Advances in Radiation Oncology (2023) **8**, 101184

advances in radiation oncology

www.advancesradonc.org

Scientific Article

Management of Patients with Cardiovascular Implantable Electronic Devices Undergoing Radiation Therapy: A National Survey of Canadian Multidisciplinary Radiation Oncology Professionals

Amir H. Safavi, MD, MSc,[a] Alexander V. Louie, MD, PhD,[a,b] Alyaa H. Elzibak, PhD,[a,b] Andrew Warner, MSc,[c] Elysia K. Donovan, MD, MSc,[d] and Jay S. Detsky, MD, PhD[a,b,*]

[a]Department of Radiation Oncology, University of Toronto, Toronto, Ontario, Canada; [b]Odette Cancer Centre — Sunnybrook Health Sciences Centre, Toronto, Ontario, Canada; [c]Department of Radiation Oncology, London Health Sciences Centre, London, Ontario, Canada; and [d]Department of Oncology, McMaster University, Hamilton, Ontario, Canada

Received 9 November 2022; accepted 11 January 2023

Abstract

Purpose: This study aimed to characterize contemporary management of Canadian patients with cardiovascular implantable electronic devices (CIEDs) undergoing radiation therapy (RT) in light of updated American Association of Physicists in Medicine guidelines.

Methods and Materials: A 22-question web-based survey was distributed to members of the Canadian Association of Radiation Oncology, Canadian Organization of Medical Physicists, and Canadian Association of Medical Radiation Technologists from January to February 2020. Respondent demographics, knowledge, and management practices were elicited. Statistical comparisons by respondent demographics were performed using χ^2 and Fisher exact tests.

Results: In total, 155 surveys were completed by 54 radiation oncologists, 26 medical physicists, and 75 radiation therapists in academic (51%) and community (49%) practices across all provinces. The majority of respondents (77%) had managed >10 patients with CIEDs in their career. Most respondents (70%) reported using risk-stratified institutional management protocols. Respondents used manufacturer recommendations, rather than American Association of Physicists in Medicine or institutionally recommended dose limits, when the manufacturer limit was 0 Gy (44%), 0 to 2 Gy (45%), or >2 Gy (34%). The majority of respondents (86%) reported institutional policies to refer to a cardiologist for CIED evaluation both before and after completion of RT. Cumulative dose to CIED, pacing dependence, and neutron production were considered during risk stratification by 86%, 74%, and 50% of participants, respectively. Dose and energy thresholds for high-risk management were not known by 45% and 52% of respondents, with radiation oncologists and radiation therapists significantly less likely to report thresholds than medical physicists ($P < .001$). Although 59% of

Presented in part at the Canadian Association of Radiation Oncology Annual Scientific Meeting, September 2020, Toronto, Ontario, and at the American Society for Radiation Oncology Annual Meeting, October 2020, Miami, Florida.

Sources of support: This work had no specific funding.

Disclosures: Dr Louie has received honoraria from Varian Medical Systems, RefleXion, and AstraZeneca. No other disclosures were reported.

Research data are stored in an institutional repository and will be shared upon request to the corresponding author.

*Corresponding author: Jay S. Detsky, MD, PhD; E-mail: jay.detsky@sunnybrook.ca

https://doi.org/10.1016/j.adro.2023.101184

respondents felt comfortable managing patients with CIEDs, community respondents were less likely to feel comfortable than academic respondents ($P = .037$).

Conclusions: The management of Canadian patients with CIEDs undergoing RT is characterized by variability and uncertainty. National consensus guidelines may have a role in improving provider knowledge and confidence in caring for this growing population.

Introduction

Patients who have cardiovascular implantable electronic devices (CIEDs), such as pacemakers (PMs) and implantable cardiac defibrillators (ICDs), and are undergoing radiation therapy (RT) are a growing population who may be at risk of device malfunction during RT.[1-3] Management of these patients and their CIEDs presents numerous challenges to multidisciplinary RT teams consisting of radiation oncologists (RO), medical physicists (MP), and radiation therapists (RTh). Although the 1994 American Association of Physicists in Medicine (AAPM) TG-34 report[4] has been the historical reference guideline for management of these patients, its recommendations, such as a device dose limit of 2 Gy, were based on limited evidence specific to PMs and RT delivery methods of the time. Recommendations from CIED manufacturers are inconsistent and contribute to clinical uncertainty when contrasted with institutional and society guidelines.[5,6] As such, surveys in multiple countries published between 2004 and 2014 demonstrated heterogenous institutional management policies, including variable CIED dose limits and cardiology referral practices,[5,7,8] as well as a lack of awareness of TG-34 guidelines and multidisciplinary roles.[3]

Updated guidelines, including the 2017 Heart Rhythm Society (HRS) expert consensus statement and the 2019 AAPM TG-203, recognize the aforementioned limitations and uncertainties and recommend management protocols stratified by risk of CIED malfunction.[9-12] Unlike The Netherlands and Italy,[10,11] Canada does not have national consensus guidelines, nor are contemporary Canadian practice patterns known in light of updated risk-stratified guidelines. Therefore, the purpose of this study was to characterize the contemporary management of Canadian patients with CIEDs undergoing RT by ROs, MPs, and RThs.

Methods and Materials

This study was approved by the Sunnybrook research ethics board (#309-2019). A 22-question web-based survey (Table E1), informed by recommendations from the AAPM TG-203 report,[4] was developed to elicit the demographics, comfort level, knowledge, and management practices of RO, MP, and RTh respondents regarding CIEDs in RT. Demographics surveyed included respondent discipline (RO vs MP vs RTh), professional status (staff vs trainee), practice setting (academic vs community), and management experience (≤10 vs >10 patients with CIEDs). Respondents were not provided definitional criteria for selecting an academic or community practice setting; responses reflect how respondents classify their own centers. The threshold of 10 patients was arbitrarily selected to stratify respondents by management experience.

Respondent understanding of institutional management policies and clinical and treatment factors considered during risk stratification, including use of neutron-producing beams, patients' pacing dependence, and high-risk CIED dose thresholds, were characterized. Practice patterns regarding referrals to cardiology, including scenarios in which a referral would not be made, were also surveyed. Given a known CIED manufacturer dose limit (0, 0-2, or >2 Gy), respondents were asked whether they would follow the manufacturer limit or follow institutionally and society-recommended dose limits.

The web-based survey was designed using Google Forms and piloted locally to optimize content validity, face validity, and usability before distribution for study participation. The survey was emailed by the Canadian Association of Radiation Oncology (CARO), the Canadian Organization of Medical Physicists (COMP), and the Canadian Association of Medical Radiation Technologists (CAMRT) to their respective memberships in January 2020. Survey responses were anonymously collected from January to February 2020. Descriptive statistics were performed to analyze responses to multiple choice, linear scale, and short-answer questions. Responses to short-answer questions underwent quantitative content analysis, wherein responses were inductively coded and the frequency of codes were quantified.[13] Fisher exact and χ^2 tests were performed to determine whether responses differed by respondent demographics (discipline, professional status, practice setting, or management experience). All statistical analyses were performed using SAS version 9.4 software (SAS Institute, Cary, NC) using 2-sided statistical testing at the $P = 0.05$ significance level.

Results

Respondent demographics

The survey was distributed to 1089 email addresses by CARO, CAMRT, and COMP. In total, 155 individuals (54 RO, 26 MP, 75 RTh) responded to the survey. The overall response rate was 14%; the response rate varied by society

(22% from CARO, 20% from CAMRT, 5% from COMP). There was a 100% survey completion rate. All Canadian provinces were represented by respondents, with the most from Ontario (45%, n = 69), British Columbia (16%, n = 25), and Alberta (10%, n = 16) (Table 1). Trainees accounted for 11% of respondents (n = 17). Amongst staff respondents, 49% of RO (20/41), 72% of MP (18/25), and 65% of RTh (49/75) respondents had been in practice for ≥10 years. Almost all staff respondents (97%, n = 138) agreed that their practice included treatment of breast and/or thoracic (lung, pleura, thymus, lymphoma, and/or esophagus) tumors. Respondents represented both academic (51%, n = 73) and community (49%, n = 70) practice settings. Most respondents (77%, n = 119) in their training and career had managed >10 patients with CIEDs undergoing RT. Discipline and professional status were associated ($P < .001$); 53% of staff (73/138) were RThs while 76% of trainees (13/17) were ROs. Discipline and practice setting were also associated ($P < .001$); 55% of academic respondents (40/73) were ROs while 77% of community respondents (54/70) were RThs. Similarly, discipline and management experience were associated ($P < .001$); 57% of respondents (68/119) who managed >10 patients with CIEDs were RThs while 67% of respondents (24/36) who managed ≤10 such patients were ROs. Professional status and management experience were associated ($P < .001$); 95% of respondents (113/119) who managed >10 patients with CIEDs were staff compared with 69% of staff (25/36) who managed ≤10 such patients. Respondent characteristics are summarized in Table 1.

Table 1 Characteristics of survey respondents

Parameter	No. (%)
Province	
Alberta	16 (10.3)
British Columbia	25 (16.1)
Manitoba	11 (7.1)
New Brunswick	3 (1.9)
Newfoundland	1 (0.7)
Nova Scotia	4 (2.6)
Ontario	69 (44.5)
Prince Edward Island	4 (2.6)
Quebec	13 (8.4)
Saskatchewan	9 (5.8)
Discipline	
Medical physics	26 (16.8)
Radiation oncology	54 (34.8)
Radiation therapy/dosimetry	75 (48.4)
Professional status	
Staff	138 (89.0)
Trainee	17 (11.0)
Staff practice setting	
Academic	73 (51.0)
Community	70 (49.0)
Management experience	
≤10 patients	36 (23.2)
>10 patients	119 (76.8)
Years in staff practice	
Medical physics	
<10	7 (28.0)
≥10	18 (72.0)
Radiation oncology	
<10	21 (51.2)
≥10	20 (48.8)
Radiation therapy/dosimetry	
<10	26 (34.7)
≥10	49 (65.3)
Staff treating breast and/or thoracic tumors	138 (96.5)

Perceived prevalence of institutional protocols

Almost all respondents (97%, n = 151) reported that their institution has a management protocol for patients with CIEDs undergoing RT (Fig. 1A). Institutional management protocols stratified by risk of device malfunction (low vs medium vs high risk) were reported by 57% of respondents (n = 88) (Fig. 1B). Respondents who had managed >10 patients with CIEDs undergoing RT were more likely to report risk-stratified protocols (61% [73/119] vs 42% [15/36]; $P = .037$). There were no significant differences in reporting of risk-stratified protocols by discipline, professional status, or practice setting ($P > .05$ for all 3 demographics). Most respondents (66%, n = 103) reported that their institution has management protocols for CIED monitoring before, during, and after RT (Fig. 1C). Although there was no significant difference in reporting of protocols for CIED monitoring by practice setting, there were differences by discipline (76% of RTh [57/75] vs 59% of RO [32/54] and 54% of MP [14/26]; $P = .046$), professional status (70% of staff [96/138] vs 41% of trainees [7/17]; $P = .019$), and management experience (71% of >10 patients [85/119] vs 50% of ≤10 patients [18/36]; $P = .017$).

Use of institutional, guideline, and manufacturer recommendations

The most used recommendations were institutional protocols (70%, n = 109) followed by AAPM (8%, n = 13) and HRS (5%, n = 8) reports (Fig. 2A). A minority of respondents (16%, n = 25) reported not knowing which guidelines they use. Respondents used manufacturer

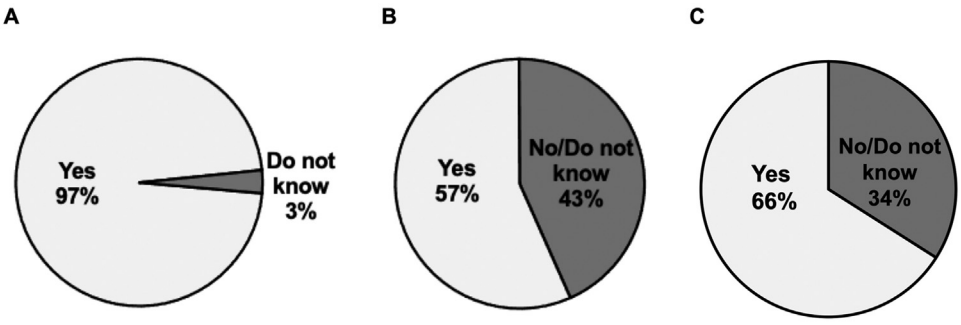

Figure 1 Prevalence and characteristics of institutional protocols for management of cardiovascular implantable electronic devices. (A) Prevalence of institutional management protocols, (B) prevalence of risk-stratified institutional protocols, and (C) prevalence of institutional protocols for cardiovascular implantable electronic device monitoring before, during, and after radiation therapy.

recommendations, rather than AAPM or institutionally recommended dose limits, when the manufacturer limit is 0 Gy (44%, n = 68), 0 to 2 Gy (45%, n = 69), or >2 Gy (34%, n = 52) (Fig. 2B). There were no significant differences in responses by discipline, professional status, practice setting, or management experience for any of the given manufacturer dose limits ($P > .05$ for all 4 demographics).

Referral practices to cardiology

The majority of respondents (86%, n = 133) reported an institutional policy to refer to a cardiologist for patient and CIED evaluation both before initiation of RT and after completion of RT (Fig. 3A). Respondents who had managed >10 patients with CIEDs undergoing RT versus ≤10 such patients were more likely to report a policy to refer to a cardiologist before RT (90% [107/119] vs 72% [26/36], $P = .008$). Respondents who had managed >10 patients with CIEDs undergoing RT were also more likely to report a policy to refer to a cardiologist after RT (91% [108/119] vs 72% [26/36], $P = .010$). There were no significant differences in likelihood of reporting a policy to refer before and after RT by discipline, professional status, or practice setting ($P > .05$ for all 3 demographics). RO was the discipline felt to be most responsible for facilitating referrals to cardiology by 72% of respondents (n = 112) followed by RTh (14%, n = 22) and MP (8%, n = 12) (Fig. 3B). There was no significant difference in likelihood of selecting RO as the responsible team member by discipline, professional status, practice setting, or management

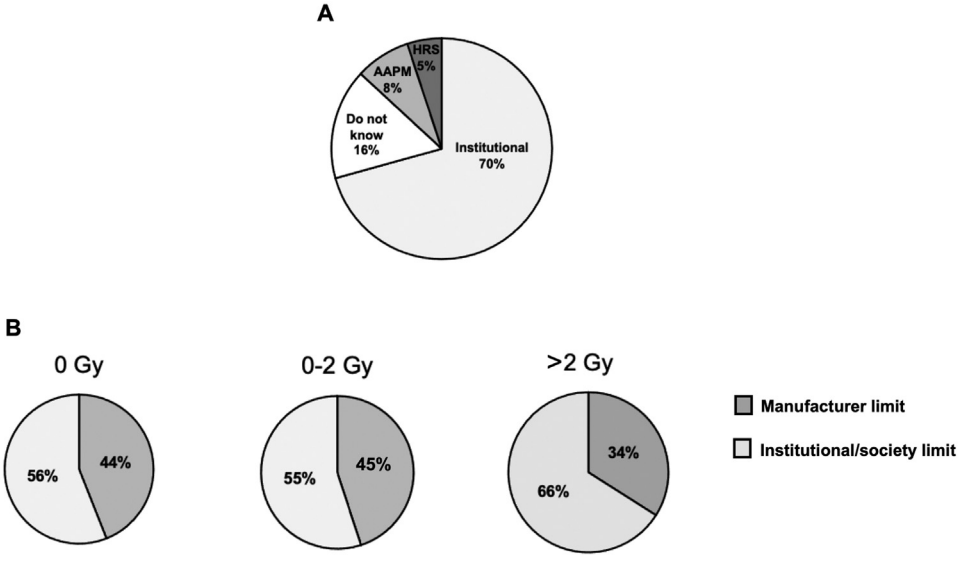

Figure 2 Use of institutional protocols, guidelines, and manufacturer recommendations for management of cardiovascular implantable electronic devices. (A) Choice of management guideline. (B) Choice of dose limit when the cardiovascular implantable electronic device manufacturer limit is 0 Gy, 0 to 2 Gy, or >2 Gy. *Abbreviations:* AAPM = American Association of Physicists in Medicine; HRS = Heart Rhythm Society.

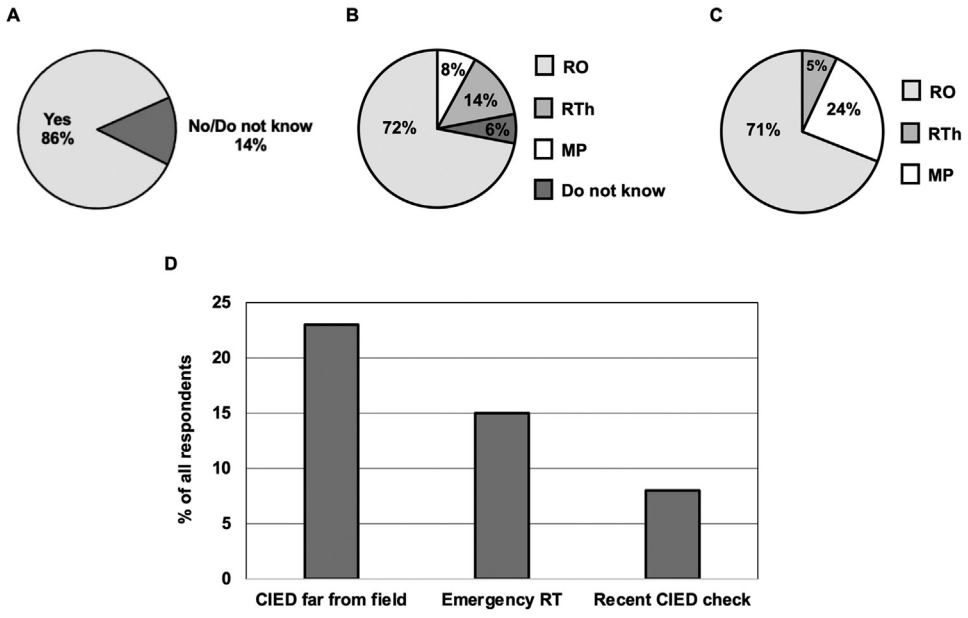

Figure 3 Referral practices to cardiology for management of CIEDs. (A) Prevalence of institutional policy of referring patients with CIEDs to cardiology before and/or after RT. (B) Discipline perceived to be most responsible for referring patients with CIEDs to cardiology. (C) Discipline perceived to be responsible for communicating treatment factors to cardiology. (D) Three most common scenarios in which respondents would not refer patients with CIEDs to cardiology before RT. *Abbreviations:* CEID = cardiovascular implantable electronic device; MP = medical physicists; RO = radiation oncologists; RT = radiation therapy; RTh = radiation therapists.

experience ($P > .05$ for all 4 demographics). RO was also the discipline felt to be most responsible for communicating relevant treatment factors to cardiology by 71% of respondents (n = 110) followed by MP (24%, n = 37) and RTh (5%, n = 8) (Fig. 3C). ROs were more likely to believe that they are most responsible for these communications (83% of RO [45/54] vs 58% of MP [15/26] and 67% of RTh [50/75], $P = .032$). While professional status was associated with selecting RO as the most responsible discipline for communication with cardiology (94% of trainees [16/17] vs 68% of staff [94/138], $P = .025$), practice setting and management experience were not ($P > .05$ for both demographics).

Most respondents (56%, n = 87) stated that there were scenarios in which they would not refer patients with CIED for cardiology evaluation before RT (Fig. 3D). The 3 most common scenarios in which respondents would not refer patients with CIEDs for cardiology evaluation before RT were (1) CIED located far from the field (23% of all respondents [n = 35]), (2) emergency RT (15%, n = 24), and (3) recent CIED check (8%, n = 13). CIED far from the field was more likely to be considered by ROs (39%, 21/54) than by MPs (19%, 5/26) or RThs (12%, 9/75) ($P = .001$). Emergency RT was more likely to be considered by academic (22%, 16/73) than community (9%, 6/70) respondents ($P = .027$). Recent CIED check was more likely to be considered by ROs (11%, 6/54) than by RThs (8%, 6/75) or MPs (4%, 1/26) ($P = .047$).

Knowledge of factors for risk stratification

Respondents selected clinical and treatment factors that they would consider when assessing the risk of CIED malfunction due to RT (Fig. 4A, 4B). Among clinical factors, CIED type (88%, n = 137 of all respondents) was the most commonly selected, followed by pacing dependence (74%, n = 114), manufacturer/model of CIED (45%, n = 69), treatment intent (33%, n = 51), and CIED implantation date (15%, n = 24) (Fig. 4A). CIED type was more likely to be considered by respondents who managed >10 patients with CIEDs (92%, 109/119) than by those who managed ≤10 such patients (78%, 28/36) ($P = .036$). Among treatment factors, proximity of CIED to the treatment field edge (97% of all respondents [n = 151]) was the most commonly selected, followed by photon energy (86%, n = 134), maximum expected cumulative dose to CIED (86%, n = 134), beam arrangement (84%, n = 130), neutron production (50%, n = 77), prior irradiation proximal to CIED (49%, n = 76), dose rate (21%, n = 32), and hypofractionation (10%, n = 15) (Fig. 4B). Proximity of CIED to the treatment field edge was more likely to be considered by respondents who managed >10 patients with CIEDs (99%, 118/119) than by those who managed ≤10 such patients (92%, 33/36) ($P = .039$). Maximum expected cumulative dose to CIED was more likely to be considered by respondents who

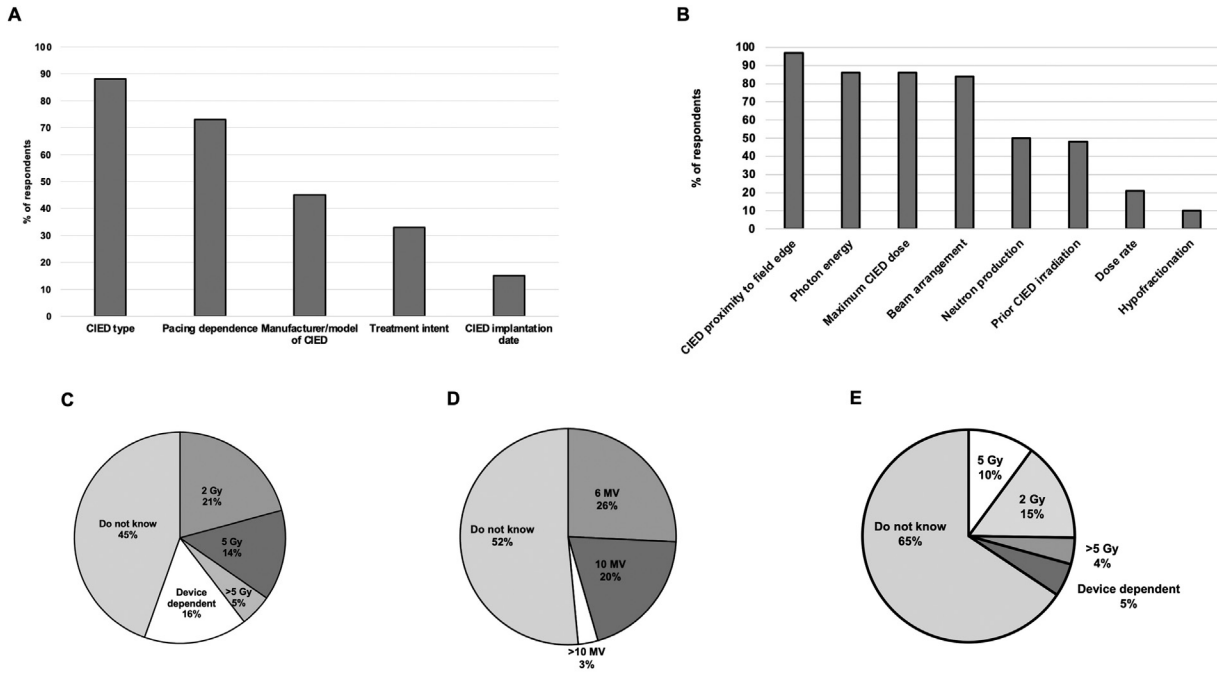

Figure 4 Knowledge of clinical and treatment factors for stratification by risk of CIED failure. (A) Clinical factors used for risk stratification. (B) Technical factors used for risk stratification. (C) High-risk dose threshold. (D) High-risk energy threshold. (E) Dose threshold for CIED relocation. *Abbreviation:* CIED = cardiovascular implantable electronic device.

managed >10 patients with CIEDs (91%, 108/119) than by those who managed ≤10 such patients (72%, 26/36) (P = .010). Neutron production, a key treatment factor identified by TG-203 for risk stratification, was more likely to be considered by MP respondents (81%, 21/26) than by RO (56%, 30/54) and RTh (35%, 26/75) respondents (P < .001). Prior irradiation proximal to CIED was more likely to be considered by MP (77%, 20/26) respondents than by RTh (44%, 33/75) or RO (43%, 23/54) respondents (P = .008).

Knowledge of high-risk dose and energy thresholds

Responses regarding high-risk dose and energy thresholds were heterogenous (Fig. 4C, 4D). "Do not know" was the most common response when respondents were asked to state the high-risk dose (45%, n = 70) and energy thresholds (52%, n = 80). Five gray and 10 megavolts (MV), the high-risk thresholds recommended by TG-203, were chosen by 14% (n = 21) and 20% (n = 31) of respondents, respectively. Other high-risk dose thresholds chosen included 2 Gy (21% of respondents [n = 32]), CIED type-specific thresholds (16%, n = 25), and doses >5 Gy (5%, n = 7). Other high-risk energy thresholds chosen included 6 MV (26% of respondents [n = 40]) and energies >10 MV (3%, n = 4). Discipline was associated with stating "do not know" regarding high-risk dose (63% of RTh [47/75] vs 41% of RO [22/54] vs 4% of MP [1/26], P < .001) and energy thresholds (65% of RTh [49/75] vs 50% of RO [27/54] vs 15% of MP [4/26], P < .001). The likelihood of stating 5 Gy as the high-risk dose threshold varied by discipline (38% of MP [10/26] vs 11% of RO [6/54] vs 7% of RTh [5/75], P < .001), but did not vary by professional status, practice setting, or management experience (P > .05). The likelihood of stating 10 MV as the high-risk energy threshold varied by discipline (50% of MP [13/26] vs 17% of RO [9/54] vs 12% of RTh [9/75], P < .001), but did not vary by professional status, practice setting, or management experience.

The majority of respondents (65%, n = 101) stated "do not know" regarding the dose below which CIED relocation is not recommended (Fig. 4E). Five gray, the dose below which the HRS does not recommend relocation, was chosen by 10% of respondents (n = 16). Two gray was chosen by 15% of respondents (n = 24). The responses to this question were associated with discipline (P < .001) but not professional status, practice setting, or management experience.

Self-confidence and perceived clarity of management protocols

Most respondents (59%, n = 92) felt comfortable managing patients with CIEDs undergoing RT (Fig. 5A). Staff respondents were more likely to be comfortable than trainees (62% [86/138] vs 35% [6/17], respectively; P = .032). Likewise, academic respondents were more

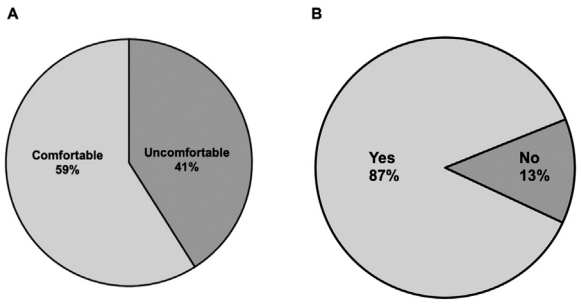

Figure 5 Respondent self-confidence and perceived clarity of institutional protocols for management of CIEDs. (A) Comfort level with managing patients with CIEDs undergoing radiation therapy. (B) Perceived clarity of institutional management protocols. *Abbreviation:* CIED = cardiovascular implantable electronic device.

likely to be comfortable than their community counterparts (70% [51/73] vs 53% [37/70], respectively; $P = .037$). Discipline and management experience were not associated with comfort level ($P > .05$ for both demographics). The majority of respondents (87%, n = 135) felt that their institution's management protocols are clear (Fig. 5B).

Discussion

This study characterized the contemporary management of Canadian patients with CIEDs undergoing RT. Our results show that the management of these patients is characterized by variability and uncertainty. The responses of survey respondents suggest incongruencies between practice patterns and updated guidelines by the AAPM in December 2019. Given the heterogeneity in practice patterns and prevalence of uncertainty with management considerations, we submit that there are unmet educational needs nationally, as well as a role for national consensus guidelines to improve knowledge and confidence in caring for this growing population. Patients with CIEDs undergoing RT are a growing population, and their RT presents challenges to the multidisciplinary team. Thus, it is increasingly important to determine practice patterns, educational needs, and the role for national guidelines.

The variable knowledge, management practice, and comfort level across the country suggest several educational needs. First, 50% of respondents considered neutron production as part of risk stratification, and 20% chose 10 MV as the high-risk energy threshold for device malfunction. Both the likelihood of considering neutron production and the likelihood of considering 10 MV as the high-risk energy threshold varied only by discipline. Although not considered by the majority of respondents, neutron production occurring at energies >10 MV is the most frequent cause of device and clinical failure.[12] These findings suggest that educational needs regarding the importance of neutron production and high-energy photon RT in risk stratification are required in some disciplines more than others. Second, the majority of respondents responded "do not know" when asked to state a high-risk dose threshold. The modern high-risk dose threshold of 5 Gy was stated by 14% of respondents while the historical TG-34 threshold of 2 Gy was stated by 21% of respondents. The AAPM revised the high-risk dose threshold from 2 to 5 Gy for several reasons: The rate of CIED complications >5 Gy is similar to that from neutron production,[14-17]), there are few reports of CIED malfunctions <5 Gy,[12] and several vendors recommend dose thresholds of 3 to 5 Gy.[12] Treatment adaptation and monitoring depends on knowledge of this high-risk dose threshold, suggesting an additional pervasive educational need. Third, pacing dependence was not considered as part of risk stratification by 26% of respondents, with no significant variability across demographic strata. Pacing dependence is one of the critical factors considered in the TG-203 guideline for risk stratification of device failure because it determines the immediacy of the effect of device failure.[12] This is another important domain for further education. Fourth, some patients noted device-dependent differences (ICD vs PM) in dose thresholds. There is no definitive evidence that ICDs are more sensitive to radiation than PMs,[18] and modern ICDs are also single-lead PMs. Education may be required to raise awareness of these considerations.

Three findings from this study suggest a role for national consensus guidelines for management of patients with CIEDs undergoing RT. First, when presented with a scenario in which the CIED dose limit recommended by the manufacturer is 0 Gy, 44% of respondents elected to follow the manufacturer limit of 0 Gy. There were no significant differences in practice for this scenario across discipline, professional status, practice setting, or management experience. The TG-203 guideline supports treating patients with devices with manufacturer recommended dose limits of 0 Gy.[12] Conversely, AAPM recommends following the manufacturer dose limit when the dose limit is >2 Gy. When presented with a scenario in which the CIED dose limit recommended by the manufacturer is >2 Gy, 34% of respondents followed the manufacturer limit. A national approach, articulated in consensus guidelines developed with stakeholders across disciplines and practice settings, may increase confidence and knowledge in reconciling incongruent manufacturer, institutional, and society dose limits. Second, participants identified practical scenarios in which they would not refer for cardiology evaluation before treatment. These scenarios included CIED located far from the field, emergency RT, and recent CIED check. However, omission of a cardiology evaluation before treatment in these scenarios is not supported by TG-203, as other factors, such as pacing dependence, may still elevate the patient's risk for clinically relevant device malfunction. Nonetheless, there

are practical scenarios in which it may be reasonable to omit a cardiology evaluation of the CIED due to clinical judgment favoring the benefit of immediate RT. Third, there was significant variability in knowledge regarding the dose threshold for device relocation. There is no definitive dose threshold for device relocation; the HRS guidelines recommend a limit of 5 Gy[9,12] while the Dutch and Italian guidelines recommend a limit of 10 Gy.[10,11] It should also be noted that available data are not sufficient to guide relocation decisions for exposures >5 Gy.[9] In fact, device relocation is a serious procedure for patients with comorbidities, and TG-203 notes that every effort must be made to manage the patient without resorting to device relocation. A national approach may increase confidence and knowledge in managing these scenarios. Of all respondents, 59% felt comfortable managing patients with CIEDs undergoing RT, and community respondents were significantly less comfortable. The increase in knowledge and confidence could be derived not only from the contextual applicability and visibility of a national resource but also from the engagement of multidisciplinary professionals across the country who could advocate for adoption of these guidelines locally.

This work has a number of limitations. The survey was completed from January through February 2020, shortly after the publication of the updated AAPM TG-203 guidelines in December 2019. RT professionals across Canada may not have been aware of these new guidelines at the time of survey completion. Furthermore, the awareness of the TG-203 guidelines may have increased between the time of survey completion and completion of this work. We believe that the broad heterogeneity of responses and the prevalence of responses indicating uncertainty in knowledge and management, despite existing historical guidelines,[4] suggests that the need for education and role for national guidelines is likely still relevant to the Canadian RT community. While there was a 100% survey completion rate, the overall response rate to the survey was 14%. The low overall response rate was driven by a disproportionately low response rate from members of COMP (5%) relative to members of CARO (22%) and CAMRT (20%). As such, there were only 26 MP respondents, and MP responses may be limited in generalizability across Canadian MP practitioners. Furthermore, while this work reports on the perceived prevalence of institutional protocols among respondents, it does not provide information on the actual prevalence of these institutional policies across Canada. To acquire this information, a targeted survey of institutional representatives, such as departmental heads of MP and RTh, could be conducted. Although our survey instrument was piloted locally for content validity, face validity, and usability by the investigators, this survey was not externally and quantitatively validated before study distribution.

Conclusion

The management of Canadian patients with CIEDs undergoing RT is characterized by variability and uncertainty. There are unmet educational needs nationally as well as a role for national consensus guidelines to improve provider knowledge and confidence in caring for this growing population.

Supplementary materials

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.adro.2023.101184.

References

1. Pedersen SB, Nielsen JC, Bøtker HE, Farkas DK, Schmidt M, Sørensen HT. Implantable cardioverter-defibrillators and subsequent cancer risk: A nationwide population-based cohort study. *Europace*. 2015;17:902-908.
2. Zaremba T, Jakobsen AR, Søgaard M, et al. Risk of device malfunction in cancer patients with implantable cardiac device undergoing radiotherapy: A population-based cohort study. *Pacing Clin Electrophysiol*. 2015;38:343-356.
3. Gossman MS, Wilkinson JD, Mallick A. Treatment approach, delivery, and follow-up evaluation for cardiac rhythm disease management patients receiving radiation therapy: Retrospective physician surveys including chart reviews at numerous centers. *Med Dosim*. 2014;39:320-324.
4. Marbach JR, Sontag MR, Van Dyk J, Wolbarst AB. Management of radiation oncology patients with implanted cardiac pacemakers: Report of AAPM Task Group No. 34. *Med Phys*. 1994;21:85-90.
5. Solan AN, Solan MJ, Bednarz G, Goodkin MB. Treatment of patients with cardiac pacemakers and implantable cardioverter-defibrillators during radiotherapy. *Int J Radiat Oncol Biol Phys*. 2004;59:897-904.
6. Hudson F, Coulshed D, D'Souza E, Baker C. Effect of radiation therapy on the latest generation of pacemakers and implantable cardioverter defibrillators: A systematic review. *J Med Imaging Radiat Oncol*. 2010;54:53-61.
7. Lester JF, Evans LM, Yousef Z, Penney A, Brown PN, Perks R. A national audit of current cardiac device policies from radiotherapy centres across the UK. *Clin Oncol*. 2014;26:45-50.
8. Soejima T, Yoden E, Nishimura Y, et al. Radiation therapy in patients with implanted cardiac pacemakers and implantable cardioverter defibrillators: A prospective survey in Japan. *J Radiat Res*. 2011;52:516-521.
9. Indik JH, Gimbel JR, Abe H, et al. 2017 HRS expert consensus statement on magnetic resonance imaging and radiation exposure in patients with cardiovascular implantable electronic devices. *Heart Rhythm*. 2017;14:e97-e153.
10. Hurkmans CW, Knegjens JL, Oei BS, et al. Management of radiation oncology patients with a pacemaker or ICD: A new comprehensive practical guideline in The Netherlands. *Radiat Oncol*. 2012;7:198.
11. Zecchin M, Severgnini M, Fiorentino A, et al. Management of patients with cardiac implantable electronic devices (CIED) undergoing radiotherapy: A consensus document from Associazione Italiana Aritmologia e Cardiostimolazione (AIAC), Associazione Italiana Radioterapia Oncologica (AIRO), Associazione Italiana Fisica Medica (AIFM). *Int J Cardiol*. 2018;255:175-183.

12. Miften M, Mihailidis D, Kry SF, et al. Management of radiotherapy patients with implanted cardiac pacemakers and defibrillators: A report of the AAPM TG-203. *Med Phys*. 2019;46:e757-e788.
13. Kleinheksel AJ, Rockich-Winston N, Tawfik H, Wyatt TR. Demystifying content analysis. *Am J Pharm Educ*. 2020;84:7113.
14. Hurkmans CW, Scheepers E, Springorum BGF. Uiterwaal H. Influence of radiotherapy on the latest generation of implantable cardioverter-defibrillators. *Int J Radiat Oncol Biol Phys*. 2005;63:282-289.
15. Mollerus M, Naslund L, Lipinski M, Meyer A, Libey B, Dornfeld K. Radiation tolerance of contemporary implantable cardioverter-defibrillators. *J Interv Card Electrophysiol*. 2014;39:171-175.
16. Hurkmans CW, Scheepers E, Springorum BGF, Uiterwaal H. Influence of radiotherapy on the latest generation of pacemakers. *Radiother Oncol*. 2005;76:93-98.
17. Uiterwaal H, Springorum BG, Scheepers E, de Ruiter GS, Hurkmans CW. Interference detection in implantable defibrillators induced by therapeutic radiation therapy. *Neth Heart J*. 2006;14:330-334.
18. Gomez DR, Poenisch F, Pinnix CC, et al. Malfunctions of implantable cardiac devices in patients receiving proton beam therapy: Incidence and predictors. *Int J Radiat Oncol Biol Phys*. 2013;87:570-575.