Doctor, what's the risk? Is our knowledge of radiation keeping up with technology?

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Aim

The aim of this poster was to investigate and contextualise the historical influences of ionising radiation practices against the need to practice safe, consenting clinical practice. This is best undertaken when considering the history of medical imaging, the subsequent growth in the use of ionising radiation, and radiation risks.

A Brief History of Medical Imaging

Wilhem Röntgen is credited with the discovery of x-rays and in 1895 produced the first x-ray image[1]. Crude forms of fluoroscopy soon followed with both patient and physician exposed to high levels of ionising radiation. A number of advancements in medical imaging occurred around the 1950’s with the development of TV cameras and image intensifiers allowing fluoroscopy to resemble what it is today[2]. Furthermore the development of ultrasonography allowed specialised imaging without the need for ionising radiation[2].

However the introduction of computed tomography (CT) in the early 1970’s is arguably the most significant advancement in diagnostic imaging since x-rays were discovered[2]. With the profits raised from the success of The Beatles, EMI was able to fund Godfrey Hounsfield’s research into CT and the development of the first CT scanner[3].

In the early 1980’s MRI was introduced clinically, providing another non-ionising radiation modality for medical imaging[2].

Radiation sources and the growth of medical imaging

Radiation exposure comes from a range of sources, the most significant being natural background and medical sources. Individual natural background radiation doses depend on a number of factors, however the world-wide average estimated dose from background radiation is 2.4mSv/year[4] while the average Australian background dose is 1.5mSv/year[5]. When considering the effective dose from medical imaging, a chest x-ray results in a dose of about 0.02mSv, equivalent to several days of background radiation, while a single chest CT is about 8mSv or several years of background radiation.

The effective dose in Australia from medical imaging sources has been estimated a number of times since the mid-nineties[5, 6]. Fig. 1 on page 3 summarises the increased dose due to CT and all other imaging services over this time frame. It is important to note that the per capita dose from medical sources now exceeds the background radiation dose in Australia and that this is largely due to the substantial increase in the use of CT.
Radiation Risk

There is no doubt that exposure to ionising radiation can cause cell damage. Radiation induced hazardous effects can be separated into two categories: deterministic and stochastic[7]. Deterministic effects are caused by cell death or damage due to exposure to radiation over a threshold amount. These effects are dose dependent with threshold amounts well over most diagnostic radiography exposures. However in certain circumstances such as long interventional fluoroscopy screening times[8] and when normal CT protocols are exceeded[9], deterministic effects including epilation ulceration and erythema have been recorded. See Fig. 2 on page 4 and Fig. 3 on page 5.

Stochastic effects are delayed effects of ionising radiation, the most commonly considered being malignancy. It is currently believed that the risk of these effects is increased by an accumulation of radiation exposure and that the risk is proportional to dose[7]. The most accepted model for predicting stochastic effects is the Linear No-Threshold (LNT) model from which it can be predicted that even for very low exposures there is an increased lifetime risk of stochastic effects[10]. When considering individual plain x-ray examinations this is almost negligible, however with the increased use of high dose modalities such as CT, often with the same patient receiving multiple scans of the same area, the risk becomes more substantiated[11]. The LNT model for low dose exposures is an extrapolation from the incidence of stochastic effects recorded in the survivors of Hiroshima and Nagasaki who received whole body doses over 100mSv. As such there is debate over the reliability of this model at low doses, however the most recent recommendations from the International Commission on Radiological Protection (ICRP) suggests that current scientific evidence supports the LNT hypothesis and that under the "precautionary principle" is still the best practical model for predicting cancer risk at low doses[12].

Images for this section:
Fig. 1: The estimated annual Australian per capita radiation dose for 1995, 2002 and 2010. Data from [5,6]
Fig. 2: Scalp ulceration and alopecia due to endovascular intervention for cerebral aneurysms performed eight years prior to the development of the ulceration.
Fig. 3: Band alopecia as a result of a CT brain perfusion scan in the US in 2009.
Methods and materials

A broad literature and journal review was undertaken, to investigate the awareness of clinicians to radiation effects, the awareness of patients to the same, and to investigate contemporary practices in informed consent, particularly in the context of ionising radiation.

Clinician Awareness

There have been numerous studies investigating the degree of understanding among clinicians of the doses and risks involved in diagnostic radiography and its overutilisation in recent years[13-18].

Research suggests that the doses received by patients undergoing common radiological investigations are being underestimated by up to 90% of clinicians[15] (see Fig. 4 on page 8 ) with the average actual dose received by patients being six times higher than the estimates[16]. Furthermore in certain examinations such as a non-contrast chest CT, 1 in 6 doctors underestimate the dose by between 20 and 500 times[13]. This is partly due to some clinicians incorrectly believing that a CT scan will give a lower or similar dose to a single chest x-ray[13-17]. Surprisingly it has been shown that up to 5% of clinicians incorrectly believe that ultrasound utilises ionising radiation and up to 27% of clinicians incorrectly believe that MRI utilises ionising radiation[13-16]. These facts are concerning as they suggest that some referrers have a poor understanding of radiation risk and therefore could be using higher risk diagnostic tools then are necessary.

With regards to the risks of radiation dose, a survey sent to all doctors at 14 major Queensland hospitals in 2010-2011 reported that nearly 10% incorrectly thought that CT had no increased lifetime risk of cancer[13]. This suggests that although there is increasing evidence linking medical radiation with increasing lifetime cancer risk, there is a small but significant percentage of clinicians for which this information has not yet reached.

Some studies have also shown a statistically significant inverse relationship between clinician years of experience and radiation dose knowledge[13, 14]. Fig. 5 on page 9 shows an example of doctors understanding of dose by years of experience. One study found that doctors with more than 15 years' experience were 3.2 times more likely to assume no increased cancer risk with radiological procedures[13]. This suggests a need for continuing education in radiation protection for clinicians as the changes in diagnostic techniques and research into doses continues to increase, with clinician's knowledge becoming outdated.

Patient Awareness
Studies show that patients do not have an accurate understanding of the risks and doses involved in diagnostic medical radiation. Lee et al.[17] reported that 100% of patients surveyed underestimated the dose they would receive from their CT compared to a single chest x-ray, with 28% believing that the CT scan would give a lower dose than a chest x-ray. There were also only 3% of the surveyed patients who thought there was an increased lifetime risk of cancer[17]. A more recent study by Ricketts et al.[18] found that 42% of patients incorrectly believed they would not be exposed to ionising radiation and 72% were unaware of the radiation risk of their examination.

**Informed Consent**

The origins of informed consent can be seen from as early as the 1900’s when it was decided that a person had the right to know what a physician or surgeon was going to do to them during an operation[19]. In the 1950’s patients were given the right to know the risks and benefits of their surgery and in 1996 the Wisconsin Supreme Court ruled that patients should be allowed to know any alternative treatment options available[19]. It has been argued that informed consent in its current form is now merely a legal obligation for clinicians to ensure their patients have been informed of any risks and alternative options before an invasive procedure, losing the true intent of educating and empowering patients to discuss their health care options[20].

Since it is a patient’s basic ethical right to make an autonomous decision on their own health care[21], patients should be given all relevant information in a format they can understand and that allows them to make an informed decision. The National Health and Medical Research Council of Australia publish guidelines relating to clinician communication with patients which indicate that any side effects from intervention that could be considered significant even if they are uncommon should be expressed to the patient[22]. Radiation induced malignancies due to repeated high dose examinations is likely to be considered a serious concern to many people, however informed consent is not required for most radiological examinations. It is therefore recommended that before a medical imaging examination takes place there is a meaningful dialogue between patients and clinicians on the risks and benefits of the examination for that patient, in particular for paediatrics and high dose examinations such as CT.

**Images for this section:**
Fig. 4: An example of doctors knowledge on the doses of common radiological procedures as reported by Keijzers and Britton[15].
**Fig. 5:** Doctors' estimates of the dose from a chest CT compared to a single chest x-ray in terms of doctors' years of experience (1-15 or 16+ years). Correct response shown in blue (200-500 times higher).
Results

Research suggests that there is poor communication between clinicians and patients regarding the risks and dose of radiation in medical imaging[13,15,17,18] with fewer patients (7%) recalling being informed of the risks and benefits of a CT than doctors (22%) recalling giving the information[17]. Furthermore 22% of doctors never discuss the risks of CT even if asked by the patient[13]. This is despite 60% of doctors reporting that they consider the risks before ordering a CT[13]. Senior doctors report being more confident in discussing potential risks with their patients than less experienced doctors even though their knowledge has not been shown to be greater[15]. Doctors also report that patients hardly ever ask about CT or radiation risks[15,18].

This then becomes an issue of where the responsibility to inform lies. Is it with the doctor to disclose information to their patients or with the patient to enquire? If referring doctors do not have accurate knowledge their ability to make an informed decision on the suitability of an examination may be compromised. Accurate information is also necessary to insure that the patient's right to make an informed decision is upheld.

Conclusion

The literature review for this poster found that there are a number of positive changes which can be implemented to improve patient care, to maintain informed consent integrity, and to ensure best practice. Of these, education and audit of practice seem to be the best way to ensure good clinical practice.

Education

Educating clinicians on the appropriate use of diagnostic imaging as well as radiation risks is necessary to ensure they can truly weigh up the benefits and risks of a diagnostic examination and express this information to their patients. The effectiveness of education programs on clinician awareness of radiation risk has been found in several studies[23,24]. Zhou et al.[23] suggest that a variety of different methods can be used to increase clinician knowledge from formal lectures to brochures aimed at clinicians which may improve access to material. However other studies have indicated that there is no significant difference in radiation knowledge between groups who have had formal training and those that haven't[15,16]. This may suggest that formal education programs need to be ongoing or other reminder systems need to be in utilised in order to provide continued education and ensure that understanding remains current. Considering the increasing use of online patient records and referral systems, continued reminders could be in the form of automated messages or "pop-ups" such as information on an individual's
total accumulative dose or a simple dose comparison to a chest x-ray for high dose examinations. Other possibilities for ongoing education could be web-based modules with integrated assessments where participation is recorded and can be used towards continued professional development requirements.

In terms of patient education, good doctor patient communication is essential in ensuring patients are able to understand the benefits of an examination. Supporting factsheets may be useful in providing patients with accurate information on the dose and risks of common procedures. They should also highlight the importance of discussing any concerns and the patients’ right to make decisions in their health care. These factsheets could include general information relevant to all diagnostic imaging examinations such as the example provided by our group (Fig. 6 on page 12) or could be modality or examination specific for higher dose examinations. Ideally the patient would be given access to the factsheet with plenty of time to assimilate the information so that they are able to understand the risks and feel empowered to ask questions to clear any doubt of the necessity of their examination.

**Clinical Audit**

Clinical audit is the process of comparing actual practise against best practise and implementing ways of improving procedures in an effort to minimise errors and adverse events[25]. Potential ways in which clinical audit could be implemented is in checking the appropriateness of requests for imaging procedures or reviewing and individualising CT protocols to ensure the minimum dose is given to obtain diagnostic images. This ongoing monitoring is likely to also act as an educational tool such that clinicians are continually reminded of the need to consider the necessity of an examination or ways to improve their practice.

**Closing Statements**

Our study reflects a poor awareness of radiation exposure and related risks in the general population as well as among clinicians. Furthermore, communication between patients and medical staff about these issues is currently lacking. We ought to change our mindset and clinical practice to give patients time to understand radiation risks and consider their choices. It should be advocated that clinicians provide detailed information to patients and also encourage patients to discuss radiation issues to ensure their understanding. Active participation of patients in their own health care requires knowledgeable clinicians to assist them in understanding the risk-benefit decision-making process. Someone has to explain and then ask the patient: *This is your risk, do you understand?*

**Images for this section:**
Fig. 6: An example of a factsheet which could be provided to patients before a radiological examination.
References


