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CONSISTENCY OF TRIAXIAL CABLE RESPONSE ACROSS LOW-SIGNAL SMALL-FIELD DOSIMETRIC MEASUREMENTS USING CABLES OF VARYING OPERATIONAL STATE

Medical Science

Sandhiya R Intern Medical Physicist, Shri Ram Murti Smarak Institute of Medical Sciences, Bareilly, Uttar Pradesh, India.

Navitha S Assistant Professor cum Medical Physicist, Shri Ram Murti Smarak Institute of Medical Sciences, Bareilly, Uttar Pradesh, India.

Jitendra Nigam Associate Professor cum Medical Physicist, Shri Ram Murti Smarak Institute of Medical Sciences, Bareilly, Uttar Pradesh, India.

Silambarasan N S Assistant Professor cum Medical Physicist, Shri Ram Murti Smarak Institute of Medical Sciences, Bareilly, Uttar Pradesh, India.

Anu Roy Medical Physicist, Shri Ram Murti Smarak Institute of Medical Sciences, Bareilly, Uttar Pradesh, India.

Piyush Kumar Professor And Head, Shri Ram Murti Smarak Institute of Medical Sciences, Bareilly, Uttar Pradesh, India.

ABSTRACT

Background: Small-field dosimetry is challenging due to loss of charged particle equilibrium, partial source occlusion and detector-size effects described in IAEA TRS-483. Small-volume ionization chambers produce weak, noisy signals, while leakage and cable-induced currents from irradiated cables may introduce extracameral charge and affect measurement accuracy. Although triaxial cables are designed to limit these effects, their performance may vary with prolonged use. This study evaluates the impact of triaxial cable dependency on machine-specific reference field absolute dosimetry. **Materials And Methods:** Two identical 20m triaxial cables were evaluated using two IBA CC13 and one IBA CC01 ionization chambers. Measurements were performed in an IBA Blue Phantom[2] water phantom on a Varian TrueBeam linear accelerator using a 6 MV photon beam. Absolute dose measurements were acquired at 100 cm SSD and 10 cm depth in water for square field sizes from 2 × 2 cm² to 10 × 10 cm², delivering 100 MU at 600 MU/min. Cable-dependent effects were assessed using two acquisition strategies: a cable-isolation method, in which each cable was fixed while chambers were interchanged, and a parallel method, in which the chamber position was fixed while cables were systematically interchanged. TRS-483 field output correction factors were applied, and all readings were normalized to the 10 × 10 cm² reference field. Positional uncertainties due to detector reconnection were included in the analysis. **Results:** Both acquisition strategies produced nearly identical mean responses for the two cables across all chambers. Standard deviations ranged from 0.0397 to 0.0439, with relative differences below 1%. Statistical analysis revealed no significant differences between cables ($p > 0.8147$), and positional uncertainties were minimal (≤ 0.0025). **Conclusion:** Identical triaxial cables do not significantly influence msr field absolute dosimetry. However, periodic quality assurance of signal cables is recommended to ensure long-term dosimetric reliability.

KEYWORDS

Triaxial cable, Small-field dosimetry, Cable-induced current.

INTRODUCTION

Modern radiotherapy demands highly accurate dose delivery [1]. Conventional linear accelerators rely on a 10 × 10 cm² reference field, but modern treatment techniques and advanced collimation require updated approaches. TRS-483 provides guidelines for non-standard fields and defines small-field conditions for accurate measurements.[2]

A small photon field, according to TRS-483, is defined by physical effects rather than field size alone. It occurs when lateral charged particle equilibrium is lost, the primary photon source is partially blocked, or the detector volume is comparable to the field. The first two criteria are beam-related properties which are responsible for the steep reduction in output with decreasing field size. The third criteria is detector related which are influenced by volume-averaging effects, perturbations, angular dependencies etc. All these conditions cause penumbral regions to overlap the detector, increasing uncertainty[3].Detector-specific corrections are also required.

Small-volume ionization chambers have low sensitivity, making them more prone to leakage current errors, which can lead to absorbed dose inaccuracies of up to 16%, depending on the technique used[2]. Even these errors can be corrected, the detector's signal cable remains a critical factor [4]. Its inherent properties may affect the collected charge, further complicating small-field dosimetry and impacting measurement accuracy.

The combination of chamber-electrometer leakage, often assumed constant, which is measured and subtracted as background signals which can significantly affect readings, particularly in microchambers. Additionally, the Compton current, which increases with cable length [5].

The leakage from cable has a greater impact on these small volume chambers due to their lower signal-to-noise ratio compared to larger chambers like the Farmer type [2].

The extracameral current, which originates from outside the sensitive volume of the ionization chamber, can contribute to polarity effects. When the connecting cable between the chamber and electrometer is exposed to radiation, it may induce both extracameral and Compton currents [6]. Although the influence of this effect is minimal under small-field conditions due to the limited field size, the same signal cable is often employed in other dosimetric measurements. Prior radiation exposure may have modified its characteristics, making it an essential factor to evaluate to ensure accurate dose assessment. Although these effects cannot be entirely eliminated, their impact can be reduced.

Guarded probing is essential for accurate low-current measurements because it prevents leakage currents that typically occur when using standard coaxial probes [7]. By using triaxial cables with a driven guard at the same potential as the force conductor, leakage through insulation is reduced greatly from nanoampere to femtoampere while the outer shield provides electromagnetic isolation [8].

All data collection cables exhibit leakage current, which varies based on their quality, maintenance, and handling. Twisted or damaged cables can generate significant noise, with typical leakage levels between 10^{-13} to 10^{-14} A [9].

Poorly maintained cables tend to have higher leakage, which can interfere with measurements, especially in small fields or beyond the field edge. Factors such as cable quality, length exposed to radiation, and connectors influence leakage noise [9].

Unlike large-field dosimetry, which is commonly affected by Compton current, leakage, and polarity effects, small-field dosimetry introduces a different set of challenges. Microdetectors used in small fields generate extremely low signals, often in the femtocoulomb range, which makes them more susceptible to interference from electrical noise particularly from irradiated or poorly shielded cables[8]. Although some detector-related perturbations can be corrected, the low signal strength combined with high background noise leads to a poor signal-to-noise ratio (SNR) [10],2. As the sensitive volume of the detector decreases, this problem becomes more significant, making accurate and stable dose measurements more difficult [8].

Long-term use and radiation exposure may alter the performance of triaxial cables, influencing precision in dose measurements. Given the increasing clinical reliance on small-field dosimetry, it is important to quantify the influence of triaxial cable dependency on absolute dose measurements This study evaluates the influence of cable dependence on small-field absolute dosimetry and compares two identical cables, prolonged used and newly procured one.

AIM:

The aim of this study is to assess the impact of triaxial cable's dependency on machine specific reference (msr) field absolute dosimetry.

MATERIALS AND METHODS:

Dosimetric Equipment:

Two identical 20 m triaxial signal cables manufactured by Rosalina Instruments were investigated to evaluate the influence of cable performance on ionization-chamber-based absolute dosimetry. The cables were designated as Cable 1 (Prolonged dosimetric use) and Cable 2 (Newly procured). Each cable was evaluated in combination with three ionization chambers: two IBA CC13 chambers, used as field and reference detectors, and one IBA CC01 chamber. This resulted in six distinct detector-cable configurations. All detectors employed in this study are recommended for small-field dosimetry in accordance with the IAEA TRS-483 Code of Practice.

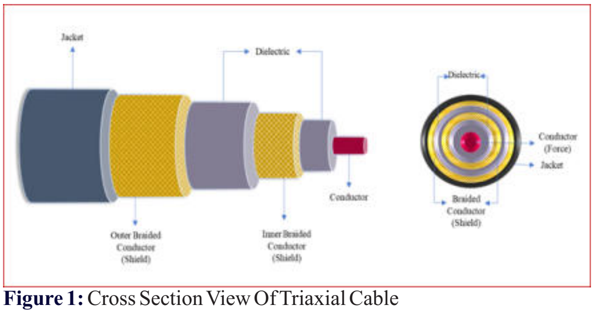

Figure 1: Cross Section View Of Triaxial Cable

Triaxial cables consist of a central force conductor, an inner guard conductor, and an outer shield, with dielectric layers separating each conductor [11]. The guard is held at the same potential as the force conductor, effectively eliminating leakage current[7]. This multilayer structure provides superior shielding and lower noise compared with coaxial cables [12].

Measurement Setup:

Absolute dosimetry measurements were performed using an IBA Blue Phantom² water phantom on a Varian TrueBeam linear accelerator operating with a nominal 6 MV photon beam. Measurements were acquired for square field sizes of 2×2 cm^2, 3×3 cm^2, 4×4 cm^2, 5×5 cm^2, 6×6 cm^2, 7×7 cm^2, 8×8 cm^2, 9×9 cm^2, and the reference 10×10 cm^2 field. All irradiations were carried out at a source-to-surface distance (SSD) of 100 cm, with the detector positioned at a depth of 10 cm in water. For each field size, 100 monitor units (MU) were delivered at a constant dose rate of 600 MU/min. Detector signals were collected using a Scanditronix Wellhofer Reference Dose-1 electrometer for both signal cables under investigation.

Measurement Strategies

To evaluate cable-dependent effects while minimizing positional and setup-related uncertainties, two complementary acquisition strategies were employed.

Cable Isolation Method:

In the Cable-Isolation Method, measurements were conducted on separate days. During each measurement session, a single signal cable was fixed in position and kept unchanged, while the ionization chambers were sequentially connected for data acquisition. This approach ensured a consistent cable configuration throughout the session, enabling isolation of cable-specific contributions to the measured signal. For each detector-cable combination, five independent trials were acquired. Between successive trials, the chamber was intentionally disconnected and reconnected prior to irradiation to assess the influence of handling, connector engagement, and residual positional uncertainty.

Parallel Method:

An alternative Parallel Method was implemented on the same day to allow direct comparison of cable responses under identical environmental and accelerator operating conditions. For each detector, the chamber position was established once and maintained throughout the entire measurement sequence to minimize uncertainties associated with repositioning. Both signal cables were routed internally and securely fixed within the phantom system to ensure mechanical stability. The two cables were then systematically interchanged while preserving the chamber position. Prior to each acquisition, the electrometer was nullified to eliminate residual charge, and measurements were recorded sequentially for all selected field sizes.

The combined use of these two acquisition strategies provided a robust framework for distinguishing cable-related effects from detector-specific and setup-induced variations.

Table 1: The Characteristics Of Detectors Used In This Study Are Listed:[13,14]

Parameters	Detector	
	CC13	**CC01**
Manufacturer	IBA	IBA
Geometric Form of sensitive volume	Cylinder	Cylinder
Cavity radius	3.0 mm	1.0 mm
Active volume	0.13cm^3	0.01cm^3
Total active length	5.8 mm	3.6mm
Typical leakage current	3 fA	3 fA
Typical sensitivity	3.6nC/Gy	0.4nC/Gy
Shielding	No	No

Data Analysis

Following data acquisition, field output correction factors were applied in accordance with the TRS-483 formalism using equivalent square field sizes. The corrected readings were subsequently normalized to the 10×10 cm^2 reference field. For each field size, the variation between corrected measurements obtained with the two cables was evaluated, thereby providing a quantitative assessment of the magnitude of cable-dependent variation in absolute dosimetric response across the investigated field sizes.

Table 2: Field Output Correction Factor (FOF) For Fields For 6MV, As A Function Of The Equivalent Square Field Size.[3]

Equivalent square field size (cm^2)	CC13	CCO1
10.0	1.000	1.000
9.0	1.000	1.001
8.0	1.000	1.002
7.0	1.000	1.003
6.0	1.000	1.004
5.0	1.000	1.0055
4.0	1.000	1.007
3.0	1.001	1.008
2.0	1.009	1.009

RESULT:

In the cable-isolation method measurements performed on cross days, the mean responses obtained with the two cables 1 and 2 for the CC13 Field (1.0576 and 1.0561), CC13 Reference (1.0552 and 1.0530), and CC01 chambers (1.0692 and 1.0643), accompanied by low standard deviations of 0.0397 to 0.041. In the parallel method measurements performed on same day, mean readings for Cable 1 and Cable 2 were nearly identical for the CC13 Field chamber (1.0580 and 1.0581), the CC13 Reference chamber (1.0553 and 1.0560), and the CC01 chamber (1.0663 and 1.0690), with comparable standard deviations ranging from 0.0416 to 0.0439. In both methods, the relative differences between the cables remained below 1%, and statistical analysis showed no significant differences, with p-values greater than 0.8147 for all detectors. Positional uncertainties were minimal throughout, with values ≤ 0.0025 across all chambers.

Parallel Method:

Table 3: Comparison Of Detector Responses Obtained Using Two Triaxial Cables Under The Parallel Measurement Method For Different Field Sizes

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Field Size	CC13 Field Chamber		CC13 Reference Chamber		CC01 Chamber	
	Cable 1 (cGy/MU)	Cable 2 (cGy/MU)	Cable 1 (cGy/MU)	Cable 2 (cGy/MU)	Cable 1 (cGy/MU)	Cable 2 (cGy/MU)
10x10 cm^2	1.0023	1.0025	1.0004	1.0009	1.0084	1.0091
9x9 cm^2	1.0169	1.0169	1.0141	1.0147	1.0224	1.0261
8x8 cm^2	1.0275	1.0281	1.0258	1.0262	1.0338	1.0369
7x7 cm^2	1.04	1.0401	1.0372	1.0383	1.0481	1.0456
6x6 cm^2	1.0516	1.0513	1.0487	1.0491	1.0598	1.0641
5x5 cm^2	1.063	1.0636	1.0602	1.0611	1.0745	1.0784
4x4 cm^2	1.0841	1.0845	1.0819	1.0827	1.0995	1.1044
3x3 cm^2	1.1096	1.1093	1.1057	1.1071	1.1234	1.1225
2x2 cm^2	1.127	1.1264	1.1234	1.1238	1.1267	1.1338
Std Deviation	**0.0422**	**0.0419**	**0.0416**	**0.0417**	**0.0430**	**0.0439**
Mean	**1.058**	**1.0581**	**1.0553**	**1.0560**	**1.0663**	**1.0690**
p-Value	**0.99768**		**0.97061**		**0.89725**	
Positional Uncertainty	**0.0002**	**0.0004**	**0.0003**	**0.0003**	**0.0025**	**0.0017**

Cable Isolation Method:

Table 4: Comparison Of Detector Responses Obtained Using Two Triaxial Cables Under The Cable Isolation Method For Different Field Sizes

Field Size	CC13 Field Chamber		CC13 Reference Chamber		CC01 Chamber	
	Cable 1 (cGy/MU)	Cable 2 (cGy/MU)	Cable 1 (cGy/MU)	Cable 2 (cGy/MU)	Cable 1 (cGy/MU)	Cable 2 (cGy/MU)
10x10 cm^2	1.0021	1.0017	1.0004	0.9957	1.0092	1.0052
9x9 cm^2	1.0165	1.0153	1.0138	1.0091	1.0265	1.0194
8x8 cm^2	1.0270	1.0241	1.0258	1.0423	1.0369	1.0342
7x7 cm^2	1.0399	1.0385	1.0371	1.0330	1.0459	1.0450
6x6 cm^2	1.0508	1.0498	1.0482	1.0437	1.0646	1.0577
5x5 cm^2	1.0627	1.0618	1.0601	1.0559	1.0784	1.0725
4x4 cm^2	1.0839	1.0828	1.0818	1.0772	1.1047	1.0977
3x3 cm^2	1.1093	1.1065	1.1056	1.1015	1.1223	1.1197
2x2 cm^2	1.1264	1.1245	1.1238	1.1191	1.1341	1.1271
Std Deviation	**0.0397**	**0.0394**	**0.0394**	**0.0382**	**0.0414**	**0.0409**
Mean	**1.0576**	**1.0561**	**1.0552**	**1.0530**	**1.0692**	**1.0643**
p-Value	**0.94077**		**0.91411**		**0.81473**	
Positional Uncertainty	**0.0002**	**0.0012**	**0.0003**	**0.0011**	**0.0025**	**0.0018**

DISCUSSION

Triaxial cables play a critical role in ionization chamber dosimetry due to their low-noise characteristics, enhanced shielding, and suitability for operation in high-radiation environments. Their design, comprising a central signal conductor, an actively driven or grounded inner shield, and an outer grounded shield, minimizes leakage currents, reduces cable capacitance, and improves electromagnetic isolation. These features are particularly important for small-field dosimetry, where detector signals are inherently low and more susceptible to electrical noise and radiation-induced extracameral effects.

Gotoh et al. investigated gamma-ray–induced currents in triaxial cables to evaluate their influence on low-noise dosimetry systems under high-radiation conditions. Their study demonstrated that cable irradiation produces time-dependent induced currents that may reverse polarity depending on the cable configuration. In particular, grounding the inner shield significantly increased the magnitude of induced charge, from 0.14–0.21 pC·Gy^{-1}·cm^{-1} when floating to 0.33–0.49 pC·Gy^{-1}·cm^{-1} when grounded. These findings highlight the strong dependence of radiation-induced currents on cable shielding configuration and emphasize the importance of appropriate cable management to ensure dosimetric accuracy [15]. In contrast, the negligible inter-cable variation observed in the present study indicates that, under the specific experimental conditions investigated, radiation-induced currents remain well below the noise threshold of the ionization chamber–electrometer system. Together, these results confirm that, when properly configured, triaxial dosimetry cables can effectively suppress clinically relevant induced currents.

In the context of small-field dosimetry, cable length and routing should be appropriate for the measurement setup, although commercially available triaxial cables generally maintain favourable signal-to-noise performance even at extended lengths. Caldas et al. examined radiation effects on ionization chamber extension cables and demonstrated that irradiated cables can introduce measurable errors in dosimetric readings. Using Cs-137, Co-60, and diagnostic-energy x-ray beams (49–142 keV), they observed energy-dependent ionization peaks at 98 keV for one cable type and 121 keV for another, along with a linear increase in induced current with cable length. Despite these effects, their measurements were reproducible within 0.70% [16]. This study underscores that cable-induced signals are dependent on cable construction, geometry, and irradiation conditions, reinforcing the need to account for such effects in precision dosimetry. In the present work, however, measurements performed with two identical triaxial cables showed minimal variability and negligible positional uncertainty, indicating that, under typical small-field megavoltage photon beam conditions and with appropriate cable selection and setup, cable-induced signals are not dosimetrically significant.

Further evidence of cable-related extracameral effects has been reported by Tanny et al., who demonstrated that Compton-induced currents originating predominantly from detector cables can distort microchamber readings. In their study, cable-only irradiation produced induced charges of −0.037 nC/cm for the A16 microchamber cable and −0.012 nC/cm for the PTW 31014, a threefold difference attributed to cable design. These results highlight the necessity of accounting for cable-related contributions when interpreting measurements obtained with small-volume detectors, particularly in electron beam dosimetry [17]. Extending these findings, the present study demonstrates that under small-field photon beam conditions, properly configured triaxial cables substantially reduce induced currents, resulting in stable, consistent, and reproducible detector responses.

For field output correction factor (FOF) measurements, leakage currents are generally expected to cancel when comparing reference and small fields acquired at the same dose rate. Nevertheless, factors such as insulation quality, cable resistance, connector integrity, and long-term cable condition may still influence signal stability. Consequently, the use of high-quality triaxial cables, combined with periodic inspection and quality assurance, remains essential to ensure reliable dosimetric performance.

Yamauchi et al. demonstrated that cable effects in megavoltage photon beams are dominated by Compton-induced currents, with leakage currents being negligible. Although the induced charge per unit cable length was measurable, its contribution to the total signal was small and became relevant mainly for micro-volume detectors. In the present study, the agreement observed between two identical triaxial cables indicates that such cable-induced contributions remain stable and do not introduce additional variability under the investigated small-field photon conditions. This supports the conclusion that, when identical triaxial cables are properly configured, cable effects remain predictable and do not compromise measurement consistency6.

Butler and Healy showed that cables can contribute to the polarity effect in ionization chamber dosimetry through small induced currents. In the present study, two triaxial cables exhibited consistent responses, indicating that such cable-induced effects are predictable and do not introduce significant variability, confirming the reliable, low-noise performance of high-quality triaxial cables [5].

Sohn et al. reported that triaxial cable quality can influence small-field dosimetry, with detector-specific FOF variations reaching up to 13.4% for the smallest fields. However, direct comparisons between cables and detectors revealed only minor differences, limited to approximately 0.2%, and no consistent dependence on cable diameter. Although non-normalized FOF differences were small (0.9% and 0.3%), their results suggested that cable characteristics may subtly affect dosimetric measurements [8]. The present study directly supports and validates these observations, demonstrating that two identical triaxial cables with different usage histories yield consistent small-field dosimetry results, with relative differences remaining below 1% across all investigated field sizes.

CONCLUSION:

Dosimetric responses from both cables showed excellent agreement for all detectors and field sizes, with relative differences below 1% and no statistically significant variation. Positional uncertainties were minimal, confirming high measurement reproducibility. Although no significant differences were observed, these findings reinforce the importance of incorporating triaxial cable quality checks as a routine part of small-field dosimetry, since cable degradation over time could introduce subtle measurement errors. This study was limited to a single-user dataset, which may introduce bias due to the relatively low frequency of measurements. Nonetheless, it provides a novel perspective on periodic cable verification as a proactive measure to ensure dosimetric accuracy and treatment quality, opening a new avenue for future investigations in high-precision radiotherapy dosimetry.

REFERENCE:

1. Dawson, P., *et al.* (2010). *Journal of the ICRU*. International Commission on Radiation Units and Measurements. https://jicru.oxfordjournals.org/
2. Das, I. J., Francescon, P., Moran, J. M., & Ahnesjö, A. (2021). Report of AAPM Task Group 155: Megavoltage photon beam dosimetry in small fields and non-equilibrium conditions. *Medical Physics, 48*(10), e886–e921. https://doi.org/10.1002/mp.15030
3. Palmans, H., Andreo, P., Huq, M. S., Seuntjens, J., & Christaki, K. (2018). Dosimetry of small static fields used in external photon beam radiotherapy: Summary of TRS-483, the IAEA–AAPM international code of practice for reference and relative dose determination. *Medical Physics, 45*(11), e1123–e1145. https://doi.org/10.1002/mp.13232
4. Butler, D. J., & Healy, B. J. (2025). The contribution of the cable to the polarity effect in ionization chamber dosimetry. *Journal of Applied Clinical Medical Physics, 26*, e70327. https://doi.org/10.1002/acm2.70327
5. Yamauchi, R., Nakano, T., Gotoh, J., Ishikawa, K., & Yoda, K. (2020). Estimation of the cable effect in megavoltage photon beams by measurement and Monte Carlo simulation. *Medical Physics, 47*(11), 5324–5332. https://doi.org/10.1002/mp.14464
6. Gibbons, J. P., & Khan, F. M. (2019). *Khan's the physics of radiation therapy* (6th ed.). Wolters Kluwer.
7. Bel Fuse Inc. (n.d.). *Using triaxial cables for low-current measurements*. https://www.belfuse.com/resources/technical-articles/using-triaxial-cables-for-low-current-measurements
8. Sohn, J. J., & Das, I. J. (2024). Investigation of triaxial cables and microdetectors in small-field dosimetry. *Biomedical Physics & Engineering Express, 10*. https://doi.org/10.1088/2057-1976/ad3xxx`
9. Das, I. J., Cheng, C. W., Watts, R. J., Ahnesjö, A., Gibbons, J., Li, X. A., Lowenstein, J., Mitra, R. K., Simon, W. E., & Zhu, T. C. (2008). Accelerator beam data commissioning equipment and procedures: Report of the TG-106 of the Therapy Physics Committee of the AAPM. *Medical Physics, 35*(9), 4186–4215. https://doi.org/10.1118/1.2969070
10. Parwaie, W., Refahi, S., Ardekani, M. A., & Farhood, B. (2018). Different dosimeters/detectors used in small-field dosimetry: Pros and cons. *Journal of Medical Signals and Sensors, 8*(3), 195–203.
11. PIC Wire & Cable. (n.d.). *Comparison of coaxial and triaxial cables for low-current and low-noise applications*. https://picwire.com/Files/Technical-Articles/Coax-vs-Triax-Cable_PIC_Technical-Article.pdf
12. PTW Freiburg GmbH. (2000). *Extension cables for ionization chambers: Design and electrical characteristics*. PTW Freiburg GmbH.
13. IBA Dosimetry GmbH. (n.d.). *CC13 ionization chamber: Product specifications*. IBA Dosimetry GmbH.
14. IBA Dosimetry GmbH. (n.d.). *Product catalog: Specifications for CC01, CC04 ion chambers and Razor diode*. IBA Dosimetry GmbH.
15. Gotoh, J., Nakano, T., Ishikawa, K., *et al.* (Year). Evaluation of gamma-ray–induced current in triaxial cables. In *Proceedings of the International Conference on Radiation Effects on Components and Systems (RADECS)* (Paper CO4-1).
16. Caldas, L. V. E., Regulla, D. F., & Pychlau, P. (1989). Ionization chamber extension cables: Radiation effects. *Radiation Protection Dosimetry, 27*(1), 49–55. https://doi.org/10.1093/oxfordjournals.rpd.a080378
17. Tanny, S., Holmes, S., Sperling, N., & Parsai, E. I. (2015). Technical note: Influence of Compton currents on profile measurements in small-volume ion chambers. *Medical Physics, 42*(10), 5768–5772. https://doi.org/10.1118/1.4929555.