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Assessment of Radiation Safety Training, Practices and Knowledge amongst Canadian Orthopaedic Resident Training Programs

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Abstract

Objective: There is ample literature demonstrating significant health risks associated with radiation exposure, yet there is no standardized radiation safety training for Canadian orthopaedic surgery residents. This is the first national survey investigating the prevalence of radiation safety training and radiation safety practices in Canadian orthopaedic residency programs.

Methods: A national online survey was distributed to orthopaedic residents currently enrolled in a Canadian program from all post-graduate (PGY) levels who were fluent in English or French with a medical doctorate or equivalent training. Fellows, international elective or observer ship students were excluded.

Results: Overall response rate across Canada was 41% (n=116). Most respondents (94%, n=102) were concerned about the negative effects of radiation, yet only 11% (n=12) felt confident with their radiation safety knowledge. Of the residents who felt confident in their knowledge, only 42% (n=5) answered all three radiation safety screening questions correctly. Overall, 58% (n=66) of respondents had undergone some form of radiation safety training.

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Compliance with protective lead was high (92%, n=93) when available, but 82% (n=92) of respondents cited issues accessing properly fitting lead. Only 18% (n=20) of orthopaedic residents reported routinely wearing dosimeters.

Conclusion: Limited access to properly fitting protective lead, poor radiation safety knowledge, and lack of routine radiation monitoring could be placing residents at risk for poor health outcomes in the future. These results provide impetus for orthopaedic residency programs across Canada to implement higher safety standards in the form of standardized radiation safety training, routine dosimeter use, improved lead availability, and continued abidance to radiation safety protocols.

Keywords

Imaging Residency; Orthopedics; Radiography; Radiographic Imaging

Introduction

Advances in orthopaedic surgery have led to minimally invasive operative techniques which have been shown to decrease patient morbidity. However, these minimally invasive techniques necessitates increased use of intraoperative fluoroscopy [1-3]. Typically, the surgeon will stand in close proximity to the patient to make small adjustments to the extremity being imaged resulting in surgeon exposure to radiation scatter [4-7]. Certain subspecialties within orthopaedic surgery are exposed to higher amounts of radiation due to the nature of procedures performed. Gausden, et al., showed that attending orthopaedic surgeons specializing in trauma or deformity surgery received the highest radiation exposure [8]. For example, fluoroscopically intensive procedures such as those that utilize locked intramedullary nailing systems are responsible for the highest radiation doses amongst orthopaedic surgeons [1,2,7].

Factors affecting a surgeon's radiation dose include: exposure time, distance from the beam's central axis, the orientation of the fluoroscopic beam relative to the patient, the position of the surgeon within the operative field, and the use of protective equipment [9]. Many patient factors also increase a surgeon's radiation exposure, including increased patient Body Mass Index (BMI) and fracture complexity [10]. In addition, the surgeon's radiation exposure per case is dependent on the years of operating room experience [8,10]. Early career surgeons within their first three years of independent practice were exposed to significantly higher radiation than their senior colleagues with greater than ten years of experience [8,10].

The current National Council on Radiation Protection (NCRP) and United States Nuclear Regulatory Commission (NRC) recommend no more than 50 millisieverts (mSv) annually in combined occupational and non-occupational radiation exposure to avoid any ill-effects [8].

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The International Commission on Radiological Protection defines 20 mSv per year as the annual occupational exposure limit¹. The known health risks associated with increased radiation exposure include cataract formation, skin cancer, thyroid cancer, and leukemia¹ [11]. Despite radiation protection measures, there is evidence of increased incidence of radiation-related diseases in orthopaedic surgeons. The published risk of developing cancer (i.e. thyroid cancer) is eight times higher in orthopaedic surgeons than in an unexposed worker. Additionally, the risk of harmful levels of radiation at eye level are highest during pelvic fixation and femoral intramedullary nailing [12,13]. In 2012, Chou, et al., showed increased risk of breast cancer in female orthopaedic surgeons [14]. As the number of female orthopaedic attending surgeons and trainees continues to increase, radiation safety in this subgroup is increasingly important.

In 2013, Chow, et al., surveyed orthopaedic surgeons' understanding of the effect of radiation on their risk of cataract formation [15]. This study found that the greatest barrier to the use and understanding of protective measures was lack of information. This suggests that orthopaedic surgeons are not receiving adequate radiation safety training. Given that orthopaedic residents are exposed to radiation from Post-Graduate Year One (PGY1) onward, appropriate training at this early stage is critical.

To date, the level of radiation safety knowledge and formalized training throughout Canadian orthopaedic surgery programs is unknown. The objective of this survey was to assess the radiation safety knowledge, training, and practices across Canadian orthopaedic surgery residents. We hypothesized that there would be significant variability in the level of radiation safety teaching, knowledge, and practice across Canada.

Material and Methods

Survey Design

Following approval from the local Conjoint Health Research Ethics Board (CHREB) and endorsement from all Canadian orthopaedic training programs, this study was conducted using an online single submission survey. This survey aimed to assess both radiation knowledge and safety concerns amongst orthopaedic surgery residents in Canada. The survey questions were designed to address three major themes: radiation training, radiation safety practices, and radiation safety knowledge. The survey was comprised of 35 closed-ended questions, with a free text box to allow for participant comments when appropriate (Appendix 1-survey).

The survey was developed by our multidisciplinary working group based on Dillman's principles of web-based survey design [16]. Question generation was informed by a review of the literature and through collaboration with resident trainees, our local program director, and a biostatistician. Content validity, clarity, and feasibility were verified through beta testing with

orthopaedic fellows from local orthopaedic training programs. Recommended changes were incorporated into the final survey prior to distribution. The survey was translated into French for distribution throughout all Canadian training programs.

Demographic data collected included age, year of training, and geographic location of training program. Questions were designed to determine type of radiation safety training provided to residents both within and extracurricular to their training program, radiation safety experience in the operating room, and access and use of personal protective equipment. Radiation safety knowledge was tested with three standardized skill-testing questions and confidence in radiation knowledge was assessed.

Survey Population

Participant inclusion criteria consisted of all orthopaedic surgery residents actively participating in a Canadian residency program in either a clinical or research role; PGY levels 1-5; Medical Doctorate (MD) degree or equivalent; English or French competency. Exclusion criteria were extended trainees seeking further subspecialty training (fellows, international electives, and observerships).

Program directors and administrators from each program were engaged across Canada and were responsible for facilitating survey delivery to each resident. Recruitment was performed via an email to Canadian orthopaedic surgery residency program directors which was subsequently distributed to individual residents for voluntary involvement (n=284). Email reminders were sent twice, at 2-week intervals, during the study period (March 2019 to April 2019). The survey was closed one month after the original deployment date.

All obtained data were stored with SurveyMonkey Inc. Their application and user security include SSL/TLS encryption, and user data is logically segregated and encrypted for authentication. SurveyMonkey (SurveyMonkey Inc.) is web-based survey software, which is compliant with Canadian privacy and accessibility standards and does not collect any participant identifying information (such as a computer Internet Protocol (IP) address).

Data Analysis

All continuous variable data are reported as mean and standard deviation of the mean. All categorical data are reported as proportions. Descriptive statistics were used for final analysis. Chi-squared with Yates correction significance tests were performed and threshold values for significance were $\alpha \leq 0.05$ and β of 0.2.

Results

The survey was sent to 284 residents from each program in Canada; of those invited, 116 participated in the survey, yielding an overall response rate of 41%. The majority of respondents were male (65%, n=70), aged 25 to 29 years (56%, n=61) and from either Western Canada (37%, n=40) or the province of Ontario (38%, n=41). A total of 10 surveys were completed in French. Demographic data are presented in Table 1.

Radiation Safety Training

The majority of respondents stated that they had received formal radiation safety training (58%, n=66). Of these, 85% (n=56) reported that the training was “facilitated by their residency program”. Fifty-five percent (n=31) of respondents who had received formal radiation safety education found that the training increased their confidence in practicing radiation safety.

Radiation Safety Awareness and Knowledge

In total, 58% (n=65) of respondents felt moderately comfortable with their current radiation safety knowledge, while 32% (n=36) felt “not very” or “not at all” confident. Only 11% (n=12) of respondents felt “very confident” with their knowledge. Of those who reported feeling ‘very confident’ with their knowledge, there was no correlation related to training level (PGY1, n=2; PGY2, n=2; PGY3, n=4; PGY4, n=2; PGY5, n=2). Additionally, of the “very confident” respondents, only 42% (n=5) answered all three of the included radiation safety skill-testing questions correctly. Overall, 93% of respondents correctly identified which end of the C-arm emits radiation, 78% correctly identified that the thyroid is the most radiosensitive organ, but only 64% were aware that radiation dose increases to the operator with increasing patient body mass index.

Radiation Protection

Ninety-two percent (n=93) of respondents indicated that they “always” wear lead; however, 82% (n=92) noted that lead is not always available in their size (Fig. 1). There were significantly more French-speaking respondents who owned their own lead (p=0.013). The type of lead protection worn most often was a thyroid shield (n=107, 96%), while there was no reported use of leaded scrub caps or face shields (Table 2). Seventeen percent (n=19) of responding trainees own their own lead, 84% (n=16) of whom purchased that lead out of pocket (Fig. 2). Of those who own their own lead (n=18), only six (33%) report annual safety testing, as is recommended. There was no significant difference in the proportion of men and women

who own personalized lead (female: $n=5$ out of 37, 14%; male: $n=13$ out of 70, 19%; $X^2(1, N=107) = 0.155, p=0.694$). Only twenty-three people responded to the question, “Do you own lead glasses?” and 26% ($n=6$) said yes. They all purchased the glasses out of pocket (Fig. 3). Eighteen percent ($n=20$) of respondents indicated that they routinely wear a dosimeter, all “yes” responses came from Western Canada or Ontario locations (Fig. 4).

Radiation Safety Practice

Sixty-nine percent ($n=74$) of respondents reported that their attending surgeons “always” or “often” demonstrate best practice, and 94% ($n=102$) “always” or “often” heard a verbal warning prior to radiation exposure. Overall, 81% ($n=88$) of trainee respondents were mildly or moderately concerned about the effects of radiation on their health, while 13% ($n=14$) were very concerned. Forty-five percent ($n=49$) of respondents felt uncomfortable about their radiation exposure, at least some of the time, however the majority (57%, $n=62$) reported that they always or often felt comfortable advocating for their safety (Fig. 1). When asked if the intent to have children affected their view on radiation safety, 56% ($n=60$) responded with “yes”. Sixteen percent ($n=17$) of respondents personally knew somebody negatively affected by radiation.

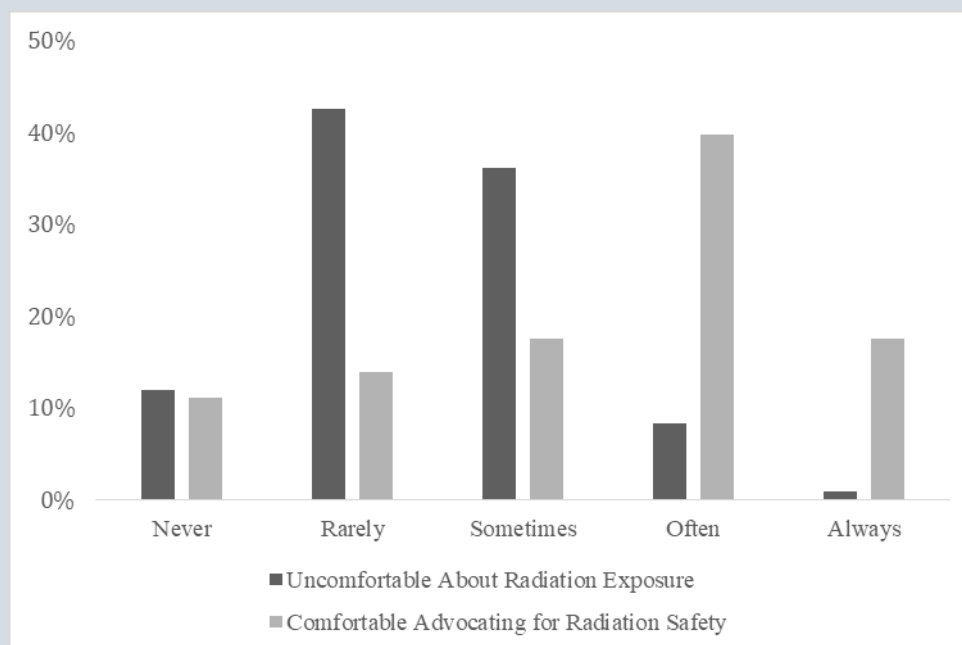


Figure 1: Resident comfort with radiation safety and exposure.

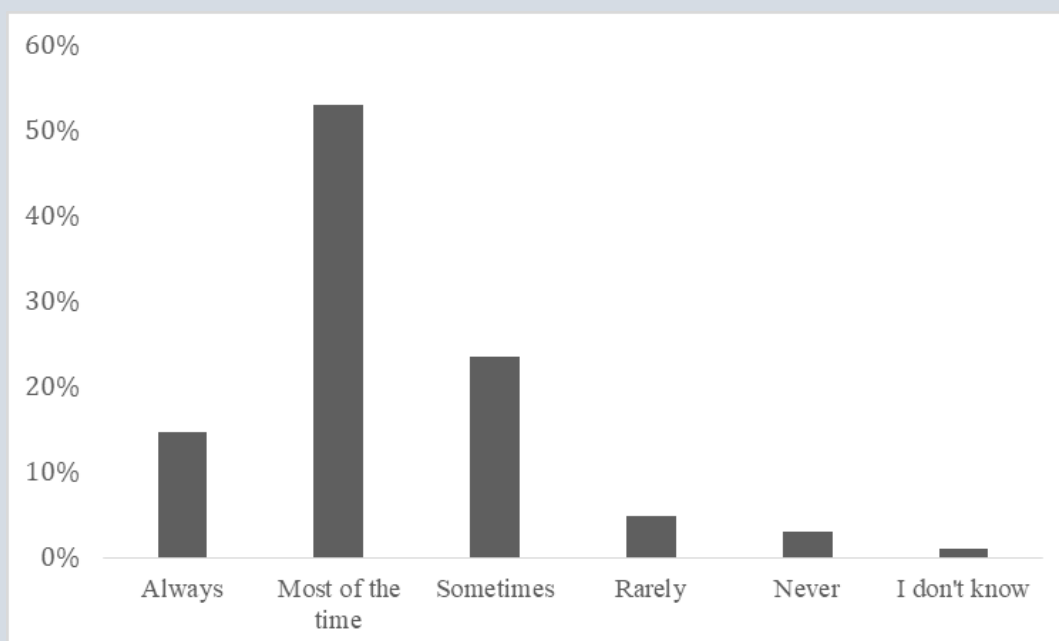


Figure 2: Availability of lead aprons in appropriate size.

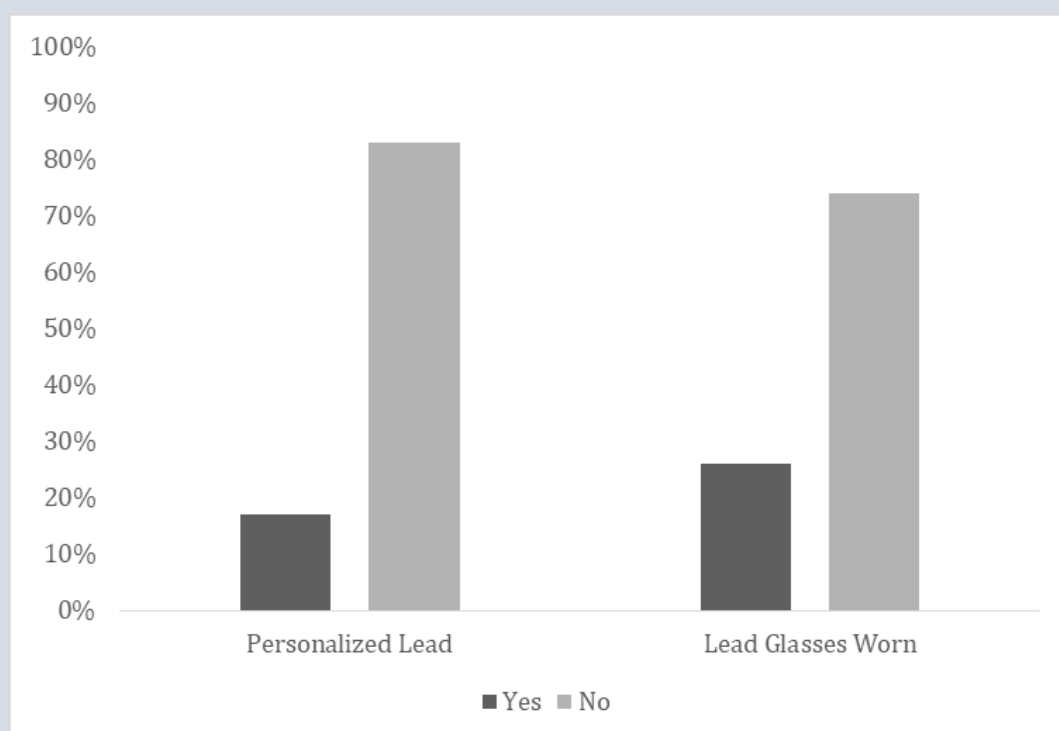


Figure 3: Types of radiation protection used by all resident participants.

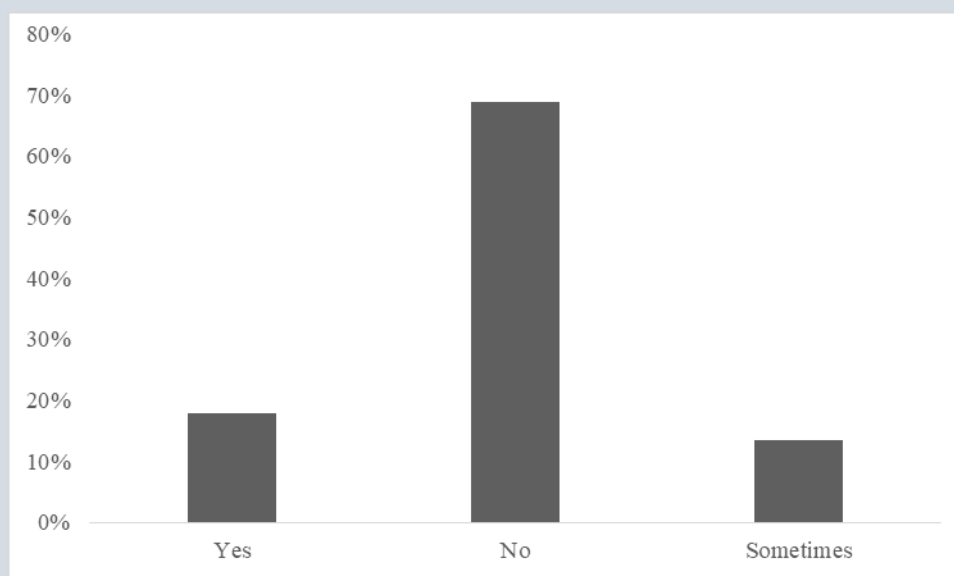


Figure 4: Reported use of dosimeters by all survey participants.

Demographic Data		N (%)
Male		70 (64.8%)
Female		37 (34.3%)
Age	>25	2 (1.9%)
	25-29	61 (56.5%)
	30-34	35 (32.4%)
	35-40	9 (8.3%)
	>40	1 (0.9%)
Location	Atlantic Canada*	6 (5.6%)
	Western Canada **	40 (37%)
	Ontario	41 (38%)
	Quebec	21 (19.4%)
	Territories***	0 (0%)
PGY	1	16 (14.8%)
	2	24 (22.2%)
	3	33 (30.6%)
	4	19 (17.6%)
	5	16 (14.8%)
* Includes NB, NS, PEI, NL		
**Includes AB, SK, MB		
*** Includes NWT, Yukon, Nunavut		

Table 1: Demographic data from survey respondents.

Lead Worn in the Operating Room	N (%)
Yes	93 (93%)
No	4 (4%)
Sometimes	4 (4%)
Safety Equipment Used	
Single piece – full apron	53 (47.3%)
Vest with wings	36 (32.1%)
Vest without wings	71 (63.4%)
Skirt	87 (77.7%)
Thyroid guard	107 (95.5%)
Leaded glasses	9 (8%)
Leaded scrub cap	0 (0%)
Leaded face shield	0 (0%)

Table 2: Resident use of protective lead.

Discussion

Interpretation of our survey data indicates a lack of standardized radiation safety training in Canadian orthopaedic surgery residency programs. The lack of training was a concern for a majority of residents and may be responsible for subjective and objective deficiencies in radiation safety knowledge. The damaging effects to human tissue caused by radiation exposure have been well-documented since the early use of radiography [17]. Deficiencies in knowledge and clinical application of radiation safety principles stemming from this lack of formal training could be placing residents at increased risk of negative health consequences. These deficiencies will continue and perpetuate as residents move into practice as independent surgeons. In 2013, Chow, et al., surveyed the Canadian Orthopaedic Association and found that these knowledge deficiencies were present at the attending staff surgeon level¹⁵. Orthopaedic surgeons cited an information deficit as the greatest limitation to awareness of cataractogenesis, dose limits, and use of radio protective eyewear. Tuncer, et al., (2017) found similar deficits in knowledge and understanding of radiation protection, in that only 8.5% of orthopaedic surgeons and residents had read at least one article pertaining to radiation safety [18].

The results of the current study indicate a need for timely intervention at the trainee level. The Royal College of Physicians and Surgeons of Canada have included radiation safety as an objective for all residents enrolled in “Surgical Foundations”; however, less than half of the total respondents had received formal radiation safety training as part of their residency program. This suggests that the current curriculum is insufficient to meet this important training

objective. A national curriculum may help to increase resident knowledge and allow Surgical Foundations objectives to be met in a standardized fashion.

In terms of radiation safety practice, residents reported high compliance with donning of protective lead, but infrequent lead evaluation. However, the majority indicated that lead is not always available in their size. Wearing appropriately-fitting lead is critical to preventing unnecessary exposure to uncovered areas [17]. When lead gowns are worn appropriately, radiation absorption can be decreased by 90 to 99% [19]. This highlights a critical gap in provision of properly fitting lead protection for trainees. Less than 10% of respondents reported using lead glasses, despite recommendations from the International Commission on Radiological Protection [16]. Of the small minority who reported owning personalized lead, most did not meet the recommended yearly evaluation. Provision of personal lead and lead glasses may increase safety measures by allowing residents to have access to the proper personal protective equipment at all times.

Our study also demonstrated that radiation monitoring are deficient in Canadian orthopaedic programs. Only 18% (n=20) of respondents reported that their radiation exposure was monitored with dosimeters. Furthermore, 18% is an overestimation, given that one resident group was participating in a study that required dosimeter monitoring at the time of survey administration. This group did not wear dosimeters prior to the study, and no longer wear dosimeters since the completion of the study. Beyond this group, there were only four individuals who reported dosimeter use that was unrelated to a radiation monitoring study. The latest review suggests that all personnel who encounter radiation exposure should wear personal dosimeters and that this data should be monitored regularly [17].

While the majority of residents are concerned about the effects of radiation on their health, only 57% of survey respondents reported feeling comfortable advocating for radiation safety in the operating room. A contributing factor may be that the hierarchal culture of the operating room has been shown to suppress open and honest communication [20]. If attending surgeons have less training and awareness, their actions may negatively influence safety practices for those with appropriate knowledge. This also highlights the need for continuing medical education for both radiation safety and operating room communication throughout one's career.

One of the notable limitations of our study is that the rigour of radiation safety training programs was not assessed. This would have been useful information, given the potential variability in content, duration, and intensity of various training programs. Given the nature of survey-based research, recall bias may have affected the accuracy of individual responses regarding radiation safety training at their institution. Additionally, despite a reasonable response rate, there was still a large contingent of non-responders across Canada (n = 168, 59%), with the Atlantic provinces underrepresented by responses. However, one of the strengths of our study is the involvement of the majority of orthopaedic residency programs

across Canada and the inclusion of both an English and French version. Overall, 116 residents participated in the survey, providing a broad picture of radiation safety knowledge in orthopaedic trainees across Canada, which supports the need for improved radiation safety practices.

Conclusion

This survey study has identified deficiencies in radiation safety training and protocols across many Canadian orthopaedic residency training programs. These results will serve as impetus for orthopaedic residency programs across Canada to implement higher safety standards in the form of standardized radiation safety training, routine dosimeter use, and improved protective lead provision and availability.

Conflict of Interest

There is no conflict of interest ensued by author.

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