RADIATION MANAGEMENT OF PATIENTS AFTER NEUROINTERVENTIONAL RADIOLOGY

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QUESTION

What is the evidence for managing patients following the use of radiation in neurointerventional radiology procedures?

SEARCH LIMITS

English-language.

SEARCH METHODOLOGY

A systematic search was conducted for literature. The results were screened by two librarians using Covidence. See the Appendix for the PRISMA chart, search terms, and Medline search strategy.

DATABASES SEARCHED

- Medline – index of peer reviewed articles across health sciences and medicine.
- Embase – index of biomed and pharmacological peer reviewed journal articles.
- Emcare – index of nursing, allied health, critical-care medicine and more.
- Cochrane Library – collection of databases containing high-quality independent evidence.
- Grey literature – Google, Google Scholar, Trip database, Biomed Central Proceedings.

HAND SEARCHING

- Hand searching was completed in *American Journal of Neuroradiology*, *Seminars in Interventional Radiology*, *Clinical Neurology and Neurosurgery*, and *Neurointervention*.

LITERATURE RESULTS

All articles can be provided in full text - email library@monashhealth.org a list of articles you require.

GENERAL RESOURCES

ONLINE RESOURCES (GREY LITERATURE)

RANCP. (2022). **Standards of Practice for Interventional Radiology and Interventional Neuroradiology.** Web link.

- All individual doses to occupationally exposed persons and the public are as low as reasonably achievable.
- Once clinically justified, examinations must be conducted and technique optimised, so that the dose to the patient is the lowest necessary to achieve the clinical aim (i.e., dose reduction strategies are implemented to ensure acceptable image quality and minimise the need for a repeat exposure).

European Standards in Medical Training. (2011). **Standards of Practice in Interventional Neuroradiology.** Web link.

- Radiation protection measures must be in accordance with national regulations.

ESNR/ESMINT/UEMS. (n.d.). **Standards of Practice in Interventional Neuroradiology.** Web link.

- Radiation protection measures in accordance with national and European regulations should be in place with designated individuals responsible for carrying out the necessary checks and audits.

PEER-REVIEWED LITERATURE - IN REVERSE CHRONOLOGICAL ORDER

Articles are grouped by theme:

Each article summary contains excerpts from the abstract and an online link.

HAIR LOSS

Corrigall, R. S., et al. (2020). **Observations of tissue reactions following neuroradiology interventional procedures.** *Journal of radiological protection : official journal of the Society for Radiological Protection*, *40*(1), N9–N15. Request full-text.

The study has shown that hair thinning and hair loss are the more likely effects and may occur in 50% of patients at dose above 4.5 Gy.

Davis, M. C., et al. (2015). **Clinical Presentation, Imaging, and Management of Complications due to Neurointerventional Procedures.** *Seminars in interventional radiology, 32*(2), 98–107. Click for full-text.

Radiation exposure during neurointerventional procedures averages 1.67 mSv, with an estimated risk of death by radiation-induced cancer of 1 per 6,000 procedures. Doses of 10 mSv or greater may occur in lengthy cases, with resultant hair loss. Radiation exposure may be controlled by minimizing fluoroscopy time and the number of images acquired during angiograms, the use of dynamic acquisition, and virtual collimation.

Gavagan, L., et al. (2011). **Is hair loss a reality in neuro-interventional radiology?** *Radiation protection dosimetry*, *147*(1-2), 68–71. Click for full-text.

An estimated 7 % of therapeutic procedures were found to reach the International Commission on Radiological Protection threshold for temporary epilation.

Marti, N., et al. (2008). **Radiation-induced temporary alopecia after embolization of cerebral aneurysms.** *Dermatology online journal*, *14*(7), 19. Click for full-text.

A 29-year-old woman underwent 2 endovascular procedures for treatment of bilateral carotid-ophthalmic artery aneurysms. After each treatment, transient alopecia occurred over the occipital area and is presumed to be radiation induced.

Huda, W., et al. (1994). **Radiation-induced temporary epilation after a neuroradiologically guided embolization procedure**. *Radiology, 193*(3), 642–644. Request full-text.

The maximum possible skin dose was estimated to be 6.6 Gy, which is consistent with the temporary epilation in the right occipital region of the skull reported by the patient approximately 5 weeks later.

SKIN INJURY

Bensimon Etzol, J., et al. (2021). **Biodosimetry in interventional radiology: cutaneous-based immunoassay for anticipating risks of dermatitis**. *European radiology*, *31*(10), 7476–7483. Click for full-text.

DosiKit was tested over 95 patients treated with neuroradiological interventions. DosiKit provides a useful way for mapping the actually absorbed doses, allowing to identify patients overexposed in interventional radiology procedures, and thus for anticipating risk of developing dermatitis.

Perry, B. C., et al. (2019). **Monitoring and Follow-Up of High Radiation Dose Cases in Interventional Radiology**. *Academic radiology*, *26*(2), 163–169. Click for full-text.

Of 52 NIR cases, 49 were interventions and 3 were diagnostic angiograms. Five of 49 (10.2%) NIR patients reported skin/hair injuries, all of which were temporary.

Jaschke, W., et al. (2017). **Radiation-Induced Skin Injuries to Patients: What the Interventional Radiologist Needs to Know.** *Cardiovascular and interventional radiology*, *40*(8), 1131–1140. Click for full-text.

This paper reviews the problem of skin injuries observed after fluoroscopically guided interventions. Also, some practical advices are given how to effectively avoid skin injuries. In addition, guidelines are discussed how to deal with patients who were exposed to a potentially dangerous radiation skin dose during medically justified interventional procedures.

Hayakawa, M., et al. (2010). **Direct measurement of patient's entrance skin dose during neurointerventional procedure to avoid further radiation-induced skin injuries**. *Clinical neurology and neurosurgery*, *112*(6), 530–536. Click for full-text.

We conclude that direct dosimetry using multiple radiophotoluminescence glass dosimeter can accurately reveal the maximum entrance skin dosem (ESD) and that precise information regarding ESD can prevent further radiation-induced skin injuries from subsequent procedures.

EYES

Gracia-Ochoa, M., et al. (2020). **Correlation between eye lens doses and over apron doses in interventional procedures.** *Physica Medica, 77*, 10–17. Click for full-text.

The results show good correlation between subjects working on the same medical specialty for 5 specialties: Interventional Radiology, Vascular Surgery, Vascular Radiology, Hemodynamics and Neuroradiology.The geometric correction factors resulting from this study could be used to estimate eye lens dose using over apron dosimeters, which are more comfortable than eye lens dosimeters, as reported by the study subjects, as long as the increased uncertainty of the over apron dosimetry compared to the dedicated eye lens dosimetry is acceptable.

Safari, M. J., et al. (2017). **Influence of exposure and geometric parameters on absorbed doses associated with common neuro-interventional procedures**. *Physica medica*, *35*, 66–72. Click for full-text.

This study showed that the DSA imaging technique contributed to the highest patient's dose and judicial use of exposure parameters might assist interventional radiologists in effective skin and eye lens dose reduction for patients undergoing neuro-interventional procedures.

Sánchez, R. M., et al. (2016). **Radiation Doses in Patient Eye Lenses during Interventional Neuroradiology Procedures.** *AJNR. American journal of neuroradiology*, *37*(3), 402–407. Click for full-text.

A relevant fraction of patients received eye doses exceeding the threshold of 500 mGy.

Sandborg, M., et al. (2010). **Local skin and eye lens equivalent doses in interventional neuroradiology**. *European radiology*, *20*(3), 725–733. Click for full-text.

Two out of the 52 patients received skin doses in excess of 2 Sv. The average and maximum doses to the eye lens (left eye) were 51 and 515 mSv (coiling) and 71 and 289 mSv (embolisation).

DOSE MEASUREMENT

Bundy, J. J., et al. (2020). **Fluoroscopically-guided interventions with radiation doses exceeding 5000 mGy reference point air kerma: a dosimetric analysis of 89,549 interventional radiology, neurointerventional radiology, vascular surgery, and neurosurgery encounters**. *CVIR endovascular*, *3*(1), 69. Click for full-text.

Fluoroscopically-guided procedures with radiation dose exceeding 5000 mGy reference point air kerma are uncommon. The results of this study demonstrate that a large proportion of cases exceeding 5000 mGy were performed by non-radiologists, who likely do not receive the same training in radiation physics, radiation biology, and dose reduction techniques as radiologists.

Kawauchi, S., et al. (2019). **Estimation of patient lens dose associated with C-arm cone-beam computed tomography usage during interventional neuroradiology.** *Radiation protection dosimetry, 184*(2), 138–147. Request full-text.

This study shows that, on average, ~25% of patients' total lens dose was contributed by C-arm cone-beam computed tomography.

Riabroi, K., et al. (2018). **Patient Radiation Dose in Neurointerventional Radiologic Procedure: A Tertiary Care Experience.** *Neurointervention*, *13*(2), 110–116. Click for full-text.

Not all therapeutic neurointerventional radiology procedures are safe from deterministic complications. A small number of patients received doses above the threshold for skin complications and radiation induced cataract. In terms of stochastic complications, most neurointerventional radiology procedures in this study were quite safe in terms of radiation-induced cancer.

Sanchez, R. M., et al. (2014). **Brain radiation doses to patients in an interventional neuroradiology laboratory.** *AJNR. American journal of neuroradiology*, *35*(7), 1276–1280. Click for full-text.

For cerebral embolizations, brain doses resulted in a maximum value of 1.7 Gy, with an average value of 500 mGy. Median and third quartile resulted in 400 and 856 mGy, respectively. For cerebral angiography, the average dose in the brain was 100 mGy.

Kawasaki, K., et al. (2013). **A new reference point for patient dose estimation in neurovascular interventional radiology.** *Radiological physics and technology*, *6*(2), 349–355. Click for full-text.

In interventional radiology, dose estimation using the interventional reference point (IRP) is a practical method for obtaining the real-time skin dose of a patient. However, the IRP is defined in terms of adult cardiovascular radiology and is not suitable for dosimetry of the head. In the present study, we defined a new reference point (neuro-IRP) for neuro-interventional procedures

D'Ercole, L., et al. (2012). **Proposed local diagnostic reference levels in angiography and interventional neuroradiology and a preliminary analysis according to the complexity of the procedures.** *Physica medica*, *28*(1), 61–70. Click for full-text.

Local preliminary diagnostic reference levels were proposed as follows: 180 Gy cm(2), 12 min and 317 frames for cerebral angiography and 487 Gy cm(2), 46 min and 717 frames for interventional procedures (intra-cranial aneurysms and arteriovenous malformations).

Alexander, M. D., et al. (2010). **Patient radiation exposure during diagnostic and therapeutic interventional neuroradiology procedures**. *Journal of neurointerventional surgery*, *2*(1), 6–10. Request full-text.

Radiation exposure is an increasingly important consideration in the development of minimally invasive neurological procedures including cerebral angiography and INR. The type of procedure and lesion type allow the practitioner to estimate radiation exposure.

Neil, S., et al. (2010). **A study of the relationship between peak skin dose and cumulative air kerma in interventional neuroradiology and cardiology.** *Journal of radiological protection, 30*(4), 659–672. Request full-text.

A cumulative entrance surface dose exceeding 3 Gy is considered a suitable action level for triggering follow-up of patients in neuroradiology for possible skin effects. Application of dose action levels defined in this way would affect 8% of neurological embolisation procedures.

Moritake, T., et al. (2008). **Dose measurement on both patients and operators during neurointerventional procedures using photoluminescence glass dosimeters.** *AJNR. American journal of neuroradiology*, *29*(10), 1910–1917. Click for full-text.

It was shown that the regional entrance skin dose could be measured by applying the photoluminescence glass dosimeters. This method should contribute to reducing the dose accumulation in patients as well as in operators.

Shortt, C. P., et al. (2007). **Thyroid dose during neurointerventional procedures: does lead shielding reduce the dose?** *Cardiovascular and interventional radiology*, *30*(5), 922–927. Click for full-text.

Considerable doses to the thyroid are incurred during neurointerventional procedures, highlighting the need for increased awareness of patient radiation protection. Thyroid lead shielding yields significant radiation protection, is inexpensive and when not obscuring the field of view, should be used routinely.

Mooney, R. B., & Flynn, P. A. (2006). **A comparison of patient skin doses before and after replacement of a neurointerventional fluoroscopy unit**. *Clinical radiology*, *61*(5), 436–441. Request full-text.

The large reductions in skin dose reduced the risk of patients suffering radiation injury and confirmed the validity of replacing ageing interventional fluoroscopy equipment with modern equipment that incorporates dose management systems.

Bor, D., et al. (2005). **Patient and staff doses in interventional neuroradiology**. *Radiation protection dosimetry*, *117*(1-3), 62–68. Request full-text.

In this study, dose area product and skin doses of 57 patients, who underwent neurointerventional examinations, were measured simultaneously with staff doses. Although skin doses were comparable with the literature data, higher DAP values of 215 and 188.6 Gy cm2 were measured for the therapeutical cerebral and carotid examinations, respectively, owing to the use of biplane system and complexity of the procedure.

Rampado, O., et al. (2005). **Entrances skin dose distribution maps for interventional neuroradiological procedures: a preliminary study.** *Radiation protection dosimetry*, *117*(1-3), 256–259. Request full-text.

The data confirms the possibility of deterministic effects during therapeutic interventional neuroradiological procedures like cerebral embolisation.

Struelens, L., et al. (2005). **Skin dose measurements on patients for diagnostic and interventional neuroradiology: a multicentre study.** *Radiation protection dosimetry*, *114*(1-3), 143–146. Request full-text.

A correlation was found between the maximum skin dose measured on a patient and the total dose-area product (DAP) value for cerebral embolisations. This correlation makes it possible to estimate the maximum skin dose from these DAP values and to determine a trigger level.

Miller, D. L., et al. (2003). **Radiation doses in interventional radiology procedures: the RAD-IR study: part II: skin dose.** *Journal of vascular and interventional radiology*, *14*(8), 977–990. Request full-text.

Most of the procedures observed may produce a peak skin dose (PSD) sufficient to cause deterministic effects in skin. It is suggested that dose data be recorded routinely for TIPS creation, angioplasty in the abdomen or pelvis, all embolization procedures, and especially for head and spine embolization procedures. Measurement or estimation of PSD is the best method for determining the likelihood of radiation-induced skin effects. Skin dose mapping is preferable to a single-point measurement of PSD.

Gkanatsios, N. A., et al. (2002). **Adult patient doses in interventional neuroradiology**. *Medical physics*, *29*(5), 717–723. Request full-text.

In interventional neuroradiology, surface doses could induce deterministic effects, and the corresponding effective doses are noticeably higher than those normally encountered in diagnostic radiology.

Mooney, R. B., et al. (2000). **Absorbed dose and deterministic effects to patients from interventional neuroradiology.** *The British journal of radiology*, *73*(871), 745–751. Click for full-text.

Although it is unlikely that the intracranial arteriovenous malformation patients will suffer serious effects from these skin doses, there remains some uncertainty over the risk of long-term effects to the skull.

Rudin, S., et al. (1996). **Application of region-of-interest imaging techniques to neurointerventional radiology.** *Radiology*, *199*(3), 870–873. Request full-text.

Region of interest filters, made of multiple layers of gadolinium, were attached to the collimators. Patient skin exposure was reduced by a factor of 3.3-10.0 across 85% of the field of view, and exposures were reduced to below thresholds for skin effects.

Bergeron, P., et al. (1994). **Radiation doses to patients in neurointerventional procedures.** *AJNR. American journal of neuroradiology*, *15*(10), 1809–1812. Click for full-text.

The maximum entrance skin dose varied from 129 to 1335 mGy. The mean effective dose was 1.67 mSv with a range of 0.44 to 3.44 mSv. No deterministic effect has been encountered. Stochastic risk linked to the highest effective dose value was approximately one death by fatal cancer for every 6000 procedures, according to the new International Commission on Radiological Protection coefficient.

PAEDIATRIC

Ashour, R., et al. (2015). **Interventional neuroradiology in children: diagnostics and therapeutics.** *Current opinion in pediatrics*, *27*(6), 700–705. Click for full-text.

Numerous steps can be taken to mitigate the potential risks of pediatric neurointerventional procedures, with recent data from high-volume centers suggesting similar, if not lower, complication rates in children compared with adults. Judicious patient selection and clarity of goals are critically important, however, because children undergoing complex and lengthy neurointerventional procedures are particularly vulnerable to the effects of ionizing radiation, vessel injury, and contrast overload.

Thierry-Chef, I., et al. (2008). **Radiation dose to the brain and subsequent risk of developing brain tumors in pediatric patients undergoing interventional neuroradiology procedures**. *Radiation research*, *170*(5), 553–565. Click for full-text.

The lifetime risk of brain tumor diagnosis was estimated to be increased over the normal background rates (57 cases per 10,000) by 3 to 40% depending on the dose received, age at exposure, and gender. Collimation and limiting fluoroscopy time and dose rate are the most effective means to minimize dose and risk of future induction of radiation-related tumors.

OTHER

Chong, A. B., et al. (2017). **Interventional Radiology Clinical Practice Guideline Recommendations for Neurovascular Disorders Are Not Based on High-Quality Systematic Reviews.** *AJNR. American journal of neuroradiology*, *38*(4), 759–765. Click for full-text.

The methodologic quality of systematic reviews needs to be improved. Although reporting clarity was much better than the methodologic quality, it still has room for improvement. The methodologic quality and transparency of reporting did not vary much among clinical practice guidelines.

Visweswaran, S., et al. (2019). **DNA damage and gene expression changes in patients exposed to low-dose X-radiation during neuro-interventional radiology procedures**. *Mutation research. Genetic toxicology and environmental mutagenesis*, *844*, 54–61. Request full-text.

Our results suggest that most of the patients had increased DNA damage and altered gene expression after receiving relatively low doses of ionising radiation. This implies that these procedures should be carried out at the lowest possible doses of radiation that do not compromise image quality.

SEARCH TERMS

Concept	MeSH headings	Keywords
Interventional neuroradiology	Radiology, Interventional	Interventional neuroradiology; Neurointerventional radiology; Neuro-interventional radiology
Radiology symptoms	Radiation Injuries; Radiation Effects; Radiodermatitis; Radiation Pneumonitis; Acute Radiation Syndrome; Radiation Dosage	Radiation [within 3 words of] dose or dosage or dosimetry or side-effect(s) or side effect(s) or reaction(s) or detriment(al) or injur(y)(ies) or symptom(s) or sick(ness) or pneumonitis or pneumonia fatigue or letharg(y)(ic) or nausea or vomit(ing) or headache(s) or vision or appetite or dry mouth or sores or difficulty swallowing or stiff(ness) or lymphedema or swell(ing)(ed) or decay(ing)(ed) or epilat(ed)(ing) or alopecia or deterministic Hair [within 3 words of] loss or shed(ding) or fall(ing) Skin [within 3 words of] red(ness)(dening) or burn(s)(ing) or itch(ing) or sore(s)(ness) or react(ing)(tion) or injur(y)(ies) or effect Tissue [within 3 words of] red(ness)(dening) or burn(s)(ing) or itch(ing) or sore(s)(ness) or react(ing)(tion) or injur(y)(ies) or effect

MEDLINE SEARCH STRATEGY

1 (interventional neuroradiology or neurointerventional radiology or neuro-interventional radiology).ti. 306

2 Radiology, Interventional/ 4729

3 1 or 2 4956

4 (radiation adj3 (dose or dosage or dosimetry or side-effect* or side effect* or reaction* or detriment* or injur* or symptom* or sick* or pneumonitis or pneumonia)).mp. 166969

5 (fatigue or letharg* or nausea or vomit* or headache* or vision or appetite or dry mouth or sores or difficulty swallowing or stiff* or lymphedema or swell* or decay* or epilat* or alopecia or deterministic).mp. 958305

6 (hair adj3 (loss or shed* or fall*)).mp 9894

7 ((Skin or tissue) adj3 (red* or burn* or itch* or sore* or react* or injur* or effect*)).mp. 137256

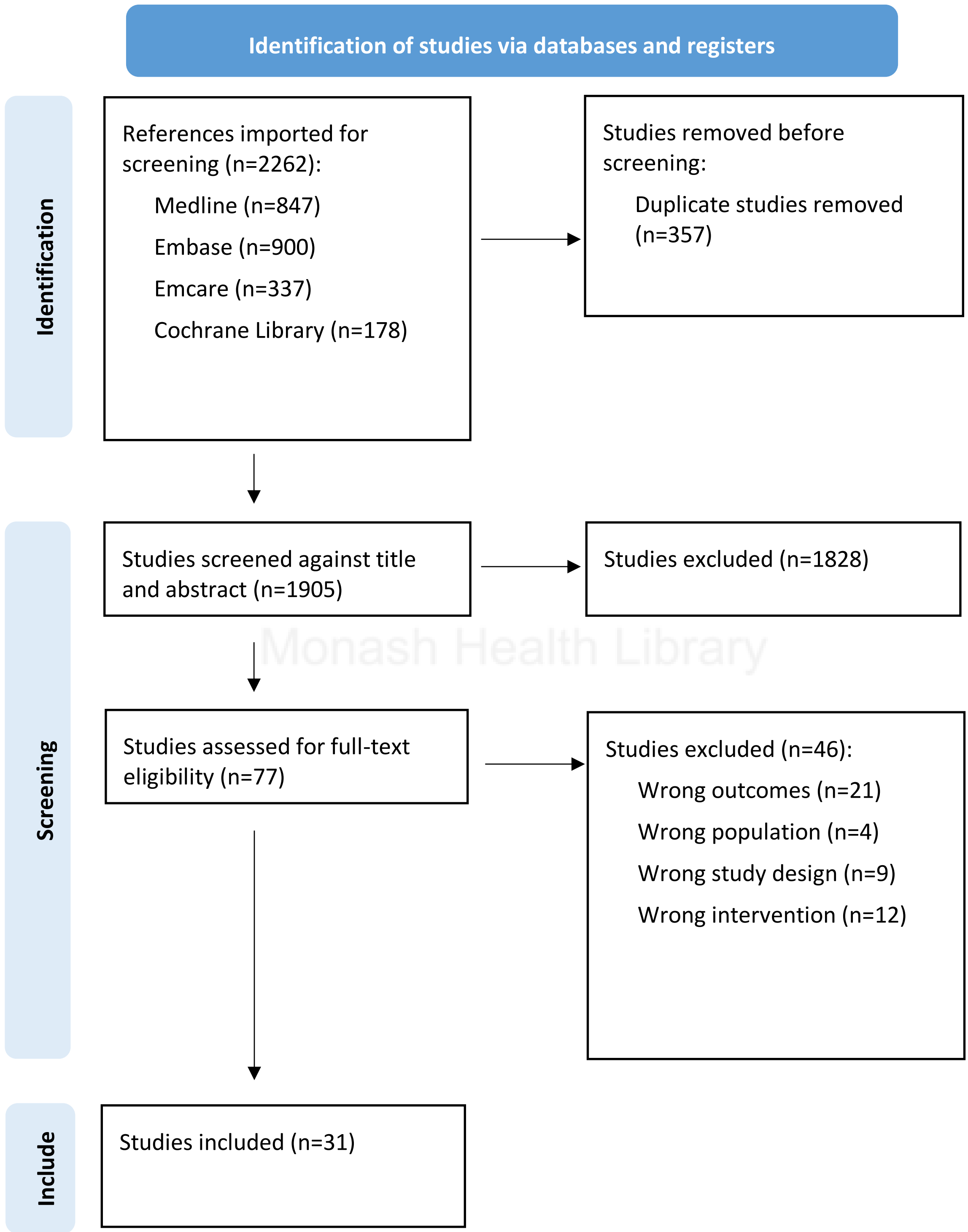
8 Radiation Injuries/ or Radiation Effects/ or Radiodermatitis/ or Radiation Pneumonitis/ or Acute Radiation Syndrome/ or Radiation Dosage/ 115741

9 4 or 5 or 6 or 7 or 8 1277410

10 3 and 9 847

APPENDIX

PRISMA CHART



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