Ionizing radiation: the silent enemy

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Abstract

Background This study aims to assessment the Brazilian orthopedic surgeon's knowledge about ionizing radiation and its implications over the health of the surgical team and the patients. Methods A Cross-sectional study was performed using a questionnaire of fifteen questions about theoretical and practical concepts regarding ionizing radiation, during the 23 rd Brazilian Orthopaedic Trauma Association Annual meeting. The participant needed to be an orthopedic surgeon or an orthopedic surgery resident in a Brazilian institution, in order to be included in the study. The questionnaire addressed the specialty within orthopedic surgery, issues such as radiation protection use and safety concepts, participants' children gender and exposition to radiation. Results 258 questionnaires were fully answered. Only 5.8% of the participants use the three basic radiation protection equipment (apron, thyroid shield, and radiation protection glasses); 47.3% use the dosimeter; 2.7% hit the acceptable annual maximum radiation dose; 10.5% knew the gestation period of greater risk to the fetus and 5.8%, the acceptable maximum radiation dose during pregnancy; 58.5% got right that the hands, the eyes and the thyroid are the most exposed and at greater risk of radiation related lesions; 25.2% knew that the distance of 3 meters or more from the radiation-emitting tube is safe; 44.2% knew the safest positioning of the radiation-emitting tube; 25.2% got right that smaller tubes emit greater entrance dose to magnify the image and, therefore, emit more radiation; and 55.4% knew that the surgery team receives more scattered radiation in surgical procedures performed in obese patients. Conclusion It is needed an immediate educational overall plan to orthopedic surgeons and orthopedic surgery residents, so that surgical staff and patients may be less exposed and, therefore, less vulnerable to harmful effects of ionizing radiation.

Background

Awareness regarding radiation exposure risks have been increasing in the last few decades along with the number of surgeries, the development of newer technologies and diagnostic tools. The medical radiation exposure increased 600% since 1980, in the United States population, and it is estimated that about 2–3% of future cancers could be related to previous ionizing radiation exposure [1]. Therefore, it is important to assess what professionals know and do to protect themselves and their patients, in order to prevent undesired outcomes while using the best technologies available to provide the best care.

There are very conflicting evidence in the literature regarding some effects of the ionizing radiation to professionals although it is very well known the harmful effects of radiation in human biology [2–4]. Although being aware of the dangerous long-term effects of radiation, health professionals might neglect some aspects of the radiation protection routine in their daily work.

The aim of this study is to assess the Brazilian orthopedic surgeon's knowledge about ionizing radiation and recommendations on how to protect from it, breaking down the data into specialty. Also evaluating some implications over the health of the surgeon, the surgical team and the patients, including controversial topics in the literature.

Methods

A Cross-sectional study was performed using a 15-question questionnaire (Appendix 1) about theoretical and practical concepts regarding ionizing radiation, during the 23rd Brazilian Orthopaedic Trauma Association Annual meeting. Inclusion criteria was an orthopedic surgeon or an orthopedic surgery resident in a Brazilian institution, reaching a total of 258 fulfilled questionnaires.

Contingency tables were used for description of data. Categorical variables were tested by Chi-square test and results were considered significant when $p < 0.05$. It was also used Spearman's Correlation test for continuous / categorical variables against another categorical variable (more than 2 categories each), also considering Confidence Interval (CI) of 95% and significance of 5%.

Results

In Table 1, we show the distribution of protection equipment use according to type of equipment and number of orthopedic surgeons in the study. Among 258 study participants, 256 (99.2%) use some kind of radiation protection and 2 (0.8%) do not use any. 170 (65.9%) use only apron as protection and, 68 (26.3%) use apron plus thyroid shield. Only 5.8% uses the whole protection including apron, thyroid shield and radiation protection glasses (Table 1).

The frequency of radiation protection equipment use is shown by specialty in Table 2, and trauma orthopedic surgeons showed to be the ones that use more protection during practice, presenting 47% of two or more equipment use within the specialty. On the other hand, shoulder surgeons and pediatric surgeons were the groups with the lowest percentages of equipment use, 15% and 0% (≥ two or more equipment), respectively and, also were the only groups with a professional not using any protection at all. According to chi-square test, there is statistically significant difference among the groups "none protection equipment use" and "≥ two equipment use" (Table 2).

In Table 3, it is shown the number of surgeries that requires fluoroscopy per week per surgeon and the distribution of surgeon's children sex throughout the sample. In regard to radiation exposure affecting orthopedic surgeon's offspring, it was not identified any statistically significant result (Tables 3 and 4). There was no significant difference in offspring sex when analyzing each group of radiation exposure (Table 3) neither when grouping into two groups, orthopedic surgeons that use up to 2 times a week and orthopedic surgeons that use 3 or more per week (Table 4).

The dosimeter is not used by the majority of the sample, 136 participants (52.7%). In addition, only 22.1% of the group that use dosimeter uses it always. There was no significant difference between the use of dosimeter among all the specialties analyzed (Table 5).

The occurrence of back pain also did not present statistically significant difference when analyzing back pain and the use of lead apron (Table 6). Most of the individuals had back pain in long surgeries (82.2%).

In regard to the variables distance, tube plus radiation, exposed body parts, maximum annual dose, gestation maximum dose and gestation period, there was no statistically significant difference when comparing the knowledge of each specialist group across the variables mentioned in Table 7 (Table 7). There were no differences related to the variables fluoroscope tube positioning, obesity, and radiation dose scenario (Table 8). In this study, none of the orthopaedic surgery specialties showed itself to have more knowledge about radiation safety than the other.

Discussion

Medical radiation exposure increased 6-fold since 1980 in the United States population, and estimates suggest that up to 3% of all future malignant neoplasia could be caused by previous ionizing radiation exposure [1]. Therefore, several studies have been and are being done to gather all the information possible to create plans in which we can utilize the best evidence and technology available to help patients without causing undesired harm to them and to medical teams.

Currently, there are very conflicting evidence in the literature regarding some effects of ionizing radiation. One topic that is very interesting is the possibility of radiation exposure during daily practice increase the frequency of females offsprings in male doctors. One of the first studies that mentioned this topic was published in 1997 by Zadeh and Briggs, in the United Kingdom, and they have reported that both male orthopedic surgeons and male obstetricians and gynecologists had a higher incidence of female children [2]. In addition, there was an increased risk for congenital abnormalities and there was statistical difference comparing to population in all those findings [2]. Since the obstetricians and gynecologists had no radiation exposure, Zadeh and Briggs proposed that occupational exposure to X-ray was not associated to those findings and, possibly the exposure to operating theatre environment was the cause [2]. However, Hama et al. from Japan broke down the participants of his study into two groups, “lightly irradiated” and “highly irradiated” (one or more incidents of annual radiation exposure > 10 mSv), and they have found a significant statistical increase in the risk of lower male proportion in the offspring of radiologists from the “highly irradiated” group [3]. Finally, the most recent study on this topic, published by Choi et al., used a sample of male invasive cardiologists. The authors found no significant difference in the proportion of male and female offspring, even when analyzing a sub-group with higher radiation exposure [4]. In the present study, we have found similar results to Choi et al. and Zadeh and Briggs. No difference in male proportions in offspring of male Brazilian orthopedic surgeons was identified and, the proportions were similar to the Brazilian population (Table 4) [5]. We also compared a group of lower radiation exposure to a group of higher exposure, which was determined by the number of surgeries requiring fluoroscopy per week per surgeons, and again no difference was found in the offspring sex proportion (Table 4).

Another controversial topic is the relationship between the use of lead apron and back pain in orthopedic surgeons or other professionals that deal with x-ray on their practice. The first study to our knowledge which looked into this relationship was published by Moore et al. and did not prove the use of lead apron as a risk factor for back pain [6]. Later, a research on the prevalence of spinal disc disease among

interventional cardiologists claims the existence of the “interventionalist’s disc disease”, when they report the significant differences between the incidence of skeletal complaints in interventional cardiologists and other two specialties compared (orthopedists and rheumatologists) [7]. In their study, it was shown a greater incidence of cervical problems instead of lumbar. It was also observed that interventional cardiologists use aprons for longer periods, which increase the effects of lead apron use in the axial skeleton [8]. However, in our study we have found similar results to Moore’s study. There was no significant relationship between back pain frequency and apron use among Brazilian orthopedic surgeons, but we could see in descriptive analysis that most of our participants complained of back pain during prolonged surgeries. Therefore, we think it might be necessary much more hours of apron use to cause harmful effects and back pain related to it, which is in accordance to the study about interventional cardiologists. However, prolonged procedures even without apron use might be a cause of back pain, which we have not seen a study comparing both situations. Furthermore, another study suggests that interventionists wearing single-sided aprons and working more than 10 hours/day complained more of shoulder and back pain, while most professionals that wear correct fit and light-weight aprons with appropriate lead equivalence did not complain of any physical problems [9].

Our study also assessed how the Brazilian orthopedic surgeons are protecting themselves from occupational ionizing radiation and if they know the theory behind the prevention from harmful effects of x-ray. Unfortunately, the results showed a lack of radiation protection equipment use and lack of knowledge about basic topics on radiation prevention. In our sample, 65.9% use only apron as protection equipment while it is very well known that radiation is the main risk factor for thyroid cancer [9]. Only 32.1% of the participants use at least apron and thyroid shield and, 5.8% use all the protection equipment, including apron, thyroid shield and radiation protection glasses. Dosimeter is not used by the majority, 52.7%, and, from the ones that use it, only 22.1% use it always. A recent study about fluoroscopic radiation exposure highlighted that eyes and hands of the surgeons receive more radiation than other body parts and, therefore surgeons should routinely use eye and hand protection in addition to the basic apron and thyroid shield [10]. It´s noteworthy that a study published by Muir et al. showed that some aprons were identified with labelling showing higher protection than in fact they presented when tested [11].

In regard to the questions about knowledge on radiation prevention, most of the Brazilian orthopedic surgeons did not present an appropriate performance. Only 2.7% hit the acceptable annual maximum radiation dose. 10.5% knew the pregnancy period of greater risk to the fetus when exposed to x-ray, and 5.8% hit the acceptable maximum radiation dose during pregnancy. 25.2% knew that the distance of 3 meters or more from radiation-emitting tube is considered safe and 44.2%, the safest positioning of the radiation-emitting tube. 25.2% got right that smaller tubes generally emit grater entrance dose to magnify the image and, therefore, emit more radiation. 55.4% knew that the surgery team receives more scattered radiation in surgical procedures performed in obese patients. And finally, the question with the best performance only had 58.5% of right answers saying that the hand, the eyes, and the thyroid are the most exposed and at greater risk of radiation related lesions. No significant differences were found when comparing the knowledge across all orthopedic surgery specialties, in any topic. All specialties had the

same performance. It seems that probably the poor performance in the questionnaire is not a particularity of the Brazilian reality. In 2013, an original study showed that orthopedic surgeons from Canada lacked knowledge about the risk of eye cataracts when exposed to radiation and 75% reported no awareness of radiation dose limits existence [12]. A survey analysis from Turkey, obviously with different set of questions, demonstrated an inadequate knowledge about the uses and risks of fluoroscopy and radiation prevention [13]. Another article from Latin America showed that 75.7% of their sample never or rarely used a dosimeter badge, only 20.2% use lead glasses on their practice and, also highlighted significant differences between countries and many other knowledge deficiencies [14].

An interventional study was performed in order to analyze the impact of a surgeon education plan about radiation protection (15). The educational intervention was applied to surgeons performing complex endovascular procedures and, a strong relationship ($p < 0.001$) between the intervention and decrease in radiation dose was found, excluding fenestrated endovascular aneurysm repair which remained a procedure with high radiation exposure [15]. In addition, some articles summarize in a didactic manner the main important aspects of how to decrease unnecessary radiation exposure, educating about radiation harmful effects, dose, and protection equipment. In those articles, they highlight that minimally invasive surgery increases radiation exposure, especially when applied to spine surgery [16, 17]. It is also highlighted the concept of ALARA (As Low As Reasonably Achievable) and the mnemonic DEBT (distance, exposure, barriers, and time) as pillars of the practical guidelines [16, 18–20].

As main limitation, our study design and sample characteristics do not allow to conclude that orthopaedic surgeons from all countries present the same knowledge regarding radiation exposure and safety procedures to prevent harmful effects. Another limitation is the lack of uniformity between subspecialties. We had 134 trauma surgeons versus 6 pediatric surgeons, 15 foot and ankle surgeons, and 17 hand surgeons, which potentially limits comparison between specialists in terms of knowledge and other variables analyzed in this study. Nevertheless, focusing on the basic education for medical residents before any specialization, we feel our data demonstrates quite clearly that orthopedic practitioners present low level of knowledge on the harmful effects of radiation exposure.

Conclusions

Radiation exposure can cause a wide range of harmful effects, including hair and skin changes, cardiovascular disease, cataracts, minor inflammatory reactions, gastrointestinal symptoms, bone marrow failure, malignancies, and heritable disease in offspring [21, 22]. A harmless radiation dose is not stablished yet with the current available data, however a dose response relationship is clear, which justifies the importance of the best radiation protection as possible [1–4, 14, 21, 22].

The data found in this study along with the other articles here summarized highlight the urgent need to create an immediate educational plan to orthopedic surgeons and orthopedic surgery residents from Brazil and possibly from the whole world. Then, surgery team and patients will be less exposed and,

consequently, less vulnerable to the harmful effects of ionizing radiation while the best care possible and the best evidence available are being applied.

List Of Abbreviations

CI: Confidence Interval

mSv: milisievert

ALARA: As Low As Reasonably Achievable

DEBT: Distance, Exposure, Barriers, and Time

Declarations

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Competing interests

The authors declare that they have no competing interests related with this article.

Ethics and Consent for publication

Ethical approval was obtained by the Department Assembly at Federal University of Minas Gerais. The manuscript contains no individual personal data. No consent for publication was necessary.

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Author's Contributions

REP and IGNR had substantial contributions to the conception of the work, acquisition of data, analysis and interpretation of data and drafting the article. ARVF gathered and managed data. VG, PJP, and WDB had substantial contributions to the conception of the work and revised the draft critically for important intellectual content. All authors read and approved the final manuscript.

Availability of data and materials

The datasets generated and/or analyzed during the current study are available in the author's database.

Footnote

Radiation Exposure Dangers Questionnaire is available as a supplementary file.

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Tables

Due to technical limitations the Tables are available as download in the Supplementary Files.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Table3.001.jpeg
- Survey.SupportingInformation.docx
- Table2.001.jpeg
- Table6.001.jpeg
- Table5.001.jpeg
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- Table1.001.jpeg
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