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(Synopsis amended July 2016 w.r.t. whole body vs site specific dose for external radiation sources)

IONISING RADIATION SOP FACTORS

Introduction

The RMA has issued amendments to most of the SOPs that have ionising radiation factors. Similar changes will be made to the remaining SOPs that have such factors in the near future. The SOPs that have been amended and those yet to be amended are detailed in SOP bulletin 150.

The changes involve standardizing and consolidating the ionising radiation factors. Previously there were separate factors for the different types of ionising radiation. There is now one main factor which covers therapeutic radiation, diagnostic radiation, cosmic radiation at high altitude, radiation from occupation-related sources as well as radiation from nuclear explosions or accidents. The inclusion of diagnostic radiation (previously only in two SOPs) is an important change with significant operational consequences.

Synopsis

To apply this new factor it may be necessary to:

a. obtain details on ionising radiation exposure from a range of different sources (e.g. details of diagnostic radiation procedures, plus a history of flights at high altitude);
b. calculate an ionising radiation dose from each source; and
c. combine those into a total cumulative dose.

In some cases this will be a complicated and detailed process.

The new SOP factors contain a wide range of ionising radiation doses – from 0.01 Sieverts (Sv) for reasonable hypothesis (RH) claims for leukaemia, up to 0.5 Sv for balance of probabilities (BOP) claims for solid cancer and other diseases. This dose must have been received by the affected site. Few claimants will have accumulated 0.5 Sv to the affected organ or site, whereas the 0.01 Sv dose to bone marrow required in the RH leukaemia SOPs may be met, for example, by having two CT (computerised tomography) scans of the chest, abdomen or pelvis.

The main new radiation sources that will now need to be considered are certain diagnostic procedures involving the affected site, i.e. CT scans and other high dose procedures such as barium enemas and angiography. Routine plain x-rays result in relatively small doses and it may require hundreds of such procedures to accumulate a SOP factor dose. There is no ionising radiation from an MRI (magnetic resonance imaging) scan or an ultrasound. CT scans and other high dose investigations to distant sites (e.g. an abdominal CT, when the disease is malignant neoplasm of the brain) will not contribute meaningfully to the required dose.

Therapeutic radiation can deliver very high doses to the targeted treatment site. If a cancer develops at the site of that treatment after the required latency period then it is likely that a SOP dose will be met. However, this will be an uncommon event. Therapeutic radiation is carefully targeted and the radiation dose away from the treatment site will be much lower and unlikely to meet a SOP factor.

Cosmic radiation at high altitude will be a consideration mainly for pilots and other aircrew with long hours of flying at high altitude. The extra whole body dose from this source (beyond the normal background levels at ground level) may be of the order of 0.001 to 0.002 Sv per year. It is unlikely that radiation from this source alone will meet a SOP factor dose, except for RH leukaemia cases. However, it may contribute appreciably to the total combined dose.

Radiation from occupational exposure (e.g. radiographers, nuclear industry workers) should have been documented and film badge or other exposure monitoring records may be available. The annual occupational exposure safety limit is 0.02 Sv (to the whole body).

Exposure levels from atomic radiation (bombs, nuclear tests) have been discussed in earlier SOP bulletins (see bulletins 42, 106 and 145).

Some types of radiation exposure deliver radiation to the whole body (e.g. cosmic radiation, external occupational exposure and external atomic radiation). The dose to a particular organ or tissue is lower than the whole body dose, mainly due to shielding by other tissues. The simplest way to derive a site specific dose from whole body radiation is to multiple the whole body dose by 0.7.

The SOP factor latency requirements (for cancers) are an important consideration. Radiation that is too close in time (within 5 yrs for RH and within 10 years for BOP for most solid cancers) to the clinical onset of a cancer cannot be considered. This is not the case in a number of non-cancer SOPs, where the radiation can be any time before.

It may be possible to look at the ionising radiation exposure history from all relevant sources in an individual claimant and conclude (particularly for those SOPs with higher dose requirements) that the total ionising radiation dose received will not meet the SOP factor. In such cases it may not be necessary to go into detail and calculate the dose that has been accumulated at the affected site (before the latency period cut-off date). A total radiation dose of 0.1 Sv or more will be uncommon.

For cases where a significant radiation dose has been accumulated it will be necessary to undertake a potentially detailed assessment.

Detailed information

Ionising radiation

Ionising radiation is invisible high energy electromagnetic radiation which includes cosmic rays, x-rays, gamma rays, alpha particles, beta particles and neutron particles. This does not include ultraviolet light, infrared radiation or electricity of its different forms.

Ionising radiation is present in the earth's surface and in the earth's atmosphere. This radiation is partly natural and partly man made.

Ionising radiation is capable of causing cellular death or damage resulting in pathology such as death, disease, neoplasia and transferable genetic mutations.

Radiation causes disease or injury through two possible mechanisms:

- Deterministic somatic damage – The deterministic somatic damage can cause acute changes varying in severity from burns to death, and chronic residual changes which are non-progressive such as infertility, organ fibrosis. There is a close temporal relationship between the radiation exposure and the acute and chronic complications; and the severity of the somatic damage depends upon the dose.
- Stochastic effect - The Stochastic or random effect of cancer and inherited genetic defects are not acute; are dose related with regards to incidence but not severity, and normally occur after a long latency period.

As radiation can operate in two different ways to cause disease or injury, there are two different types of ionising radiation factors, which for simplicity are latency and no-latency factors.

No-latency factor:

A no-latency factor is where the radiation damage accumulates on exposure to ionising radiation. Examples of the diseases for which the no-latency radiation factor operates are 'Acquired cataract', 'Fibrosing Interstitial Lung Disease', 'Cirrhosis of the liver'.

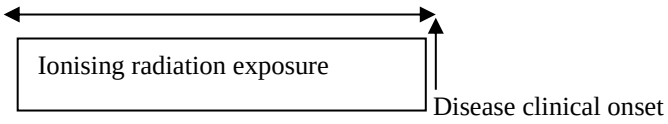
Other non-SOP conditions involving this process would be acute radiation effects affecting the central nervous system, blood, gastrointestinal system, skin, hairs and testes and ovaries.

This is similar to the accumulated microtrauma hypothesis of lumbar spondylosis. As such the reader will be familiar with the operation of the no-latency factor since it operates in a similar manner to the carrying and lifting load factor of lumbar spondylosis.

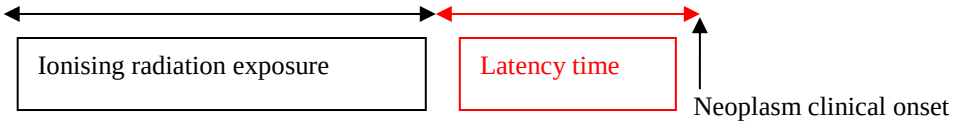
> "carrying or lifting loads of at least thirty-five kilograms while bearing weight through the lumbar spine to a cumulative total of at least 168 000 kilograms within any ten year period before the clinical onset of lumbar spondylosis…".

An example for acquired cataract is:

> "having received a cumulative equivalent dose of at least 0.5 Sievert of ionising radiation to the affected eye before the clinical onset of acquired cataract"



Latency factor:
The latency factor is for neoplasms. In this factor, there is a requirement for the required dose of radiation to be acquired, then for a latency period of time to expire before the neoplasm can be said to be related to the ionising radiation exposure. Hence the normal close temporal relationship does not operate for radiation exposure and neoplasms, since it takes time for the neoplasm to develop after receiving the critical pathogenic radiation dose.



Hence if the neoplasm is acquired in a shorter time than the required latency time, then the neoplasm is not related to this ionising radiation exposure. That is the factor has not been met and is not valid in this case.

Procedure for claims when service-related ionising radiation exposure is a contention:

1. Is there an RMA SOP that applies?
2. Is there an ionising radiation factor in the SOP?
3. Determine the clinical onset of the disease.
4. Examine the ionising radiation factor to see whether it requires a latency period. All neoplasms will require a latency period. What is the latency period?
   If the neoplasm has occurred prior to the expiration of the required latency, the case does not meet the radiation exposure factor and further calculation of the ionising radiation is not required.
5. Calculate the lifetime accumulated ionising radiation to the diseased or damaged organ or tissue prior to the clinical onset for no-latency case, or, calculate the lifetime accumulated ionising radiation to the diseased or

neoplastic organ or tissue prior to the clinical onset minus the stated latency period for the latency case.

Note that the ionising radiation dose that needs to be calculated is the dose to the diseased organ or tissue, NOT the overall body dose. The organ or tissue dose will be significantly different from the total body dose. Table 1 (later in this bulletin) shows the different organ doses for typical diagnostic imaging. Tables 2 and 3 provide overall body doses.

Calculation process:
Calculate the radiation exposure (in Sieverts) for any:

a) therapeutic radiation to the affected organ or tissue.
b) diagnostic radiation to the affected organ or tissue.
c) cosmic radiation at high altitude to the affected organ or tissue.
d) occupation related radiation to the affected organ or tissue.
e) nuclear bomb radiation to the affected organ or tissue.
f) nuclear accident radiation to the affected organ or tissue.

Advice on calculating the exposure for each of the types of radiation is found later in this bulletin.

If the radiation dose is provided in Grays, multiple this dose by the correct radiation weighting factor to convert to Sieverts. The radiation weighting factor is 1 for gamma, beta and x-rays; 5 for slow neutrons; 10 for fast neutrons; and 20 for alpha particles. For therapeutic, diagnostic and cosmic radiation exposure will generally be to x-rays or gamma rays so 1 Gray will be equal to 1 Sievert

Algebraically sum the calculated subcomponent radiations in Sievert in a) to f) above.

> Cumulative equivalent dose of ionising radiation = therapeutic + diagnostic + cosmic + occupation + bomb + accidents.

6. Does the calculated dose at the affected tissue or organ meet or exceed the required dose. The RMA has set 4 different accumulated dose thresholds for neoplasms being 0.01, 0.05, 0.1 and 0.5 Sv for respectively non-solid tissue reasonable hypothesis standard, non-solid tissue balance of probability standard, solid organ reasonable hypothesis standard, and solid organ balance of probability standard.
7. As for all claims, the relationship of the ionising radiation exposure to service needs to be determined.

Examples of latency cases:
Malignant neoplasm of the lung is claimed with the stated clinical onset in 2007 and contended ionising radiation of 0.1 Sv.

An examination of this case indicates that:

1. There is a RMA SOP for this condition.

2. There is an ionising radiation factor in the SOP. The relevant RMA instrument states that for the reasonable hypothesis standard the radiation factor has a latency of 5 years with a cumulative dose at the organ of 0.1 Sv.
3. The clinical onset is confirmed to be 2007.
4. There is a latency period of 5 years, but in this case the required dose was accumulated after 2002. The contended radiation was from coronary angiographies in 1998 and 2005 and a cardiac catheterisation in 2005. The total lifetime dose of ionising radiation may reach 0.1 Sv to the lung, but the accumulated dose up to 2002 does not. Hence the factor is not met on the basis of the timing of the radiation exposure with respect to the latency period.

The second example is a malignant neoplasm of the colon with clinical onset in 2001 and contended accumulated dose of 60 Gy.

An examination of this case indicates that:

1. There is a RMA SOP for this condition.
2. There is an ionising radiation factor in the SOP. The factor is "having received a cumulative equivalent dose of 0.5 Sievert of ionising radiation to the colorectum at least 10 years before the clinical onset of malignant neoplasm of the colorectum".
3. The clinical onset is confirmed to be 2001 based on actual contemporary documentation.
4. There is a latency period of 10 years, hence the lifetime ionising radiation exposure is to be calculated before 1991.
5. The veteran has had a significant ionising radiation exposure of 60 Gray in 1989. Given the latency period, the contended radiation exposure is within the time period to be considered. This exposure was from therapeutic radiation to the larynx, using gamma rays. Using the radiation weighting factor of 1, the laryngeal exposure is 60 Sievert.
6. The issue with this case is that no materially significant proportion of the total 60 Sv applied to the neck would reach the colon. As such the ionising radiation factor has not been met for this cancer.

The third example is a claim for leukaemia, with onset in 2007 and past radiotherapy to the spine for ankylosing spondylitis in 1955.

An examination of this case indicates that:

1. The diagnosis is chronic myeloid leukaemia.
2. There is a RMA SOP for this condition.
3. There is an ionising radiation factor in the SOP. The factor is "having received a cumulative equivalent dose of 0.05 Sievert of ionising radiation to the bone marrow at least 2 years before the clinical onset of chronic myeloid leukaemia".
4. The clinical onset is confirmed to be 2007 based on actual contemporary documentation.
5. There is a latency period of 2 years, hence the lifetime ionising radiation exposure is to be calculated before 2005.
6. The veteran has had a significant ionising radiation exposure of 10 Gray in 1955 to the thoracolumbar spine to treat ankylosing spondylitis.

This exposure was due to gamma rays which, using the radiation weighting factor of 1, is an exposure of 10 Sievert.

7. The radiation exposure to the spine is likely to deliver a significant proportion of the 10 Sv to the active red bone marrow. Hence this factor would be met for this neoplasm.

The fourth example is for a brain neoplasm with clinical onset in 2001, with a contention of 3 CT scans of the chest in the early 1990s, one CT scan of the brain in 2002, one MRI scan of the brain in 2002, 10 chest x-rays, 4 right ankle plain x-rays and 1 plain wrist x-ray between 1980 and 1995.

An examination of this case indicates that:

1. The diagnosis is malignant neoplasm of the brain.
2. There is a RMA SOP for this condition.
3. There is an ionising radiation factor in the SOP. The factor is "having received a cumulative equivalent dose of 0.5 Sievert of ionising radiation to the brain at least 5 years before the clinical onset of malignant neoplasm of the brain".
4. The clinical onset is confirmed to be 2001 based on actual contemporary documentation.
5. There is a latency period of 5 years, hence the lifetime ionising radiation exposure is to be calculated before 1996.
6. The contended ionising radiation exposure needs to be sorted:
    - The MRI scan is not ionising radiation so it is not considered.
    - The CT scan of the brain in 2002 is outside the time requirements and hence is not considered.
    - Hence the CT scans of the chest, 10 chest x-rays, 4 right ankle plain x-rays and 1 plain wrist x-ray should be considered. Of these contended x-rays, the limb x-rays are remote from the brain and hence are not relevant to the accumulated dose at the brain.
    - It does not appear that the chest radiation would provide much collateral radiation to the brain but an examination of the total possible dose and the known organ related doses can be sought.

	Total dose	No.		Thyroid	No.	
CT scan of chest	0.007	3	0.021	0.00225	3	0.007
Plain chest xray	0.0001	10	0.001	0.00001	10	1E-04
Total estimate =			**0.022**			**0.007**

It is noted that the total dose from the 3 CT scans of the chest and the 10 plain x-rays of the chest is 0.022 Sv which falls short of the required 0.5 Sv to the brain. Hence there is no need to even consider the specific dose to the brain given that the contended total body dose does not meet the factor.

However I have examined the tabulated data on diagnostic radiation for the CT scan of the chest and the plain chest x-ray and have not found a specific measurement for the brain but believe that the column concerning the thyroid would provide useful data. It is noted that the calculation of the radiation dose at the thyroid from the contended chest diagnostic radiation is 0.007 Sv which falls short of the required 0.5 Sv to the brain. It should be noted that radiation classically falls off at the inverse

square of the distance, so actual dose that the brain should be considerably lower than the 0.007 Sv estimated at the thyroid.

Example of a no-latency case:
A client has a diagnosis of a cataract with clinical onset of 1995 with an accumulated dose of 1.2 Sv of ionising radiation before 1995.

An examination of this case indicates that:

1. There is a RMA SOP for this condition.
2. There is an ionising radiation factor in the SOP.
3. The clinical onset is confirmed to be 1995.
4. There is no latency period.
5. The veteran has had exposure of 1.2 Sv to the body but the dose to the eye needs to be calculated.
6. From the data provided it appears that only 1.0 Sv to the eye occurred before the clinical onset but this is sufficient to meet the SOP requirement of "having received a cumulative equivalent dose of at least 1.0 Sievert of ionising radiation to the affected eye before the clinical onset of acquired cataract".

Calculating radiation doses for different types of radiation

A. Therapeutic radiation

Therapeutic radiation is chiefly used to eradicate or palliate neoplasia, but is also used for some limited applications to treat non-malignant diseases such as hyperthyroidism. There were also in the past other more widespread applications of radiation for non-malignant conditions including high doses of spinal radiation for ankylosing spondylitis. As such therapeutic radiation is not restricted to cancer therapy.

Radiotherapy can be delivered using beams of radiation (gamma rays, x-rays, radioactive particles); or by locally applied radioactive particles (Brachytherapy to interstitium, intracavity, and surface).

Radiotherapy is provided in fractions of a total dose delivered in a number of treatments over a period of time. It is delivered in this manner since the application of the whole radiotherapy dose necessary to eradicate the neoplasia, would cause the normal tissue surrounding the neoplasia and in the path of the radiation source to suffer radiation damage. Bomford et al (1993, p. 256)[1] states that radical radiotherapy can involve doses of 2 Gray per day with an interval of at least 6 hours.

The prescription of the ionising radiation to cure or palliate a cancer is provided as a total dose to a target tissue volume as well as the number of fractions into which this total dose is divided. The total dose is provided on the central axis or axes where there are multiple intersecting fields. For example for cancer of the tongue, Bomford et al (1993, p. 317)[1] provides a prescription of 60 Gy in 25 daily fractions over 5 weeks (4-6 MV photons). As such, this is 60 Sv of radiation in the area of cancer irradiation, but the dose suffered to the surrounding tissues falls off according to the radiation contours provided on the treatment plan.

For the purposes of a compensation claim related to radiation, it is required that the accumulated radiation dose at the affected organ be estimated.

To estimate the accumulated radiation to the affected organ, it is required to examine the 'radiation treatment plan' and 'portal or check simulator film' for the cancer.

The 'radiation treatment plan' for external beam therapy is a graphical representation of the radiation isodose curves superimposed on the body. The 'portal or check simulator film' is an exposed x-ray film indicating the radiation treatment volume and its surrounding anatomy.

Radiotherapy is a carefully targeted treatment, and radiation intensity declines according to an inverse square law, so it seems reasonable not to include radiation exposure to any tissue or organ not in the immediate vicinity of the treatment plan.

As such, with the example of radiotherapy to the tongue cancer, only the head and neck would be considered for collateral radiation exposure, with the thyroid, salivary gland, local skin, local spinal cord all in contention.

An examination of the radiation treatment plan for the example of a cancer of the tongue mentioned above, indicated a 45% isodose contour just touches the front of the spinal cord in the neck, so for a claimed spinal cord tumour of the neck, 45% of 60 Sv or 27 Sv is experienced by the spinal cord.

A gross total dose of typical radiotherapy regimens can be obtained from radiotherapy textbooks such as Bomford, Kunkler and Sherriff (1994)[1].

It is recommended that a medical adviser be asked to provide a medical opinion concerning the likely radiotherapy dose. The relevant medical specialist for this issue is a specialist radiation oncologist, with provision of the radiation prescription data and radiation treatment plan from the treating radiation oncologist.

B. Diagnostic radiation

Normally this is delivered by x-rays and gamma rays and as such the radiation measurement dose is in Sievert (Sv) or Grays (Gy) since the biological weighting factor is 1. As such the dose in Grays equals the dose in Sieverts for diagnostic radiation.

Diagnostic radiation is delivered in standard format so that the respective dose of each procedure is approximately the same for an average adult. Having said that, the dose has changed somewhat with the change in technology and radiological practices with the passage of time.

Tables 1 to 3 below were constructed from Mettler et al (2008, p. 256-257, tables 1-5)[2] for the overall dose (column 1 of the first table); and from Berrington de Gonzalez (2004, p. 346, table 1)[3] for the estimated organ specific doses by type of diagnostic radiological procedure. The gonadal collateral doses were taken from Iturralde (1990, p. 438. table 4)[4]. References to "chest", "hip" etc in these tables refer to plain x-rays. "RBM" in table 1 stands for red bone marrow.

Table 1: Collateral organ doses in Sievert from Diagnostic ionising radiation												
	Average Overall	Bladder	Breast	Colon	Liver	Lung	Oesophagu	RBM	Stomach	Thyroid	Testes	ovary
Abdomen	0.0007	0.00114	0.00005	0.00163	0.0011	0.00027	0.00003	0.00037	0.00164	0.00003	0.001	0.0022
Coronary angiography	0.007	0.00023	0.00042	0.00051	0.00154	0.03769	0.01379	0.00739	0.00067	0.00108		
Cerebral angiography	0.005	0	0.0002	0	0.00001	0.00114	0.00198	0.00927	0.00001	0.02506		
Barium meal	0.006	0.00028	0.00062	0.00182	0.00948	0.00123	0.00054	0.00169	0.00824	0.00022		0.003
Barium enema	0.008	0.01445	0.00014	0.02151	0.00355	0.00039	0.00006	0.00749	0.00498	0.00001	0.003	0.017
Cardiac catheterisation	0.015	0.00023	0.00042	0.00051	0.00154	0.03769	0.01379	0.00739	0.00067	0.00108		
Cervical spine	0.0002	0	0	0	0	0.00007	0.00012	0.00007	0	0.00084		
Chest	0.0001	0	0.00001	0	0.00003	0.00007	0.00004	0.00002	0.00002	0.00001		
Hip	0.0007	0.00116	0	0.00071	0.00001	0	0	0.00012	0.00002	0	0.006	0.0012
Hysterosalpingography		0.00467	0	0.00282	0.00001	0	0	0.00081	0.00003	0		
Intravenous urogram	0.003	0.00442	0.0002	0.0051	0.00349	0.00042	0.00003	0.00083	0.00604	0	0.0021	0.0059
Lumbar myleogram		0.0079	0.00001	0.01085	0.0013	0.00004	0.00001	0.00406	0.00162	0		
Lumbar spine	0.0015	0.00249	0.00003	0.0024	0.00216	0.00015	0.00002	0.00068	0.00151	0	0.0022	0.0072
Mamogram	0.0004	0	0.002	0	0	0	0	0	0	0		
Pelvis	0.0006	0.00213	0.00001	0.00185	0.00013	0.00001	0	0.00025	0.00029	0	0.0036	0.0021
Skull	0.0001	0	0	0	0	0.00001	0.00002	0.00012	0	0.00014		
Thoracic spine	0.001	0	0.00047	0	0.00057	0.00225	0.00115	0.0005	0.00025	0.00297		
CT abdomen	0.008	0.00507	0.00072	0.0066	0.00005	0.0027	0.00056	0.00558	0.0222	0.00005		
CT chest	0.007	0.00002	0.0214	0.00007	0.00564	0.0224	0.0283	0.00594	0.00406	0.00225		
CT head	0.002	0	0.00003	0	0.00001	0.00009	0.00007	0.00267	0	0.00185		
CT of inner ear		0	0.00002	0	0.00001	0.00008	0.00007	0.00083	0	0.00203		
CT orbits		0	0.00001	0	0	0.00004	0.00003	0.00105	0	0.00087		
CT pituitary		0	0.00001	0	0	0.00004	0.00003	0.00096	0	0.00077		
CT pelvis	0.006	0.0232	0.00003	0.0151	0.00068	0.00005	0.00001	0.00562	0.00106	0		
CT cervical spine	0.003	0	0.00009	0	0.00003	0.00058	0.00051	0.00112	0.00002	0.0439		
CT thoracic spine		0	0.0277	0.00002	0.00148	0.0134	0.0157	0.00292	0.00098	0.00046		
CT lumbar spine		0.00067	0.00013	0.0033	0.00688	0.00034	0.00008	0.00252	0.0105	0.00001		0.0008

Note that the first column of table 1 does not directly relate to the data in columns 2-12 because the data comes from 2 different sources.

Further note that the first column of table 1 is the average whole body dose that the typical diagnostic imaging would produce. There is a range of different doses for each diagnostic imaging procedure in the published literature depending on patient factors (age, body size and body mass) and machine factors (type and generation of machine, tube current, scanning time, scan range, scan pitch, tube voltage).

The overall or whole body dose is the dose that would have been received if the amount of radiation from the diagnostic procedure had been delivered uniformly to the whole body. The dose to a particular organ or tissue differs from the whole body dose. If the organ or tissue was in the radiation field for the diagnostic procedure (e.g. heart and lungs for a CT of the chest), then the radiation dose to that organ or tissue is higher than the whole body dose. If the organ or tissue was outside the radiation field then the dose to that site will be lower and may be negligible.

Table 1 can be used to estimate the radiation dose to an affected site for each type of diagnostic procedure. This will be an average dose for that procedure. The total dose to the affected site can then be estimated from adding up the doses from individual procedures.

Where the table does not contain the specific organ or tissue for which the ionising radiation is a contended causal factor, an estimate can be substituted from a nearby organ or tissue which is listed in the table. For example, this table can help the decision maker who is considering the ionising radiation to the brain, to disregard a past CT scan of the pelvis, since there is no significant dose present at the thyroid.

Table 2: Imaging procedures	**Average**				
	Total dose	Number of tests to reach the dose level			
	Sv	0.5 Sv	0.1 Sv	0.05 Sv	0.01 Sv
IVP [Intravenous pyelogram]	0.003	167	33	17	3
Upper GI series	0.006	83	17	8	2
Small bowel series	0.005	100	20	10	2
Barium enema	0.008	63	13	6	1
CT dental	0.0002	2500	500	250	50
CT head	0.002	250	50	25	5
CT neck	0.003	167	33	17	3
CT coronary angiogram	0.016	31	6	3	1
CT cardiac calcium score	0.003	167	33	17	3
CT chest	0.007	71	14	7	1
CT chest for PE	0.015	33	7	3	1
CT thoracic spine					
CT lumbar spine					
CT abdomen	0.008	63	13	6	1
CT liver 3 phase study	0.015	33	7	3	1
CT - virtual colonoscopy	0.01	50	10	5	1
CT pelvis	0.006	83	17	8	2
CT body					
CT spine	0.006	83	17	8	2
Dual energy xray absorptiometry	0.000001	500000	100000	50000	10000
DEXA + CT	0.00004	12500	2500	1250	250
mamogram	0.0004	1250	250	125	25
Coronary angiogram	0.007	71	14	7	1
Coronary procedures	0.015	33	7	3	1
Head and/ or neck angiography	0.005	100	20	10	2
Thoracic aorta or angiography	0.005	100	20	10	2
Abdominal aorta or angiography	0.012	42	8	4	1
Cholecystography					
ERCP	0.004	125	25	13	3
Dental xray	0.000005	100000	20000	10000	2000
Dental bitewing					
Teeth pantogram	0.00001	50000	10000	5000	1000
Skull series	0.0001	5000	1000	500	100
Chest series	0.0001	5000	1000	500	100
Chest PA	0.00002	25000	5000	2500	500
Cervical spine series	0.0002	2500	500	250	50
Thoracic spine series	0.001	500	100	50	10
Lumbar spine series	0.0015	333	67	33	7
Abdomen series	0.0007	714	143	71	14
Pelvis series	0.0006	833	167	83	17
Hips	0.0007	714	143	71	14
Shoulder	0.00001	50000	10000	5000	1000
knee	0.000005	100000	20000	10000	2000
Other extremities	0.000001	500000	100000	50000	10000

In tables 2 and 3, the first column is the average whole body dose that the typical diagnostic imaging would produce. There is a range of different doses for each diagnostic imaging procedure in the published literature depending on patient factors (age, body size and body mass) and machine factors (type and generation of machine, tube current, scanning time, scan range, scan pitch, tube voltage).

In the second to fifth columns, a calculation is provided of the necessary number of that specific investigation that would be required to meet the threshold of organ specific or tissue specific radiation dose in the different RMA SOPs.

The Repatriation Medical Authority has now effectively standardised the ionising radiation factor thresholds as:

Required threshold of ionising radiation (Sv)	Reasonable hypothesis standard of proof	Balance of probabilities standard of proof
Solid cancer	0.1	0.5
Blood cancer	0.01	0.05

Note that this calculation in tables 2 and 3, is only a rough guide for the decision maker and is not definitive.

A rough calculation based on tables 2 and 3 can be used to establish whether a significant amount of diagnostic radiation has been received and therefore whether a detailed assessment of the radiation dose to the affected organ or affected tissue needs to be undertaken.

It making this calculation it must be kept in mind that the organ or tissue dose will be higher if the organ or tissue was in the radiation field for the diagnostic procedure, but much smaller or even negligible if the organ or tissue was remote from the procedure.

Table 3: Radionucleotide imaging procedures	**Average**				
	Total dose	Number of tests to reach the dose level			
	Sv	0.5 Sv	0.1 Sv	0.05 Sv	0.01 Sv
Thyroid scan - Iodine	0.0019	263	53	26	5
Thyroid scan - Technetium	0.0048	104	21	10	2
Cardiac thallium scan	0.0407	12	2	1	0
CardiacTechnetium scan	0.0094	53	11	5	1
Chest Ventilation perfusion V/Q scan	0.0025	200	40	20	4
Bone scan	0.0063	79	16	8	2
Gastrointestinal bleeding scan	0.0078	64	13	6	1

C. Cosmic radiation at high altitude

Cosmic radiation despite the name, is different from x-rays or gamma rays being a collection of high energy high speed subatomic particles (protons, neutrons, electrons, muons, photons). These particles can be directly damaging and can additionally act through the formation of secondary particles on colliding with the earth's atmosphere.

These high energy primary particles originate chiefly from galactic sources but also from the sun. The earth is shielded from this radiation due to the earth's atmosphere and the electromagnetic fields formed from the earth and the solar wind.

This shield has decreasing effectiveness at times of low solar activity; at latitudes at distance from the equator; and at altitudes above the earth. As such, the chief variables with respect to cosmic radiation at high altitude exposure are:

- Time of exposure
- Altitude of exposure
- Physical location (latitude)
- Duration of exposure
- Sources of shielding (more difficult to ascertain)

These high energy particles impacting upon the human body can cause DNA damage and have different radiation effectiveness according to the radiation weighting factors. Protons 5; neutrons 5 to 20; photons, electrons and muons 1.

Alves and Mairos (2007, p. 436)[5] state estimate that aircrew of a C130 Hercules transport mission would be exposed to 140 to 167 μSv per month with a yearly exposure of 1.5 to 1.8 mSv [0.0015 – 0.0018 Sv].

Grajewski et al (2002, p. 34)[6] state that flight attendants on commercial jet airliners were exposed to 1.5-1.7 mSv per year [0.0015 – 0.0017 Sv].

There are several websites that provide individual calculations of the accumulated dose of cosmic radiation for each airplane flight, being the Australian ARPANSA site[7], the USA Federal Aviation Administration online calculator[8] and the French SIEVERT on line calculator[9].

D. Radiation from occupation related sources

Ionising radiation is known to be utilised for medical diagnostic and therapeutic purposes and in industrial non-destructive testing.

Ionising radiation exposure from known occupational sources is continuously monitored by use of radiation personal monitoring badges.

These badges are read by the Australian Radiation Laboratory and the Cumulative Effective Dose is provided on the veteran's file.

Ionising radiation exposure from accidental sources would need to be specially calculated based on the evidence provided. Given the significant occupational health and safety risks that such an accident would pose, it is likely that there would be significant documentation from the military relating to this incident. All the data should be sought to permit an examination of the accumulated radiation dose.

Note that SOP bulletin No. 116 discusses radium dial painters and depleted uranium exposure.

E. Radiation from nuclear bomb explosions

This ionising radiation associated with nuclear bomb explosions or nuclear bomb tests have been previously dealt with in the atomic radiation SOP bulletins:

- 17/11/00 – Bulletin No. 42.
- 13/7/06 – Bulletin No. 106
- 1/7/10 – Bulletin No. 145.

F. Radiation from Nuclear accidents

This ionising radiation may be from individual exposure from an accident at a nuclear power station such as the recent Japanese experience.

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