UPS typically would not be used for devices with high-power needs such as the scanner.

Cause of incidents

Direct cause

Across all incidents from 2020, human error was reported as the direct cause in 65% (519). 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.

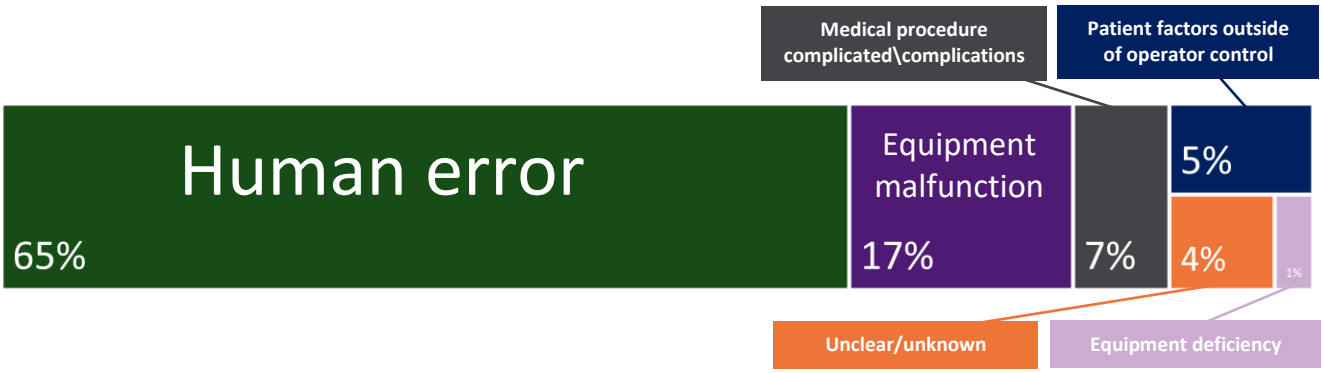


Figure 3: Incidents in 2020 by primary cause

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 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 as 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 9% 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 that could result in unrelated incidents.

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 reductions in the likelihood of an incident with significant outcomes occurring.

The most common contributing factor was 'individuals not following procedures', which was identified in 38% of incidents. The next biggest factors were errors in quality control and issues related to orders or referrals. This is consistent with previous years' findings.

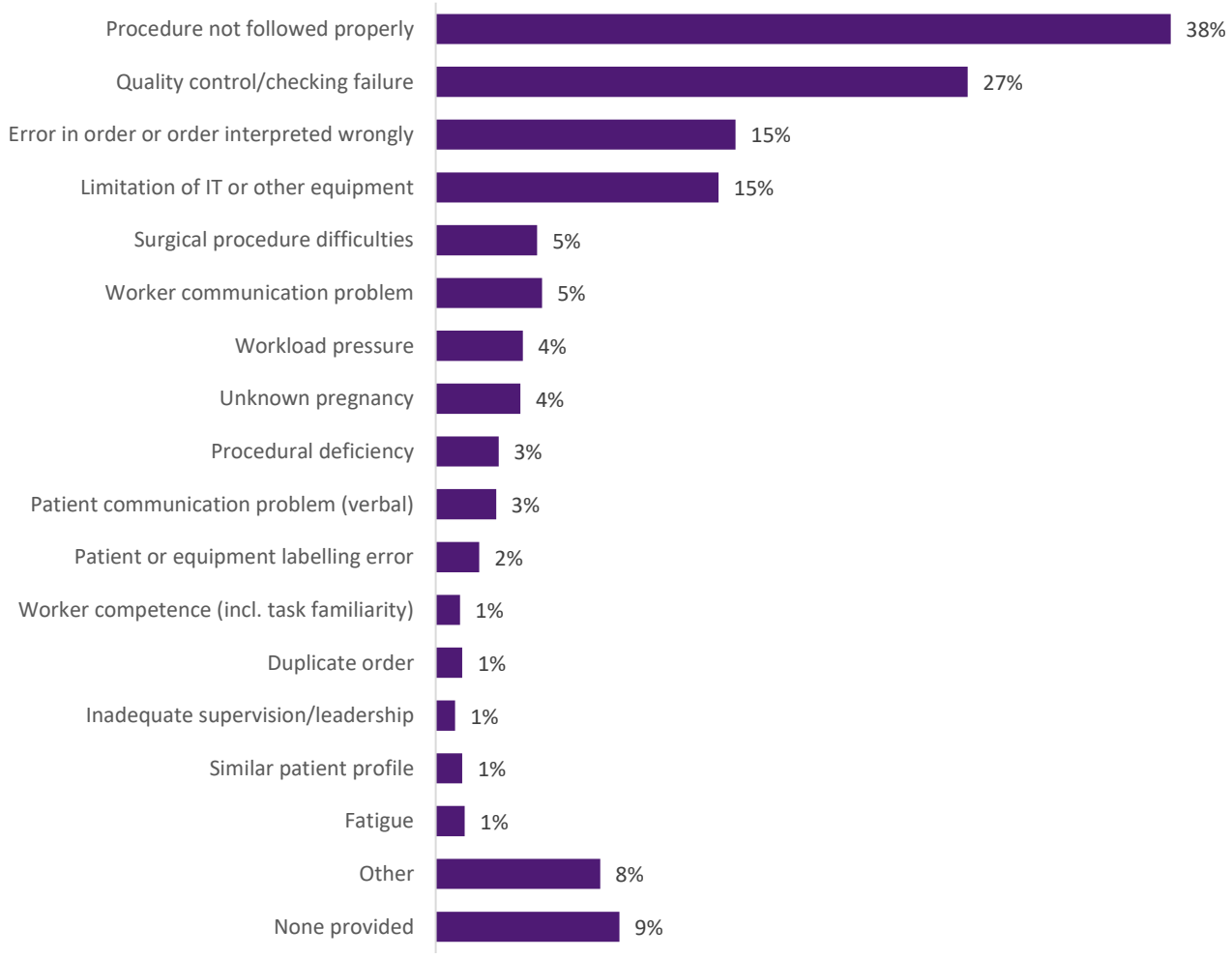


Figure 4: Contributing factors identified in 2020 incidents

Summary of controls and preventive measures implemented

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

Reinforcement of procedures and reminders of good practice remain the most common actions taken after an incident. In 2020 such actions were taken in 52% 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.

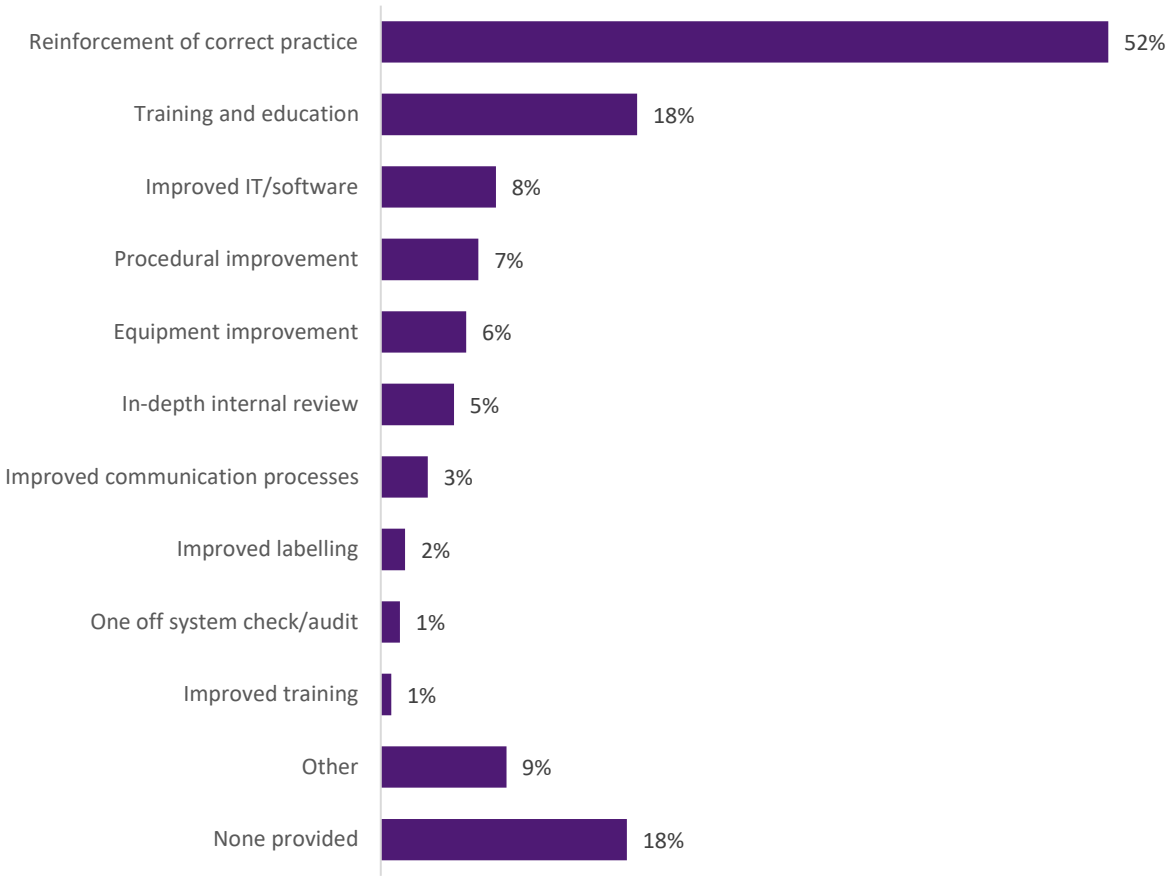


Figure 5: Remedial actions taken to prevent recurrence in 2020

Summary of incidents by category

Medical – diagnostic imaging

This category covers medical imaging performed using X-ray apparatus.

Table 3: Overall statistics for 2020 diagnostic imaging incidents by modality

Modality	Number of incidents reported	Effective dose per incident Note: does not include skin or critical organ doses.	
		Average	Range
Computed tomography (CT)	295	6.6 mSv	0–68 mSv
General X-ray	234	0.4 mSv	0–25 mSv
Nuclear medicine	157	5.4 mSv	0-31 mSv
Fluoroscopic/interventional	46	1.4 mSv	0-27 mSv skin doses up to 14 Gy
Dental	14	0.02 mSv	0–0.1 mSv

Table 4: Overall statistics for 2020 diagnostic imaging incidents by description (excluding nuclear medicine)

Type	Number of incidents reported	Percentage	Effective dose per incident Note: does not include skin or critical organ doses.	
			Average	Range
Unnecessary scans or scans not as intended	360	61%	4.2	0-68 mSv
Equipment failure	108	18%	2.1	0-61 mSv
Medical procedure complications	39	6%	1.2	0-13 mSv skin doses up to 14 Gy
Unknown pregnancy	36	5%	4.1	0-28 mSv
Other	46	2%	2.7	0-20 mSv
Total/average	**533**		**3.4 mSv**	**0-68 mSv**

Unnecessary scans or scans 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, wrong procedure, wrong site, or an unnecessarily repeated scan. These were discussed in detail in in the feature topic of the ARIR Annual Report 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.

Example case: Wrong procedure

A patient referred for a CT of the abdomen and pelvis received a CT of the brain and carotid arteries instead.

The patient was brought into the CT scanning room where the radiographer had 2 referrals in their hand at the time and looked at the wrong referral when determining which test to perform - incorrectly performed the check for 'patient, procedure and site'.

(Effective dose 3.7 mSv)

Timeouts are particularly important for therapeutic or interventional procedures as these can have high clinical impact (e.g. surgery of the wrong patient) or may involve higher doses of radiation. The importance of the timeout was highlighted by the International Atomic Energy Agency in their newsletter Safety in Radiation Oncology (SAFRON) published in March 2021. They identify issues preventing an effective timeout as including: a lack of a formal timeout policy and procedure, staff not feeling empowered to stop a procedure, distraction, and feeling rushed to complete a complicated task.

Communication with the patient or between staff is often identified as a contributing cause.

Example case: Wrong patient

The wrong patient received chest x-rays.

'I called the patient's name from the waiting room and the incorrect patient stood up and went into the room. I asked him if his name was xxx and his date of birth was xxx and he said yes. I asked him what happened and where his pain was, and it matched with what was on the referral. The entire time I called him by the name on the referral however the patient at no stage told me that this wasn't his name. He also told me his lower back was sore, so I called the referring emergency doctor who told me to just X-ray that too. I X-rayed his chest and right ribs and lower back. Half an hour later the correct patient told the receptionist that he hadn't been X-rayed. I went to look for the patient I had X-rayed but could not find him and he was not booked for any other modality. I'm assuming he was a patient for the GP who we share the same waiting room for. In my opinion I think he may have had dementia or other mental impairment.'

(Effective dose 0.3 mSv)

Learnings:

Asking 3 different open questions e.g. 'what is your name?' rather than 'is your name xxx?' should be carried out.

A lack of effective protocols, written procedures, was also identified as contributing to this type of incident.

Example case: Repeat exposures

A patient was referred for a CT colonograph exam that was performed 3 times.

The first CT colonograph scan should not have been performed because the scout image showed poor insufflation which resulted in a non-diagnostic colonograph scan. A second CT colonograph exam was performed which was adequate however the CT radiographer thought another scan was required. A third colonograph scan was performed and was later confirmed to be unnecessary.

(Effective dose 7.7 mSv)

Learnings:

Review CT protocols (procedures) to ensure they contain sufficient specific information to assist the radiographer in taking a clinically useful image.

The referral form/system, which is the primary way in which the referring doctor informs the person performing the procedure of the requirements also played a significant part in many incidents.

Example case: Referrals
Incorrect CT procedure performed after the incorrect procedure was booked by the admin officer. The handwritten CT request form from the GP was very difficult to read causing both the radiographer and radiologist to misread/misunderstood the handwritten request. Further contributing factors include a new staff member and an elderly patient. *(Effective dose 10 mSv)*
A patient received an unnecessary CT head examination due to an old referral being re-faxed (6 days later). *(Effective dose 10 mSv)*
The wrong patient received a CT of the abdomen. A referral from the emergency department (ED) was received. The radiographer collected the patient 2 hours later, checked the patient's ID against the details on the request and checked with the patient's nurse. The patient was confused as they had a CT earlier in the day. Shortly after the radiographer scanned the patient an emergency doctor came to ask when another patient was going to be scanned. The radiographer told him that they did not have a request for the patient he was talking about. The ED doctor described the patient's symptoms and it was the same as the patient that had just been scanned. The radiographer showed this referral to the doctor who noted he had put the incorrect patient sticker on the form. *(Effective dose 10 mSv)*
Learnings: • *Electronic and printed referrals can reduce legibility issues* • *All staff should seek advice if unable to fully interpret clinical information from the referrer* • *Receiving referrals prior to the patient arriving would allow for vetting of request form and follow up without the additional pressure of the patient waiting* • *Having multiple requests with you when collecting patients can increases the risk of mistakes.*

Workloads can also be a contributing factor.

Example case: High Workload
A patient received a CT scan that was not due for 12 months. *Patient presented to department with a handwritten radiology request form. It was a busy clinical morning, and a single radiographer was covering CT and XR that day performing 26 exams. The form was given to him 12 months in advance and the due date was not picked up by admin staff at time of booking or by the radiographer taking the scan. Patient did not indicate that he thought this scan was meant to be performed later. There were no previous scans performed at the practice to indicate that this was a follow up exam.* *(Effective dose 11 mSv)*
The wrong patient received a CT scan. *The incorrect patient was brought down to CT to be scanned and details for both patients to be scanned were similar. The radiographer was distracted by too many issues from other departments including phone calls requiring urgent imaging. One radiographer was working to scan 2 patients on 2 scanners.* *(Effective dose 3.6 mSv)*
Learnings: • *Adequate staffing levels can reduce pressures on clinical team. For example, policies can be put in place to reduce the number of bookings taken if staff are unavailable or to increase staffing levels for high demand periods.* • *Reduce the number of handwritten and illegible radiology requests by moving to electronic or printed forms.* • *Referrers should ensure patients understand any delayed referrals or issue them closer to the required date.*

Shielding

Why is PPE needed?
Time, distance, and shielding are important controls for radiation protection. In most cases shielding is constructed so that staff can be in a shielded location when operating equipment. However, in interventional situations staff performing the procedure must be next to the patient while they are being X-rayed. In this case personal protective equipment (PPE) such as lead gown/glasses are a primary defence against exposure. These should be used in conjunction with mobile shielding (e.g. ceiling mounted or wheeled) and administrative controls where applicable.

Example case: Lack of PPE during fluoroscopic procedure

A consultant (locum) doctor refused to wear the required PPE or remain behind shielding.

The radiographer told the consultant he needed to 'wear lead' before proceeding. The doctor insisted he was standing far enough away and wore the lead skirt (but no jacket or thyroid shield) and that it was not necessary for him to stand behind the lead shield.

Following the incident, the hospital wrote to the consultant stressing the need to abide by the radiation protection requirements. It was also reinforced to the radiographers that they are not to start any procedure in theatres without all staff wearing the correct PPE.

(Effective dose was not calculated but is estimated to be less than 1 mSv)

Learnings:

Staff need to feel empowered to stop if safety rules are not being followed. This can be particularly difficult in a hospital situation where highly paid staff are performing potentially lifesaving procedures and requires clear management support.

Example case: Accidental depression of footswitch

Fluoroscopy system was left on during patient transfer and patient trolley rolled over the exposure foot paddle which initiated exposure. Staff members in the vicinity of the system were not wearing lead gowns during the exposure. Radiographer immediately disabled the system.

(Effective dose was not calculated but is estimated to be less than 0.01 mSv)

Learnings:

Footswitch protection is mandatory in some jurisdictions to prevent accidental activation such as by trolleys. As this is not required in all jurisdictions it is often not supplied by the manufacturer and has to be sourced separately.

Interventional – higher dose

There were 39 incidents involving a higher dose due to circumstances beyond the operator's control such as a complex procedure or large patient. These 'incidents' should not be considered as wrongdoing on anyone's part. Steps can be taken to minimise dose without impact on the clinical outcomes and patient follow-up after high skin dose should occur.

Example case: High dose

A hospital patient underwent 3 difficult splenic/pancreatic bleed embolisation procedures in a period of six days under fluoroscopic guidance. Throughout the procedure, steps were taken to keep the dose as low as reasonably achievable. The patient did not develop any erythema.

(The skin entrance dose for the procedure was approximately 14 Gy.)

The reporting requirements for this type of incident vary by jurisdiction, for example in Victoria 'A human diagnostic procedure that results in a skin dose that exceeds 6 Gy' is reportable but this may not be considered reportable in some other jurisdictions.

Equipment malfunction

There were 108 incidents related to equipment malfunction or limitation. There were no significant trends in equipment malfunctions that might indicate a flaw that could be subject to a recall or similar. An effective maintenance strategy is one of the key controls for this type of incident. Equipment malfunction was the feature topic of the ARIR report covering 2019 incidents.

Radiotherapy

Radiotherapy is the use of radiation as treatment often for cancer. This was the feature topic of the ARIR report on 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.

Doses in therapy
Radiotherapy doses are different to those from diagnostic imaging. A very large dose is delivered to a 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 hard to compare with an effective dose (Sv) for the whole body.

Table 5: Radiotherapy incident statistics in 2020

Category	Number of reports	Fraction of prescription	Dose (excess/underdose)
Planning/Imaging	12	Pre-treatment imaging is low compared to prescribed treatment	0-24 mSv (planning)
Incorrect treatment site	12	15 - 20%	1-5 Gy (treatment)
Incorrect treatment dose	3	6 - 25%	1.2-2.6 Gy (treatment)
Patient positioning	6	0 - 20%	0-4 Gy (treatment)
Equipment malfunction	3	0 - 20%	3 mSv (planning) 4 Gy (treatment)
Other	4	0 - 66%	1-10 mSv (planning) 11 Gy (treatment)
Total	**40**	**0-66%**	**0-11 Gy**

Patient treatment pathway
Treatment plans are developed for each patient. First, planning images (CT) are taken of the patient in the same position as the treatment will be delivered. The plan is developed and checked before the treatment sessions. Patients generally attend multiple times for a course of treatments – for example a fraction of the dose might be delivered each weekday over several weeks.
During each treatment session the patient must be positioned precisely. This is done by aligning the position of anatomical features in the X-ray (e.g. the location of the spine, ribs etc) or surface marks such as tattoos. The patient must avoid movement between alignment and delivery of each treatment field; this may be aided by supports or restraints such as a mask. Following treatment, verification and review is performed.

Planning

During the planning stage 12 Incidents were identified. Typically, if an issue is picked up early such as during planning the impact to the patient can be minimised or prevented and only a small additional dose due to imaging being repeated is required.

Example case: Planning

A patient received a planning CT for the abdomen that did not include the correct area and had to be retaken.

New tattoos for current treatment were not deemed to be required as previous ones could be used. The first scan was performed using the scan limit requested on the booking form rather than scout view and so did not incorporate the previous treatment tattoos. After the patient got off the CT couch it was noticed that their scan did not include tattoo markers in the pelvic area.

It had previously been stressed to staff to follow the scan limits on the booking form. However, it is also necessary to include tattoos. Staff may not have been expecting the position of the tattoos as current policy is to place new tattoo if previous ones are more than 10 cm from current site; in this case the tattoo was 20 cm from the site. It was also noted that a person with more experience could probably have used the existing scan but this was not identified at the time and staff involved did not ask for assistance before rescanning.

(Effective dose 11 mSv)

Pre-treatment imaging was 10 cm inferior to correct imaging centre and so needed to be repeated.

There had been recent changes to the setup page (software) where isocentres were changed to be couch movements rather than patient movements (the direction of resultant movement is reversed). In this case the imaging was set up 5 cm inferior to the reference rather than 5 cm superior resulting in the treatment site not being adequately imaged.

Human factors may not have been sufficiently considered in design. The current method involves lots of scrolling and flicking through windows to see all the necessary information, which is cumbersome and time consuming. The details and reference images are now in multiple places, not a central combined space. The treatment field may not always be easily visualised due to the setup procedure details being attached to the imaging (CBCT) field.

(Effective dose 0.2 mSv)

Learnings:

- *Ensure that changes including software changes are well designed, understood, risk assessed, and communicated.*
- *Clinical policies can support effective routines that help to ensure repeatable results. However, where something is different to the expected scenario or a change occurs, this should be clearly identified and communicated to staff.*

Treatment site

Misalignment or targeting the wrong site can occur for a variety of reasons. Mismatching using the spine was a factor in more than half (7) of these types of incidents.

Example case: Incorrect treatment site (spine)

Treatment prescribed is 20 Gy in 5 fractions to T10-T12. Fraction 2 was matched incorrectly due to poor image quality and treatment delivered to T9- T11 for that fraction only. Incident was discovered on weekly chart check.

(Unintended dose to T9, 4 Gy)

On the 4th fraction (out of 5 fractions) for a spine radiation therapy treatment the automatic registration feature was incorrectly assessing the positional shifts required for this patient.

This was noticed and rectified via a manual image match. Further investigation into previous matching identified that the patient had been incorrectly positioned for one of the treatments which occurred 2 days previously.

(Unintended dose 2.9 Gy)

Treatment was delivered to wrong area of a patient who presented with extreme pain to mid back and hip region.

The patient decided they wanted to proceed with RT treatment despite the pain. They were propped up on a 20-degree elevation wedge as per CT scan. Staff position patients as best as they can to minimise causing pain. Patient was unable to lie still due to pain. T-spine image taken to max size under the pressure of patient screaming of pain and moving, setup was difficult, and image was hard to match. Offline review of the image showed that T9-L1 was treated incorrectly by one vertebra. Remain 4 fractions were delivered correctly.

(additional dose to L2 and underdose to T9 in 1 of 4 fractions)

Example case: Incorrect treatment site (spine)

Learnings:

- *If unable to clearly identify the correct location, open image larger and offset imager to a stable bony structure – e.g. image could have been offset more inferior to verify pelvic crest and T-12 spine*
- *If the image is difficult to see or it is hard to make a decision, get another opinion from an independent person.*

Challenges in matching skin markings was also reported in several incidents.

Example case: Incorrect treatment site (skin)

One of 18 fractions was delivered to the wrong site.

Patient was prescribed orthovoltage radiation therapy of 36 Gy in 18 fractions to a post-surgical site. The area to be treated was an irregularly shape approximately 4.2 cm by 3.2 cm on the back of the neck. The first fraction was delivered as per the plan. Before the second fraction the patient asked the staff where they should be applying cream and pulled back their hair to show the area. At this point staff realised that the area the patient was showing was not the area that had been defined for treatment. As the oncologist who defined and prescribed the treatment area was not available, staff sought clarification from another radiation oncologist who suggested to defer treatment for the day until the primary oncologist was available. The next day the primary oncologist rang the GP/surgeon and confirmed that the treatment area that was initially defined was in fact just a crease in the patient's neck/skin and not the scar that should be treated. The treatment was restarted in the correct location.

(2 Gy was delivered to the incorrect area)

Learnings:

- *Introduce a protocol to defer treatment until all information is available including when the referring GP/surgeon is not contactable*
- *Oncologist to take clinical photograph of the area at the time of initial clinical appointment (to be referred to at the time of treatment area definition) especially if the referring surgeon did not take any photos.*

Incorrect dose

The use of incorrect settings can lead to increased or decreased doses.

Example case: Incorrect dose

Patient was underdosed due to one fraction not being performed.

Due to miscommunication between staff regarding appointments that had been booked, cancelled and rescheduled a treatment booking was missed. The documentation was unclear and some of the quality assurance tasks had not been completed correctly.

(1 of 15 fractions, 2.7 of 40 Gy, not delivered)

Patient was setup correctly to receive low-energy treatment for skin cancer however the wrong patient record was open on the computer console and the settings from this patient were used. This resulted in one fraction being delivered to the correct area but at a higher dose.

(Additional 0.2 Gy skin dose)

Learnings:

- *Establish clear digital pathways for information including patient booking, referral, treatment and medical records.*

Patient positioning

Patient movement should be avoided by providing effective stabilisation and clear instructions to patients and the staff positioning the patient. This is particularly important for extremities, which can inadvertently enter the beam path.

Example case: Patient positioning

A hospital patient undergoing radiation therapy to their chest, shoulder and abdomen received an unintended dose to their arm.

The treatment position for the abdomen required the patient's right arm to be positioned on their chest. During one fraction of treatment the patient's right arm was not repositioned between treatment fields and was subsequently directly irradiated by the oblique radiation angles used for the abdomen treatment.

(Dose to unplanned area of the arm was 4 Gy)

Equipment-related

Three incidents were related to equipment failures or limitations. These types of incidents were also discussed in the feature topic of the ARIR report covering 2019 incidents. Some incidents that are attributed to equipment factors relate to how the equipment was used or where checks of the equipment were not performed.

Example case: Understanding equipment limitations

Image mismatch of planning image (CBCT) prior to treatment using auto-match option.

Initially thought to be due to a change in contour due to reduction in tumour volume but when checked by third party post treatment found to be due to reliance on the auto-matching facility of the software.

(Partial underdose during one of five fractions <4 Gy)

Learnings:

- *Senior staff should be available as a third person to give advice when making a clinical decision.*
- *Raise awareness of the potential for overreliance on and weaknesses of automatic image matching.*

Patient factors

Some factors are outside the control of the clinical team. This can include where a patient takes an action or discontinues treatment.

Example case: Patient factors

A patient received palliative radiotherapy treatment for a malignant neoplasm of the left brain and cerebral meninges. The prescribed treatment plan was for 18 Gy in one fraction. The dose was planned to be delivered via 4 separate Volumetric Modulated Arc Therapy radiation beams in one session. After completion of two of the 4 beams the patient was unable to remain still due to discomfort and anxiety caused by the thermoplastic immobilisation mask that was custom-formed to secure the patient. Treatment was abandoned on the day and delivery of the remaining beams was attempted a week later. That treatment was unfortunately not delivered, again due to patient discomfort. Therefore, only 34% of the prescribed dose was delivered before the patient elected to cease treatment.

(Underdosing ~11 Gy)

Other incidents

Contamination with radioactive material

Example case: Contamination (non-medical)
One staff member had low level contamination on their PPE during maintenance activities. Three further staff members had negligible levels of contamination. *Due to COVID restrictions alternate entry requirements were put in place and some walkthrough portal monitors were removed, as a result detection of contamination was not conducted at the same places as usual. This increased the potential to spread contamination further and for it be undetected for longer. Once identified, staff followed decontamination procedures and areas were surveyed. The contamination was found to be restricted to the immediate work area and had not spread to non-active work areas.* *(Effective dose ~0.0003 mSv, Skin dose of 0.034 Gy)*
Contamination of producing cell and low-level contamination of 2 operators occurred during FDG production. *In the production of FDG, ^{18}F from the cyclotron is synthesised in a shielded production hot cell and then transferred to a bulk product vial in the dispensing hot cell. This transfer is done via a transfer line connected to a sterile filter and a needle that is inserted into the bulk vial.* *Operator 1 (Op1) failed to take the cap off the needle and failed to insert the needle into the bulk vial. Operator 2 (Op2) failed to check as required that all connections had been done correctly before product transfer was initiated. Soon after initiating transfer of the product Op2 noted that the needle was still capped and was not inserted into the bulk vial. Op1 then paused the transfer. Op1 assumed that the product had not reached the dispensing hot cell and opened the dispensing hot cell, removed the cap from the needle and inserted the needle into the bulk vial before closing the perspex cover and shield door. The transfer was resumed and the next steps in the production operation proceeded. However, due to the pressure in the line approximately 0.5 to 0.6 mL of product sprayed from the needle contaminating the floor of the dispensing hot cell and Op1's gloves. Op1 transferred some activity into the production area (benches, PPE and cloths) prior to decontamination. The spill was left to decay.* *(Effective dose 0.7 and 0.2 mSv, Extremity dose 5.7 and 0 mSv)*
Learnings: • *Any deviation from normal routine practices (such as the removal of barriers or detectors) should be properly assessed for impact. This should include consideration of past events and potential hazards. Temporary change measures (such as additional/more frequent checks) can be put in place to ensure risks remain low* • *Practices that are considered routine should be periodically reviewed for drift. Where practices vary based on personal preference (as the sequence is not critical to success) these factors should be taken into account in risk assessments* • *Highlights the importance of independent checks by a second operator.* • *An environment should be established where operators have the time and resources to complete checks and assess risks where they deviate from standard practice.*

Lost, stolen or unauthorised disposal of sources

Example case: Lost/stolen
A gauge was stolen together with equipment that was stored in a 20 ft steel container. *Steel plates were cut and broken around the padlock by thieves to gain entry to the container. Carpark sensor was activated at 6.51 am on Sunday morning, security was on-site within 10 minutes. Security did not exit the vehicle and did not check doors, gates and back alleyway.*
Learnings: • *Highlights the importance of an effective response by security service contractors.* • *Physical security measures that increase the delay time before the source can be removed increase the likelihood that the response will arrive in time and therefore reduce desirability to potential thieves. Following this incident the container was strengthened with additional welded steel.*

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 shipments 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 transport company was engaged by a non-destructive testing company to transport an industrial radiography source container with a decayed radioactive source to Sydney for a source change over. About a week after the source left the premises of the non-destructive testing company, the company was advised that the company supplying the new source had not received the source container. The transport company was unable to locate the source container and instigated a search of its Sydney and Melbourne depots. The searches were completed but the source remained unaccounted for. It eventually arrived at the transport company's Sydney depot 9 days after it had been shipped.

Learnings:

Companies need to ensure they have a good track and trace system when transporting radioactive sources.

Note: Transport incidents in nuclear medicine are discussed in as part of the feature topic of this report.

Non-ionising radiation

Only incidents that are covered by radiation protection legislation in a particular jurisdiction are reported to the ARIR. Depending on the jurisdiction, this may include the use of cosmetic lasers and industrial applications of lasers. One reported incident involved non-ionising apparatus used in cosmetic applications.

Example case: IPL incident

A client received severe burns to legs after treatment for pigmentation. Investigation showed the equipment was intense pulsed light (IPL) treatment, which is not regulated in this jurisdiction. It was suspected that operator training was a significant factor.

High badge reading

Personal monitors record the dose of the person wearing the badge. Any unexpected result, such as a reading higher than normal range, should be investigated promptly. Depending on the jurisdiction it may be required to report the reading on a personal monitoring badge of more than 1 mSv/month. Two such incidents were reported.

Example case: High reading

A potential high dose was recorded on a worker's 'film badge' (sic) following X-ray and gamma ray radiography. The worker advised he removed his shirt due to increasing temperature and left the badge in the pocket. Several hours had passed before he realised.

Industrial

Two incidents involved a borehole logging probe that got stuck but was later retrieved.

One incident involved damage to a gauge on a construction site.

Example case: Damage to gauge
A density and moisture gauge was being used to test earthwork layers for compaction. The gauge was positioned on the pad and was subsequently damaged by a roller. The gauge's source was not exposed and remained in the safe position. Training and awareness initiatives were undertaken on site. *(No additional dose received)*
Learnings: *It is important that all workers are aware of all hazards, particularly on a construction site. Awareness-raising initiatives can include verbal (e.g. toolbox talks) and physical (e.g. portable signage).*