

Exposure To Diagnostic Ionising Radiation in Sports medicine.

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Doctors have a number of investigations available to them to help them better diagnose suspected injuries in sports medicine. Many of the tests (X rays, CT scanning, Bone scanning), involve exposure to diagnostic ionising radiation whereas others do not (MRI, Ultrasound).

One of the dictums of medical practice was first stated by Hippocrates, '*Primum non nocere*' (First do no harm). Diagnostic ionising radiation, like other medical tests and procedures, is associated with a risk to the patient. In this case, there is a potential risk, albeit small (see tables below), of a radiation-induced cancer and/or a genetic disorder in one's offspring.

The elite sportsperson nowadays can have a career spanning many years, and the investigation of any injuries he or she sustains may involve numerous exposures to ionising radiation. Therefore this population may be considered at particular risk for increased exposure to diagnostic ionising radiation.

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How are diagnostic ionising radiation DOSES measured?

The more common sports medicine tests associated with ionising radiation involve ionising radiation in the form of “x rays” (from conventional x rays or from CT scanning) or gamma rays emitted by radiopharmaceuticals that are used in bone scanning. X rays and gamma rays ionise atoms and molecules in human tissues through the deposition of energy. DNA strand breakages from this ionisation process may be the first step in a series of events that lead to a biologic (cancer) and/or genetic effect.

In order to better quantify diagnostic ionising radiation doses and in turn the risk it carries the International Commission on Radiological Protection (ICRP) has defined the term, ‘Effective dose’. The effective dose takes into account the dose absorbed by each irradiated organ and the organ’s relative radiosensitivity. The unit of effective dose is the sievert (Sv). As a general rule of thumb the more radiosensitive tissues are located in the trunk region (gonads, lung, breast, gut, bone marrow, thyroid) and therefore tests (x ray and CT scanning) in the trunk region carry a much greater effective dose than these tests done of the extremities.

The effective dose associated with most diagnostic imaging modalities is in the range of 0.03 to 20 millisieverts (mSv). This dose may be compared with the annual dose from natural background radiation (mainly in the form of cosmic rays from outer space) in Australia of about 1.5mSv or with the doses received by the survivors of the 2 atomic bombs of 1945, which were in the range of 5mSv to 2 Sv.

The effective dose for the various common x rays and CT scans performed in sports medicine can be estimated for a theoretical patient athlete X (80 kg male athlete) using complex mathematical modelling (see Tables 1 and 2).

Table 1.

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Table 2.

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The effective dose for a bone scan for athlete X is calculated to be 4.6 mSv if 800 MBq of technetium radioisotope is injected intravenously.

The above tables and the bone scan estimate of effective dose is roughly transferable to adult female patients and paediatric patients providing adjustments are made by the radiographer/nuclear medicine technician performing the test.

How is the RISK associated with diagnostic ionising radiation estimated?

At the very low levels of radiation used in diagnostic procedures, radiation-induced injury is expressed in terms of the probability of biologic (carcinogenesis) and/or genetic effects. Since the first excess cancers were observed following the atomic bombs of 1945 scientists have worked hard to establish the relation between dose of radiation and the risk of that exposure. The ICRP have extensively reviewed the research and believe that all radiation exposure, albeit at an extremely low level, carries a risk. Using accepted mathematical modelling the risk estimates for athlete X have been calculated for common sports medicine x ray examinations and CT scans (see tables 3 and 4).

The term “risk estimate” is defined, as the risk incurred by the theoretical patient (athlete X) that he will develop a fatal cancer earlier in life than he would otherwise have developed had he not been exposed to that particular level of ionising radiation.

Table 3.

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The effective dose in bone scans, as described previously, depends on the dose/activity of the radiopharmaceutical injected intravenously and is independent of the anatomic region studied in the bone scan. The effective dose for athlete X of 4.6 mSv confers a risk estimate of induction of a fatal cancer of 1 in 3,500.

For adult female patients the above risk estimates are roughly transferable. However for paediatric patients, the risk estimates are higher than for adults. The reason for this is that young patients' tissues are more radiosensitive and their longer life expectancy means that they carry the risk for a longer period of time. The ICRP estimates the relative risk to be 1.8 times higher for children exposed to the same effective dose of radiation as a 30-year-old adult.

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Uncertainties in the estimation of RISK.

Risk estimates are derived from epidemiological studies of survivors of the 2 atomic bombs of 1945. Complex mathematical modelling by the ICRP have estimated/extrapolated the risk estimates for very low levels of ionising radiation associated with the diagnostic tests stated above but it is worthwhile to consider that

there remain some uncertainties in this process. Indeed many scientists argue many of the DNA breakages incurred by very low levels of radiation are repairable and therefore there exists a “threshold” level of ionising radiation below that there exists no risk.

No definitive convincing studies in the medical literature exist that have proved/disproved individuals exposed to diagnostic radiation from x-rays, CT scans or bone scans have developed early fatal cancers or have an increased incidence of birth defects in their offspring.

Risk of Genetic anomaly?

No statistically significant genetic effects have been observed in the children of the atomic bomb survivors of 1945. It is extremely difficult to accurately demonstrate causality between low-dose radiation and risk of inheritable disease. This is because the natural incidence of genetic anomalies in children is high (1 in 44 births). It is estimated by the ICRP that 1mSv of radiation exposure may transfer an increased risk of a genetic anomaly in 1 in 77,000 births.

Cumulative effective dose and cumulative risk.

It should be appreciated that radiation-induced effects are believed to be cumulative. That is, the dose and risk associated with each exposure is added to the dose and risk from any previous exposure.

The “cumulative effective dose” and in turn the “cumulative effective risk” for an individual who suffers many injuries over many years that require investigation with ionising radiation may become quite significant. Such an individual may be an elite athlete who has a long career.

Minimizing the exposure and reducing the risk.

The ICRP promotes 2 very important principles, or rather, dose reduction strategies, in the minimisation of radiation exposure to patients:

1. Justification
2. Optimization

It is ethically right to restrict the use of diagnostic tests that involve ionising radiation to only those who will benefit from them. It is the treating doctor's responsibility to balance the expected benefits and the possible risks for every investigation that is ordered in each patient's particular case. It should be stated clearly that if the result of performing an investigation on a patient will benefit his

of her overall health (in the short and longer term), despite the possible theoretical risk of the radiation exposure, the investigation is justified. This is the principal of JUSTIFICATION.

When a patient presents to a radiology practise for a x ray, CT scan or a bone scan the aim should be to reduce the radiation to as low as reasonably achievable without compromising the quality of the diagnostic images. This is the principal of OPTIMIZATION.

Whenever possible, diagnostic procedures that do not use diagnostic radiation (MRI and ultrasound) should be used if they can yield the same, or in many instances superior information. At present the cost of MRI in Australia is prohibitive for many patients.

These dose-reduction strategies discussed above should be considered by the treating doctor for all patients that may require diagnostic tests. However these strategies are particularly pertinent for children and also elite athletes where every exposure needs to be justified and optimised.

Conclusion

The doctor caring for patients who require sports medicine diagnostic procedures that involve exposure to ionising radiation should have a working knowledge of the effective doses and risk estimates associated with the more common tests. In addition, the doctor should appreciate the concepts of justification and optimisation, particularly when caring for paediatric patients. Investigations that do not involve ionising radiation should be considered whenever possible and affordable.