TOWARDS HOLISTIC RADIATION PROTECTION. LESSONS FROM THE LITERATURES

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ABSTRACT

The effects of radiation on man and his health had been noticed since the early years after the discovery of X-rays. These biological concerns were more commonly known as "radio-sensitiveness" in the early publications. Later, the term radiation protection was introduced to express the need for protective measures to be promoted, formulated, implemented, evaluated and sustained to reduce the biological effects associated with radiation exposure. The principles of radiation protection were then supported with the concepts of justification, ALARA and "Benefits against the risks". But these could not ensure that the application of radiation protection has been optimized. Amidst the technological advancements associated with radiation based imaging modalities in healthcare for more than 120 years, those advancements have yet to be able reduce the impact of these modalities being a source of risks upon the more beneficial role as a diagnostic tool. This paper reports a review on radiation protection from articles indexed in an online database. Considering that the titles of the articles contain the core subject matter that a publication carries, data were retrieved on those titles with the term "radiation protection". Publications from 2008 to middle of November 2017 and aligned to Medicine and Health professions were included for further elaborations. The data were classified into four subject areas; education and training, administration and organization, practice and research. Discussions within each classification and their individual sub-classifications, supported by selected publications to the classification, highlight the importance of the particular subject area to the overall concept of radiation protection. Lessons learnt from the classifications could provide the necessary guidance on how one should adopt and adapt the concept of radiation protection holistically. The discussions that are presented are seen within the professional obligation in adhering to the principles of radiation protection.

KEYWORDS: Radiation protection, Medical imaging, Literature review, classifications

INTRODUCTION

Concerns over the health effects of radiation on humans were noted as early as 12 months after the discovery of X-rays in 1895 (Clarke and Valentin 2008). In a publication by Rollerstone (1927) called The Mackenzie Lecture it was reported that conjunctivitis associated to radiation exposure was detected in 1896 and the term "Radiodermatitis" was used in 1906. Fifty- four cases of cancer that were attributed to radiation were reported in 1911. The term "radio-sensitiveness" that appeared in the same publication suggested the apparent different intensities in the effects of radiation, as well as susceptibilities to those effects. These are attributed to metabolic rate, types of cells, production of aplasia in bone marrow, gastro-intestinal lesions and even the colour of the hair and skin! A prominent work "Law of Bergonie and Tribondeau" in 1906 outlined that radio sensitivity is more prominent in stem or immature cells, younger tissues or organs, cells with higher metabolic activity and tissues that exhibit greater proliferation and growth rate (Forshier, 2012).

The pioneering efforts towards establishing safety standards was undertaken by a concerned group of scientists in 1915, followed by an International X-ray Unit committee in 1925 (Rollerstone, 1927). This eventually led to the setting up of the International Commission on Radiation Protection (ICRP) in 1928 (Clarke and Valentin, 2008). The Commission functions to this day in making recommendations on effective management of radiation and the risks it poses.

The general objective of radiation protection is to protect man and the environment against the risks of ionising radiation. The specific objective of radiation protection in Medical imaging, meanwhile, is to limit radiation risks to patients, staff and the general public. The effects of radiation are multifaceted. Radiation effects are divided into somatic and genetic effects. While somatic effects appear in the person exposed to the radiation, genetic effects appear in the off springs. A further classification divides the effects into deterministic and stochastic effects. A certain threshold level in the radiation exposure is required before the deterministic effect is visible. For example, radiation burns. Greater concerns exist with stochastic effects. These effects do not have a threshold value for them to occur. The probability for these effects to occur, but not the severity, increases with amount of radiation exposure. The uncertainties or probabilistic nature pertaining to the radiation effects presented above could present a challenge to the practitioner in accepting radiation protection holistically, or otherwise.

The principles of radiation protection are appreciated within the concepts of justification, As Low as Reasonably Acceptable (ALARA) and Benefits Againsts the Risks. Later, the concept of optimisation was introduced that deals with the balancing act involving the technicalities, image quality, radiation dose (safety) and economics. Radiation protection initiatives also give special attention to women of child bearing age with the application of the 10 or 28 days rule. . The conduct of the examination will also adhere to the protection principles of Shielding, Time and Distance (STD). Radiation dose reference levels (DRLs) in the various radiological examinations have been documented to assist positively to ensure radiation dose to patients are within acceptable levels. Attention is also given to staff where practice guidelines are available to guide the practitioners on standards of good practice. The concept of Maximum Permissible Dose (MPD) has been used to ensure that the radiation doses received by the practitioners and the public are within acceptable levels. An important point to be made is amidst the technological advancements associated with radiation based imaging modalities in healthcare for more than 120 years, it seems that those advancements has yet to be able reduce the impact of these modalities being a source of risks over their more beneficial role as diagnostic tools. Hence, the above discussions could not ensure that the application of radiation protection has been optimised.

Thus, efforts were made to examine the discussions, as evident in literature, that are related to radiation protection. This study generated titles of articles with the term "radiation protection" imbued in them in publications between 2008 till middle of November 2017. These titles, as indexed in the Scopus database, were then classified into various subject areas within the context of radiation protection. The ensuing discussions relate those classifications with the aim to provide an understanding towards appreciating the various dimensions needed in order to execute holistic radiation protection. This is seen within the professional obligation towards embracing and internalising the principles of radiation protection.

METHODOLOGY

The Scopus online database was accessed to retrieve publications that have the term "radiation protection" in their titles. The search for the term in the article titles is made based on the core subject matter of a publication lies in the title. Using the CSV (comma-separated values) application available on the database, the data was downloaded into an Excel file. This enabled an in-depth examination of the data be made. The first phase of data generation involved all disciplines. Later the data were filtered to those publications between 2008 till middle of November 2017 and those associated to Medicine and Health professions only.

RESULTS

A total of 3709 articles, covering all disciplines, have the term "radiation protection" in their titles. The three earliest documents were published in 1941. The titles of these three documents suggest studies on radiation protection in selected hospitals. The data were then limited to subject areas Medicine and Health professions. A total of 2761 articles were listed. A prominent surge in the discussions that relate to radiation protection was observed for 2011. This surge could be attributed to concerns, and interests pertaining to radiation and its effects, following the March 2011 Fukushima incident. The number of publications dropped after 2011 only to increase again around 2015. No possible justification to the observed increase for 2015 can be made.

Efforts were then concentrated to limit the data to the last 10 years, 2008 till mid November 2017. Further filtering was done to determine the articles that relate to Medical imaging only. This is done to examine the publications that may still be relevant to today's medical imaging theory and practice. This was also done taking into consideration the advancements in imaging within the period. The manual filtering resulted in 508 articles. These articles were then classified into various classifications. These classifications were derived from the understanding of the researcher towards the core subject matter as evident in the title. Education and training, administration and organisations, practice and research formed the four main classifications. These were supported by their individual sub-classifications.

DISCUSSION

The results above show the various dimensions that the publications address that could be used as guidance in adopting holistic radiation protection. The ensuing discussions are made based on the extraction of certain important appreciation of the results in the various classifications. The author wishes to reiterate at this junction while the classifications looked distinct from each other the interconnectedness between them have to be appreciated.

Education and training

Undeniably the role of education in any profession is it forms the foundations that lead to the knowledge, skills and competencies of the practitioners. The theory of radiation protection is usually mentioned at the foundation studies alongside the knowledge in Radiobiology. With time, the advancements in imaging technologies may require some updates to be presented. This constitutes continuous education which may be supported by formal retraining. Updates in radiation protection can be presented in academic sessions such as the yearly "Lauriston S. Taylor lecture" (2008 – 2016). These updates could also benefit those still in foundation studies as the students will have access to the latest evidence based knowledge. In the current era of multiple imaging techniques and complex interventional studies (Roberts and Peet, 2016) specific radiation protection methods are required and need to be practiced. The application of e-learning on the subject (Leong, Mc Laughlin, O'Connor, O'Flynn and Maher, 2012) and the use of mobile apps (Ryckx and Verdun, 2013) will be more conducive to the present generation of IT savvy practitioners. The user-friendliness of the aforementioned applications can be optimised. The ability of having access to knowledge through the use of ICT and internet could ensure that continuous education and training can be effectively achieved.

Dose effects

The understanding about effects of radiation and the relationship of dose to those effects are perquisites towards appreciating radiation protection. It is to be appreciated that concerns over the effect of radiation is not new. The study showed that the term "radiation protection" was used in 1941. This does not mean that safety concerns towards the effect of radiation were only realised then. Rather, the Law of Bergonie and Tribondeau that was put forward in 1906 is the evidence that those safety concerns were realised much earlier. The publication by Rollerstone (1927) has the phrase "protection of X-ray". This further suggests that safety concerns pertaining to radiation had been around for quite some time.

Publications that present dose effects of radiation can be seen in discussions that relate to general tissue reactions (Miyazaki and Hill, 2015), in relation to radiation biology (Rühm, et al, 2015), evaluation of cancer risks (Tatsumi and Tanooka, 2014), tissue responses (Rozhdestvenskiĭ, 2014), behavioral and brain protein level changes (Ganesan, et al, 2014), individual radiosentivity (Bourguignon, Foray, Colin and Pauwels, 2013) and effects on mesenchymal stem cells (Hu, Sun, Guo and Ai, 2010). These publications can broaden the knowledge base of practitioners to understand that the concept of radiation protection is beyond the traditional appreciation of radiation protection; justification, optimisation, ALARA and STD.

Reviews

Publications in the form of review serve to make readers to think or talk about something again in order to make changes or facilitate a decision (Cambridge Dictionary, 2017). They are also means in updating knowledge, presenting what had been and what is currently accepted. Aspects in radiation protection that can be subjected to reviews are multi-faceted. They include biological basis of radiation protection (Paunesku, Haley, Brooks and Woloschak, 2017), current status of radiation protection in a certain country or institution (Muhogora and Rehani, 2017; Milu and Dumitrescu, 2008), dosimetry (Tilla, Beck, Grogan and Caffrey, 2017), radiation protection for staff (Meisinger, Stahl, Andre, Kinney and Newton, 2016), Computerised Tomography (Cupp, 2016), interventional radiology (Moura and Bacchim Neto, 2015), Pediatric (Farman, 2014), patients in interventional procedures (Roche, 2010) and existing issues, ethics and principles (Schreiner-Karoussou, 2008). These publications are just a sample of the numerous publications and the various aspects involving a safety concern in medical imaging. This should also be seen in terms of the possibilities to add to the literature on radiation protection.

Administration and organization

The concept of radiation protection, if properly promoted, planned, implemented, evaluated, monitored and sustained, can fulfil several objectives of healthcare. Beginning with the concept of non-maleficence (to bring no harm), it can further be viewed from fulfilling the rights of patients for a practice that is safe. From the professional perspective, this can be viewed as meeting expected professional obligation.

In order to achieve the above objectives, a certain organisational structure is needed. There is an authority that comes up with the policy, complementing the policy with a suitable legislation and licensure. In most countries, these are in place. Collectively this is known as a regulatory system. In other words, this set up comes with a legal implication. Examples of such a system can be seen in European Union (Layer, 2017), Senegal (Faye, 2012) and other countries (Arial, et al, 2010). The licensing requirement will include compliance to the measures as stipulated in the license. Failure to adhere to those requirements can not only nullify the license but could also be brought to court.
Supporting the above are professional organisations that promote radiation protection through the issuance of practice guidelines and recommendations. These guidelines, which in essence are "soft laws" for they carry no legal binding, are formulated based on research findings or through consensus by the professional fraternity. Eventually some of these guidelines and recommendations are accepted as international standards. Ambrosi (2011) described these standards in relation to individual national standards.

At the departmental level, the administrative structure should be directed to ensure adherence and compliance to the requirements as stipulated in the license. The concept of "reward or reprimand" should earnestly be exercised by those administrators; rewarding those who comply and reprimanding those who do not. Documents pertaining to radiation protection measures as stipulated by the higher authorities must be made available for easy perusal by the practitioners. Continuous education sessions, seminars, conferences and campaigns can help in enhancing practitioners' understanding and commitment towards adhering to radiation protection principles. Cole, et al (2014) highlighted the need to develop a strong safety culture within the institution. All these initiatives are only possible with the presence of a strong administrative willpower.

Ethical issues

The ethical issues that confront the concept of radiation protection are also multifaceted. Holmberg, Malone, Rehani, McLean and Czarwinski (2010) raised concerns over increasing individual's cumulative dose and collective dose to the global population from medical exposure. These were attributed to the substantial percentage of diagnostic imaging examinations that were deemed unnecessary. Sia, Chhem and Czarwinski (2010) argued the ethical dimension from the philosophical viewpoint; a shift in paternalistic attitude of practitioners to one that stresses the rights of the individual patient. Other ethical issues were from possible infection risks from thyroid radiation protection (Feierabend and Siegel, 2015), cost-risk-benefit analysis (Moores, 2016) and over-utilisation of imaging that leads to radiation protection issue (Kainberger, 2017). The present author opines the non-compliance of practitioners to establish and adhere to dose reference levels in their practices is an ethical issue. This calls a definitive stance and administrative willpower. Professional organisations are expected to identify possible ethical issues and provide professional guidance to the higher authorities as well as practitioners. This is to reduce the impact that these ethical issues can have on the service.

Practice

Traditionally, the appreciation of radiation protection are directed to the concepts of justification, optimisation, ALARA and STD. While the concept of justification is within the jurisdiction of the clinicians, optimisation, ALARA and STD are within the scope of radiographers. The balancing act between the selection of exposure factors and image quality is an effort in the optimisation approach. A study that relate to optimisation was reported by Inkoom, Schandorf and Fletcher (2009). The authors studied the radiation protection component by using the reject analysis using screen-film systems. Almen and co-workers (2016) used video recordings to study the optimisation of occupational radiation protection in image-guided interventions. Specific efforts to study the practice of radiation protection can also be seen in interventional angiography (Kamusella et al, 2017), surgical staff (Galonnier, et al, 2016), radiological equipment adaptation for children examination (Daníčková, Chmelová and Roček, 2014), pelvic x-ray (Ofori, Antwi Scutt and Ward, 2012), mammography (Siavashpour, Mehdizadeh, Farshadi and Baradaran-Ghahfarokhi, 2012) and Computerised Tomography examinations (Drage, Carmichael and Brown, 2010). The diversified nature of radiological procedures could open for more studies to be made pertaining to the practice involving individual tailoring of radiological examinations to the different types of patients. This will help to further shape radiation protection initiatives such that individual tailoring of radiation protection to the different types of patients can be effectively made.

Dosimetry

Discussions in this particular classification dwell around the use of effective dose in risk assessment, dose measurements, dose reference levels and dose monitoring. There are also comparative studies of restriction times (Bessières, Vrigneaud, Toubeau, Cochet, Dygaï-Cochet, 2016), measuring scatter radiation (Vlachos, et al, 2015), and comparative studies on operator radiation exposure in ad hoc percutaneous coronary interventions by radial and femoral routes (Lo, et al, 2008). With the increase in interventional procedures, special emphasis towards monitoring the eyes receives multiple attentions from researchers (Bordy, 2015; Watanabe, 2017).

The present author wishes to highlight some doubts to the concept of occupational exposure for radiation practitioners. The occupational exposure is taken at 20 millisieverts (mSv) per year in any period of 5 years. While this amount is generally accepted worldwide, questions had been raised as to whether genetics and body sizes, as evident between the different geographical demographics, had been taken into account in the determination of the Maximum Permissible Dose. This is to encourage future researchers to take into account those two variables in their study in dosimetry.

Research

Research is an essential component that could contribute to the growth in the knowledge base of a profession. It also provides the much needed evidence in order for a profession to justify that the service given to the patients are evidenced based. To some extent, patients who come for radiological procedures might be aware of the risks that radiation carries. Their accessibility to knowledge through the use of ICT and social networking will actually challenge practitioners who fail to observe safety considerations to these patients.

There are several forms of research that were reported in the database. They include surveys, comparative studies, experimental studies and epidemiological studies. Strategic research agendas have been drawn up to streamline research in radiation protection (Cole, et al, 2015; Repussard, 2015; Aerts, et al 2014). Comparative studies reported radiation protection in an interventional laboratory in hospitals in two countries (Alahmari, Sun and Bartlett, 2016) and the different methods of measurement on the lead equivalent of radiation protection clothing (Schöpf and Pichler, 2016). Surveys were used to study compliance and knowledge to radiation protection among operating room personnel (Jentzsch et al, 2015) as well as awareness among staff and students (Kargar, Parwaie, Farhood, Atazadegan and Ardekani, 2017; Faggioni, Paolicchi, Bastiani, Guido and Caramella, 2017). Surveys were also used to study about the status of radiation protection within a country (Adhikari, Jha and Galan, 2012), between countries (Ciraj-Bjelac, et al, 2011) and level of compliance towards radiation protection (Friberg, Widmark, Solberg and Wøhni, 2011)

The results showed that some innovations in radiation protection had been made within the last 10 years. These include the use of tungsten functional paper (Monzen, et al, 2017), breast model based on ethnicity (Qiu, et al, 2017), lead-free polymer based shield (Mortazavi, Zahiri, Shahbazi-Gahrouei, Sina, Haghani, 2016), tungsten bismuth caps (Ramos-Avasola, Díaz, Roldán, Gamarra and Catalán, 2016) radiation protection cabin (Alexeev, et al, 20149), tungsten nanocomposites for protection screens (Adliene, Griskonis, Vaiciunaite and Plaipaite-Nalivaiko, 2015), radiation protection system (Fattal and Goldstein, 2013) and new lightweight leaded eyewear (Schueler, Sturchio, Landsworth, Hindal and Magnuson, 2009). It is also appreciated that non-conventional approaches towards radiation protection can be found in the possibility of using biogas (Abdollahi, Atashzar and Amini, 2015), cellular auto fluorescence (Abdollahi, 2015), inorganic filters and matrix polymers (Lanina, Kaminskaia, Beniaev, Suslova and Grigor'evskaia, 2012), in tablet form (Pues and Blau, 2011), antimicrobial agents (Epperly, et al, 2010), antioxidant defense system (Tyagi, Singh, Devi, Goel and Rizvi, 2009) and 6-palmitoyl ascorbic acid-2-glucoside (Chandrasekharan, Kagiya and Nair, 2009).

Evident in the retrieved publications are models that relate to radiation protection. Weber, Monnin, Elandoy and Ding (2015) presented a model-based approach of scatter dose contributions and efficiency of apron shielding for radiation protection in Computerised Tomography. Van Soom U (2014) published calculation models for radiation protection, radiation physics and dosimetry, while Gualdrini and Ferrari (2010) reviewed voxel model development and radiation protection applications. The presence of these models could help practitioners understand and predict outcomes as well as provide avenues for further research.

Innovations and models discussed above essentially takes the concept of radiation protection beyond the traditional appreciation of high atomic number materials. This constitutes "thinking out of the box" at its best. This opens more avenues for practitioners to exercise their critical mindedness to look for alternative methods towards radiation protection.

CONCLUSION

With more than five hundred publications, the study shows that radiation protection is still actively being studied and discussed in the four classifications involving education, administration, practice and research. The sub-classifications further fortify the importance of this particular safety aspect of radiation, broadening the knowledge even further. Lessons learnt from these publications facilitate the continuous education in the field, while at the same time puts a challenge upon the practitioners to meet the intricate details of radiation protection. This can be translated into the adoption and internalisation of holistic radiation protection. It is to be reminded that holistic radiation protection is not only part and parcel of the objectives in healthcare but should be seen within fulfilling the professional obligations upon the practitioners.

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