Section: Radiation Oncology

Original Research Article

DOSIMETRIC EVALUATION OF HIGH DOSE RATE BRACHYTHERAPY TREATMENT PLANS WITH VARIOUS APPLICATORS USING IR-192 & CO-60 SOURCES FOR CARCINOMA CERVIX

Shashikala N[1], Savitha A K[2], Basavaraj H[3], Nanda Kumar M[4]

[1]*Medical Physicist, Department of Radiation Oncology, Kidwai Memorial Institute of Oncology, Bangalore, Karnataka, India.*
[2]*Assistant Professor, Department of General Medicine, Shivamogga Institute of Medical Sciences, Shivamogga, Karnataka, India.*
[3]*Assistant Professor, Department of Radiation Oncology, Karnataka Medical College and Research Institute, Hubballi, Karnataka, India.*
[4]*Medical physicist & Radiation Safety Officer, Department of Radiation Oncology, Apollo BGS Hospital, Mysore, Karnataka, India.*

Received *: 31/07/2026*
Received in revised form *: 26/08/2026*
Accepted *: 08/09/2026*

Corresponding Author:
Dr. Nanda Kumar M,
Medical physicist & Radiation Safety Officer, Department of Radiation Oncology, Apollo BGS Hospital, Mysore, Karnataka, India.
Email: nandakumar16.NK@gmail.com

DOI: 10.70034/ijmedph.2026.3.743

Source of Support: Nil,
Conflict of Interest: None declared

Int J Med Pub Health
2026; 16 (3); 4815-4820

ABSTRACT

Background: Cobalt-60 (Co-60) offers logistical advantages over iridium-192 (Ir-192), but source modeling, treatment-planning implementation, and applicator geometry may influence target and organ-at-risk (OAR) dosimetry. The objective is to compare CT-based high-dose-rate intracavitary brachytherapy plans generated with Co-60/SagiPlan and paired Ir-192/BrachyVision replans using Fletcher or Henschke applicators.

Materials and Methods: Fifty patients were analyzed retrospectively (25 treated with Fletcher and 25 with Henschke applicators). Original Co-60 plans were generated in SagiPlan 2.0; paired Ir-192 replans were generated in BrachyVision 15.6 using the same CT dataset, corresponding dwell positions, and a 6 Gy point-A prescription. HR-CTV and OAR dose-volume endpoints were compared using paired two-sided t-tests.

Results: HR-CTV D90 and D50, bladder endpoints, and rectal endpoints showed no nominally significant paired differences (all p>=0.08). Co-60/SagiPlan produced higher sigmoid D2cc than Ir-192/BrachyVision with Fletcher (5.0+/-0.2 vs 4.6+/-0.1 Gy; mean difference, +0.4 Gy; p=0.002) and Henschke applicators (5.1+/-0.2 vs 4.8+/-0.1 Gy; mean difference, +0.3 Gy; p=0.006). Other sigmoid endpoints were not significant.

Conclusion: The evaluated planning configurations produced broadly similar target coverage and bladder and rectal doses, with higher sigmoid D2cc in Co-60/SagiPlan plans. Because radionuclide and TPS changed together, the study evaluates two complete planning configurations rather than an isolated isotope effect. A controlled comparison in a common TPS is warranted.

Keywords: brachytherapy; cervical cancer; cobalt-60; iridium-192; Fletcher applicator; Henschke applicator; treatment planning; dosimetry

INTRODUCTION

Cervical cancer radiotherapy requires a deliberate balance between adequate tumor dose and protection of the bladder, rectum, sigmoid, and other pelvic tissues. Intracavitary brachytherapy is central to curative treatment because it places the radioactive source close to the cervix and creates a steep dose gradient. This geometry permits dose escalation to the central disease while limiting exposure beyond the applicator region. Contemporary treatment recommendations therefore consider brachytherapy an essential component of definitive radiotherapy for locally advanced cervical cancer rather than an interchangeable boost technique.[1]

Image-guided adaptive brachytherapy has shifted evaluation from a mainly point-based approach toward individualized three-dimensional assessment. The prospective EMBRACE-I cohort demonstrated the clinical value of magnetic-resonance-guided adaptive brachytherapy delivered within a structured target- and organ-at-risk framework. Its multicenter

results support the use of volumetric target coverage and dose-volume limits as meaningful components of cervical cancer treatment planning and outcome assessment.[2]

Point A remains useful for prescription, historical comparison, and confirmation of a standardized loading intention. Nevertheless, a single reference point cannot describe the complete three-dimensional relationship between applicator channels, tumor extent, and nearby normal tissues. The EMBRACE II framework integrates target dose, organ-at-risk dose, applicator selection, and external-beam treatment into a unified planning strategy, emphasizing the importance of evaluating each brachytherapy plan as part of the complete treatment course.[3]

Computed-tomography-based planning enables applicator reconstruction, delineation of the high-risk clinical target volume (HR-CTV), contouring of organs at risk, and production of dose-volume histograms. HR-CTV D90 and D50 summarize target coverage, whereas D0.1cc, D1cc, and D2cc describe the doses received by the most exposed small volumes of an organ. The development of image-guided adaptive brachytherapy has depended on multidisciplinary agreement about these concepts and on reproducible planning workflows across institutions.[4]

Clinical series using image-guided brachytherapy have reported favorable disease control when target coverage is optimized while respecting organ-at-risk limits. Such evidence also shows why a numerical planning difference should be interpreted in context: its importance depends on the absolute magnitude, the delivered fractionation, the external-beam contribution, the cumulative biologically equivalent dose, and its relationship to clinically used constraints. Dosimetric differences alone do not automatically establish a difference in toxicity or tumor control.[5]

Iridium-192 (Ir-192) is widely used for HDR remote afterloading, while cobalt-60 (Co-60) provides a longer-lived alternative source. The two radionuclides differ in photon energy, source construction, anisotropy, and attenuation behavior. These physical distinctions can influence the surrounding dose distribution, particularly when tissue inhomogeneity and finite patient dimensions are considered. The longer replacement interval of Co-60 may also offer logistical advantages for centers in which recurrent source procurement and source exchanges are difficult.[6]

Applicator geometry, dwell-position arrangement, patient anatomy, packing, reconstruction, normalization, and optimization may all modify the relationship between source channels, HR-CTV, and organs at risk. Fletcher and Henschke applicators should therefore be evaluated within their respective clinical configurations. The present study compared original Co-60/SagiPlan plans with paired Ir-192/BrachyVision replans in 50 CT-based cases, comprising 25 Fletcher and 25 Henschke patients. Its objective was to compare HR-CTV coverage, point-A dose, and bladder, rectal, and sigmoid dose-volume endpoints while determining whether the direction of any difference was repeated across both applicator cohorts.[7]

MATERIALS AND METHODS

Study design, setting, and unit of analysis: This retrospective paired plan-comparison study included 50 patients treated with CT-based intracavitary brachytherapy for carcinoma of the cervix: 25 with a Fletcher applicator and 25 with a Henschke applicator. The unit of analysis was the within-patient plan pair. For every patient, the original Co-60/SagiPlan plan was matched to one Ir-192/BrachyVision replan generated from the same CT dataset. This paired structure was selected to limit anatomical variation within each source/TPS comparison, consistent with the logic of comparative brachytherapy planning studies.[8]

Contouring and treatment planning: Radiation oncologists reconstructed the intracavitary applicator and contoured the HR-CTV, bladder, rectum, and sigmoid on the planning CT images. These structures were used for three-dimensional dose-volume evaluation. CT-based contouring provides a practical image-guided pathway when magnetic resonance imaging is not used for each application, and published consensus recommendations support standardized identification of cervical target and organ-at-risk boundaries on CT.[9]

The original plan was generated in SagiPlan version 2.0 with a SagiNova Co-60 HDR source. A paired plan was generated in BrachyVision version 15.6 with a GammaMed Plus Ir-192 HDR source using the same CT dataset, corresponding dwell positions, and the same prescription of 6 Gy to point A. The methodology reports geometric optimization to obtain the intended pear-shaped distribution. Because the radionuclide and TPS were changed together, all analyses compare complete planning configurations. Commissioning guidance emphasizes that source modeling and dose-calculation implementation are integral to the performance of a brachytherapy planning system.[10]

Dosimetric endpoints: Target endpoints were HR-CTV D90 and D50, defined as the minimum dose received by 90% and 50% of the HR-CTV, respectively. Organ-at-risk endpoints were D0.1cc, D1cc, and D2cc for the bladder, rectum, and sigmoid. Point-A dose was retained as the common prescription reference. Dose-volume assessment complements point-A reporting by describing target coverage and the spatial extent of dose delivered to nearby organs.[11] All dose values are presented in Gy as mean +/- standard deviation (SD).

Statistical analysis: The available statistical results were reported as aggregate means, SDs, paired two-sided t-test p values, and a significance threshold of $p<0.05$. Within each applicator cohort, the paired test compared Ir-192/BrachyVision with Co-60/SagiPlan.

Absolute mean differences were calculated from the displayed means as Co-60/SagiPlan minus Ir-192/BrachyVision and are labeled approximate because they use rounded values. The paired t-test is designed for two measurements obtained from the same observational unit, which matches the original-plan/replan structure used here.[12] Fletcher and Henschke cohorts were summarized separately.

Ethics: The study was conducted in accordance with the principles of the Declaration of Helsinki and applicable institutional ethical guidelines. Ethical approval was obtained from the Institutional Ethics Committee prior to commencement of the study. Written informed consent was obtained from all participants before their inclusion in the study. Participant confidentiality and privacy were maintained throughout the study, and all collected data were anonymized and used solely for research purposes.

Table 1: Study design and treatment-planning characteristics.

Characteristic	Study specification
Design	Retrospective CT-based paired replanning study
Study sample	50 patients with 50 original-plan/replan pairs (25 Fletcher; 25 Henschke)
Original plan	SagiPlan v2.0 with SagiNova Co-60 HDR source
Paired replan	BrachyVision v15.6 with GammaMed Plus Ir-192 HDR source
Prescription	6 Gy per fraction to point A
Controlled features	Same CT dataset, dwell positions, and point-A prescription within each pair
Configuration-level confounding	Radionuclide and TPS changed together
Contoured structures	HR-CTV, bladder, rectum, and sigmoid
Target endpoints	HR-CTV D90 and D50; point A
OAR endpoints	D0.1cc, D1cc, and D2cc for bladder, rectum, and sigmoid
Statistical approach	Aggregate means and SDs; paired two-sided t-test; $p<0.05$ threshold

RESULTS

Target coverage and reference dose: All 50 original Co-60/SagiPlan plans had a corresponding Ir-192/BrachyVision replan generated from the same CT dataset. The reported average point-A dose was 6.0 Gy in both configurations for both applicator cohorts, reflecting the study design rather than an independently observed equality. Consequently, point-A dose could not discriminate between the planning configurations, and interpretation focused on the volumetric target and OAR endpoints.

In the Fletcher cohort, mean HR-CTV D90 was 4.9+/-0.5 Gy with Ir-192/BrachyVision and 5.1+/-0.4 Gy with Co-60/SagiPlan. The approximate difference calculated from the rounded means was +0.2 Gy in favor of Co-60/SagiPlan, but the paired comparison did not reach the nominal significance threshold (p=0.10). Mean HR-CTV D50 was 8.4+/-0.9 Gy with Ir-192/BrachyVision and 8.7+/-0.8 Gy with Co-60/SagiPlan, corresponding to an approximate +0.3 Gy difference (p=0.20). Thus, both reported target indices were numerically higher with Co-60/SagiPlan, but neither provided evidence of a statistically significant paired difference.

The Henschke cohort showed the same numerical direction with smaller absolute differences. Mean HR-CTV D90 was 5.2+/-0.9 Gy with Ir-192/BrachyVision and 5.3+/-0.9 Gy with Co-60/SagiPlan, an approximate difference of +0.1 Gy (p=0.10). Mean D50 was 8.5+/-0.9 and 8.7+/-0.8 Gy, respectively, an approximate difference of +0.2 Gy (p=0.20). Neither target endpoint met the $p<0.05$ threshold. The agreement in direction across D90 and D50 indicates that the displayed means were consistently slightly higher for Co-60/SagiPlan, while the statistical results did not identify a paired target-dose difference in either applicator cohort.

Organs at risk: Bladder doses were numerically higher with Co-60/SagiPlan for every reported endpoint, but none reached nominal statistical significance. In the Fletcher cohort, bladder D0.1cc was 5.49+/-0.08 Gy with Ir-192/BrachyVision and 5.50+/-0.08 Gy with Co-60/SagiPlan (p=0.60). D1cc was 5.0+/-0.42 versus 5.1+/-0.43 Gy (p=0.40), and D2cc was 4.5+/-0.12 versus 4.7+/-0.16 Gy (p=0.08). In the Henschke cohort, the corresponding values were 5.5+/-0.6 versus 5.6+/-0.6 Gy for D0.1cc (p=0.60), 5.0+/-0.42 versus 5.1+/-0.43 Gy for D1cc (p=0.40), and 4.6+/-0.14 versus 4.7+/-0.16 Gy for D2cc (p=0.09). Therefore, the displayed bladder D2cc p values do not support the thesis conclusion that this endpoint differed significantly.

Rectal endpoints were also similar between configurations. With Fletcher applicators, rectal D0.1cc was 5.4+/-0.1 Gy with Ir-192/BrachyVision and 5.5+/-0.1 Gy with Co-60/SagiPlan (p=0.20); D1cc was 4.9+/-0.2 Gy in both configurations (p=1.00); and D2cc was 4.67+/-0.2 versus 4.66+/-0.2 Gy (p=0.90). With Henschke applicators, D0.1cc was 5.4+/-0.1 versus 5.5+/-0.1 Gy (p=0.20), D1cc was 5.0+/-0.2 versus 5.1+/-0.2 Gy (reported p=1.00), and D2cc was 4.67+/-0.2 versus 4.66+/-0.2 Gy (p=0.90). Across the six rectal comparisons, absolute differences calculated from the rounded means ranged from -0.01 to +0.1 Gy.

For the sigmoid, D0.1cc and D1cc were not significantly different. In both applicator cohorts, D0.1cc was 4.4+/-0.1 Gy with Ir-192/BrachyVision and 4.5+/-0.1 Gy with Co-60/SagiPlan (p=0.40), while D1cc was 4.5+/-0.1 and 4.6+/-0.1 Gy, respectively (p=0.30). In contrast, sigmoid D2cc was higher with Co-60/SagiPlan in both cohorts. For Fletcher applicators, mean D2cc was 5.0+/-0.2 Gy compared with 4.6+/-0.1 Gy for Ir-192/BrachyVision, an approximate absolute

difference of +0.4 Gy (p=0.002). For Henschke applicators, the values were 5.1+/-0.2 and 4.8+/-0.1 Gy, respectively, an approximate difference of +0.3 Gy (p=0.006). These were the only two comparisons with p<0.05 among the reported target and OAR endpoints.

Table 2: Paired OAR dose comparisons by applicator and source/TPS combination.

Applicator	OAR	End point	Ir-192 / BrachyVision, Gy	Co-60 / SagiPlan, Gy	Approx. difference, Gy	p value
Fletcher	Bladder	D0.1cc	5.49 +/- 0.08	5.50 +/- 0.08	+0.01	0.60
Fletcher	Bladder	D1cc	5.0 +/- 0.42	5.1 +/- 0.43	+0.1	0.40
Fletcher	Bladder	D2cc	4.5 +/- 0.12	4.7 +/- 0.16	+0.2	0.08
Fletcher	Rectum	D0.1cc	5.4 +/- 0.1	5.5 +/- 0.1	+0.1	0.20
Fletcher	Rectum	D1cc	4.9 +/- 0.2	4.9 +/- 0.2	0.0	1.00
Fletcher	Rectum	D2cc	4.67 +/- 0.2	4.66 +/- 0.2	-0.01	0.90
Fletcher	Sigmoid	D0.1cc	4.4 +/- 0.1	4.5 +/- 0.1	+0.1	0.40
Fletcher	Sigmoid	D1cc	4.5 +/- 0.1	4.6 +/- 0.1	+0.1	0.30
Fletcher	Sigmoid	D2cc	4.6 +/- 0.1	5.0 +/- 0.2	+0.4	0.002
Henschke	Bladder	D0.1cc	5.5 +/- 0.6	5.6 +/- 0.6	+0.1	0.60
Henschke	Bladder	D1cc	5.0 +/- 0.42	5.1 +/- 0.43	+0.1	0.40
Henschke	Bladder	D2cc	4.6 +/- 0.14	4.7 +/- 0.16	+0.1	0.09
Henschke	Rectum	D0.1cc	5.4 +/- 0.1	5.5 +/- 0.1	+0.1	0.20
Henschke	Rectum	D1cc	5.0 +/- 0.2	5.1 +/- 0.2	+0.1	1.00*
Henschke	Rectum	D2cc	4.67 +/- 0.2	4.66 +/- 0.2	-0.01	0.90
Henschke	Sigmoid	D0.1cc	4.4 +/- 0.1	4.5 +/- 0.1	+0.1	0.40
Henschke	Sigmoid	D1cc	4.5 +/- 0.1	4.6 +/- 0.1	+0.1	0.30
Henschke	Sigmoid	D2cc	4.8 +/- 0.1	5.1 +/- 0.2	+0.3	0.006

Values are mean +/- SD. Approximate difference = Co-60/SagiPlan minus Ir-192/BrachyVision, calculated from rounded displayed means. p values are from paired two-sided t-tests. Green shading identifies p<0.05. *The Henschke rectum D1cc p value is reproduced as reported.

Table 3: Target-dose and point-A results by applicator.

Applicator	Endpoint	Ir-192 / BrachyVision	Co-60 / SagiPlan	Approx. difference	p value
Fletcher	HR-CTV D90, Gy	4.9 +/- 0.5	5.1 +/- 0.4	+0.2 Gy	0.10
Fletcher	HR-CTV D50, Gy	8.4 +/- 0.9	8.7 +/- 0.8	+0.3 Gy	0.20
Fletcher	Point A, Gy	6.0 +/- 0	6.0 +/- 0	0.0 Gy	Not applicable
Henschke	HR-CTV D90, Gy	5.2 +/- 0.9	5.3 +/- 0.9	+0.1 Gy	0.10
Henschke	HR-CTV D50, Gy	8.5 +/- 0.9	8.7 +/- 0.8	+0.2 Gy	0.20
Henschke	Point A, Gy	6.0 +/- 0	6.0 +/- 0	0.0 Gy	Not applicable

Approximate difference = Co-60/SagiPlan minus Ir-192/BrachyVision, calculated from rounded means. Point-A p values are not applicable because both configurations used the same prescribed point-A dose.

Overall pattern of findings: Overall, the two planning configurations showed similar results rather than generalized dosimetric divergence. Point A was fixed, target indices were numerically but not significantly higher with Co-60/SagiPlan, and bladder and rectal endpoints were not significant. Higher sigmoid D2cc was the only repeated nominally significant finding. Because no applicator comparison was performed, the data cannot establish superiority of Fletcher or Henschke.

Representative planning images: Representative CT-based plans from BrachyVision and SagiPlan illustrate applicator reconstruction, dwell-position display, organ-at-risk contours, and the intended pear-shaped intracavitary dose distribution in the two planning environments.

Figure 1: Representative BrachyVision CT-based plan showing applicator reconstruction and a pear-shaped isodose distribution.

Figure 2: Representative SagiPlan CT-based plan showing applicator reconstruction, dwell positions, OAR contours, and the prescription isodose.

DISCUSSION

This paired plan-comparison study found broadly similar HR-CTV, bladder, and rectal dosimetry between the Co-60/SagiPlan and Ir-192/BrachyVision configurations in both applicator cohorts. Point A was identical by design, while target differences calculated from the rounded means ranged from +0.1 to +0.3 Gy and did not meet the p<0.05 threshold. Sigmoid D2cc was the only endpoint that differed in both cohorts: Co-60/SagiPlan was approximately 0.4 Gy higher with Fletcher and 0.3 Gy higher with Henschke. A recent comparative analysis likewise found that modern Co-60 and Ir-192 HDR sources can produce broadly comparable cervical brachytherapy plans while retaining endpoint-specific dosimetric differences.[13]

The repeated sigmoid D2cc direction is more informative than an isolated low p value because it appeared with both applicator types. D0.1cc and D1cc for the sigmoid differed by only +0.1 Gy and were not statistically significant, whereas the larger D2cc volume showed the distinct separation. This pattern suggests a difference in the spatial extent of the higher-dose region around the sigmoid rather than a uniform increase across every reported sigmoid endpoint. Radiobiological and dosimetric comparisons of Co-60 and Ir-192 have also emphasized that similar plan quality can coexist with small variations in individual target or organ-at-risk indices.[14] The present observation should nevertheless be attributed to the complete planning configurations tested here.

That configuration-level interpretation is essential. Co-60 and Ir-192 differ in photon energy, source geometry, radial dose function, anisotropy, attenuation, and scatter conditions. At the same time, SagiPlan and BrachyVision may differ in source implementation, reconstruction workflow, calculation behavior, normalization, and optimization. Investigations that include tissue inhomogeneity and finite patient dimensions show that source-related effects can vary with distance, material, and anatomy.[15] In this study, changing both radionuclide and TPS means the measured difference represents the combined Co-60/SagiPlan and Ir-192/BrachyVision workflows. It cannot be assigned exclusively to isotope physics, software behavior, or optimization.

The magnitude of the sigmoid D2cc difference should also be considered alongside its clinical meaning. The study reports a per-plan dosimetric comparison, not a comparison of toxicity, tumor control, or survival. A difference of 0.3-0.4 Gy per fraction may become more or less important depending on fractionation, the external-beam dose contribution, cumulative EQD2, organ motion, and the constraint used by a treating protocol. Clinical outcome comparisons of cervical HDR brachytherapy using Co-60 and Ir-192 have reported similar treatment outcomes, supporting caution against translating one dosimetric endpoint directly into a clinical advantage or disadvantage.[16] The present results therefore identify a planning signal rather than a demonstrated outcome effect.

The target findings reinforce that distinction. HR-CTV D90 and D50 were consistently slightly higher with Co-60/SagiPlan, but all four target p values were 0.10 or 0.20. The fixed 6 Gy point-A prescription ensured a common reference dose, yet identical point-A values did not force identical three-dimensional distributions. Studies comparing integral dose and dose-volume measures for Co-60 and Ir-192 similarly show that point normalization and volumetric assessment answer different questions.[17] For practical plan review, point A can confirm the prescription basis, while HR-CTV and organ-at-risk indices reveal how that prescription is distributed around the patient anatomy.

Bladder and rectal findings were stable across applicators. None of their reported endpoints met $p<0.05$; the closest values were bladder D2cc at $p=0.08$ for Fletcher and $p=0.09$ for Henschke. This directly corrects the thesis narrative that characterized bladder D2cc as statistically significant. Dose-volume evaluation remains sensitive to contour definition and image modality because small changes in organ boundaries or organ position can affect the sampled hottest volumes. A CT-versus-MRI contouring comparison found similar mean organ-at-risk doses overall but also documented patient-specific variation related to organ mobility and target definition.[18] Consistent contouring is therefore important when interpreting small differences near steep brachytherapy dose gradients.

The study design has several useful internal controls. Each original plan was linked to a replan on the same CT dataset, the corresponding dwell positions were retained, the point-A prescription remained 6 Gy, and the two applicator cohorts were analyzed separately. The available statistics provide aggregate means, SDs, paired two-sided t-test p values, and a defined $p<0.05$ threshold. At the same time, the radionuclide and TPS are inseparable components of the comparison, and the many related endpoints make the overall pattern more informative than any single result. Model-based dose-calculation research demonstrates that algorithm choice can alter calculated cervical brachytherapy doses, especially outside homogeneous water-like conditions.[19] Recalculation of both sources in one commissioned TPS would therefore provide the clearest technical follow-up.

The most defensible interpretation is that the two evaluated workflows were dosimetrically similar for HR-CTV coverage and for bladder and rectal exposure, while Co-60/SagiPlan produced higher sigmoid D2cc in both cohorts. Separate Fletcher and Henschke groups do not constitute a paired comparison of applicator designs, so no claim of applicator superiority is supported. Future work should use identical contours, applicator reconstruction, dwell positions, dose-calculation settings, normalization, and optimization rules for both radionuclides, then report paired effect estimates and cumulative treatment doses. Large image-guided adaptive brachytherapy series demonstrate that carefully controlled target and organ-at-risk dosimetry can be linked to favorable clinical outcomes.[20] Such a design would show whether the sigmoid D2cc pattern persists under a common technical platform and whether it is clinically consequential.

CONCLUSION

In this retrospective paired planning analysis of 50 patients, Co-60/SagiPlan and Ir-192/BrachyVision produced broadly similar HR-CTV coverage and

bladder and rectal doses in the 25 Fletcher and 25 Henschke cases. The common 6 Gy point-A prescription was reproduced in both configurations. None of the HR-CTV, bladder, or rectal endpoints met the $p<0.05$ threshold. In particular, bladder D2cc yielded $p=0.08$ with Fletcher and $p=0.09$ with Henschke, so the available results do not support a statistically significant bladder D2cc difference.

Sigmoid D2cc was the only endpoint meeting $p<0.05$ in both applicator cohorts. Co-60/SagiPlan was approximately 0.4 Gy higher with Fletcher applicators and 0.3 Gy higher with Henschke applicators. The repeated direction makes sigmoid D2cc the central finding of the comparison, while the aggregate pattern shows similarity for the other target and organ-at-risk indices. The clinical importance of this per-plan difference should be evaluated within the complete radiotherapy schedule, including fractionation, external-beam dose, cumulative EQD2, treatment constraints, and observed outcomes.

Overall, the study supports dosimetric comparability of the two evaluated planning configurations for most endpoints but does not isolate a radionuclide-only effect because the source and TPS changed together. A definitive technical comparison should model Co-60 and Ir-192 in a common commissioned TPS with identical CT data, contours, applicator geometry, dwell positions, dose-calculation settings, normalization, and optimization rules. Such a study would determine whether the repeated sigmoid D2cc difference is attributable to source physics, software implementation, or their interaction and whether its magnitude is clinically relevant. The present comparison therefore provides a focused, testable basis for subsequent commissioning and validation work while preserving the distinction between measured workflow performance and isolated source effects. It also defines a clear endpoint for future independent replication across institutions and planning platforms.

REFERENCES

1. Chargari C, Peignaux K, Escande A, Renard S, Lafond C, Petit A, Kee DL, Durdux C, Haie-Méder C. Radiotherapy of cervical cancer. Cancer/Radiothérapie. 2022 Feb 1;26(1-2):298-308.
2. Pötter R, Tanderup K, Schmid MP, Jürgenliemk-Schulz I, Haie-Meder C, Fokdal LU, Sturdza AE, Hoskin P, Mahantshetty U, Segedin B, Bruheim K. MRI-guided adaptive brachytherapy in locally advanced cervical cancer (EMBRACE-I): a multicentre prospective cohort study. The lancet oncology. 2021 Apr 1;22(4):538-47.
3. Pötter R, Tanderup K, Kirisits C, de Leeuw A, Kirchheiner K, Nout R, Tan LT, Haie-Meder C, Mahantshetty U, Segedin B, Hoskin P. The EMBRACE II study: The outcome and prospect of two decades of evolution within the GEC-ESTRO GYN working group and the EMBRACE studies. Clinical and translational radiation oncology. 2018 Feb 1;9:48-60.
4. Tan LT, Tanderup K, Hoskin P, Cooper R, Pötter R. Image-guided adaptive brachytherapy for cervix cancer—a story of successful collaboration within the GEC-ESTRO GYN network and the EMBRACE studies. Clinical Oncology. 2018 Jul 1;30(7):397-9.
5. Simha V, Rai B, Patel FD, Kapoor R, Sharma SC, Singh OA, Singla V, Dhanireddy B, Ghoshal S. Clinical outcomes with MRI-guided image-based brachytherapy in cervical cancer: an institutional experience. Brachytherapy. 2018 Mar 1;17(2):345-51.
6. Vrankar M, Stanic K, Jelercic S, Ciric E, Vodusek AL, But-Hadzic J. Clinical outcomes in stage III non-small cell lung cancer patients treated with durvalumab after sequential or concurrent platinum-based chemoradiotherapy–single institute experience. Radiology and oncology. 2021 Nov 19;55(4):482-90.
7. Suryadevara A, Kumar MV, Vasundhara E, Alluri KR, Ahamed S, Guduru S. A dosimetric comparison between applicators used for brachytherapy in carcinoma cervix–A single-institute prospective study. Indian Journal of Cancer. 2018 Jul 1;55(3):230-2.
8. Chakrabarti B, Basu-Roy S, Kar SK, Das S, Lahiri A. Comparison of dose volume parameters evaluated using three forward planning–optimization techniques in cervical cancer brachytherapy involving two applicators. Journal of Contemporary Brachytherapy. 2017 Oct 10;9(5):431-45.
9. Mahantshetty U, Poetter R, Beriwal S, Grover S, Lavanya G, Rai B, Petric P, Tanderup K, Carvalho H, Hegazy N, Mohamed S. IBS-GEC ESTRO-ABS recommendations for CT based contouring in image guided adaptive brachytherapy for cervical cancer. Radiotherapy and Oncology. 2021 Jul 1;160:273-84.
10. Beaulieu L, Ballester F, Granero D, Tedgren ÅC, Haworth A, Lowenstein JR, Ma Y, Mourtada F, Papagiannis P, Rivard MJ, Siebert FA. AAPM WGDCAB Report 372: a joint AAPM, ESTRO, ABG, and ABS report on commissioning of model-based dose calculation algorithms in brachytherapy. Medical physics. 2023 Aug;50(8):e946-60.
11. Serban M, Kirisits C, Pötter R, de Leeuw A, Nkiwane K, Dumas I, Nesvacil N, Swamidas J, Hudej R, Lowe G, Hellebust TP. Isodose surface volumes in cervix cancer brachytherapy: Change of practice from standard (Point A) to individualized image guided adaptive (EMBRACE I) brachytherapy. Radiotherapy and Oncology. 2018 Dec 1;129(3):567-74.
12. Mishra P, Singh U, Pandey CM, Mishra P, Pandey G. Application of student's t-test, analysis of variance, and covariance. Annals of cardiac anaesthesia. 2019 Oct;22(4):407.
13. Wen A, Wang X, Wang B, Yan C, Luo J, Wang P, Li J. Comparative analysis of 60co and 192ir sources in high dose rate brachytherapy for cervical cancer. Cancers. 2022 Sep 29;14(19):4749.
14. Wen A, Wang X, Wang B, Yan C, Luo J, Wang P, Li J. Radiobiological and dosimetric comparison of 60Co versus 192Ir high-dose-rate intracavitary-interstitial brachytherapy for cervical cancer. Radiation Oncology. 2022 Dec 13;17(1):206.
15. Fotina I, Zourari K, Lahanas V, Pantelis E, Papagiannis P. A comparative assessment of inhomogeneity and finite patient dimension effects in 60 Co and 192 Ir high-dose-rate brachytherapy. Journal of Contemporary Brachytherapy. 2018 Feb 28;10(1):73-84.
16. Tantivatana T, Rongsriyam K. Treatment outcomes of high-dose-rate intracavitary brachytherapy for cervical cancer: a comparison of Ir-192 versus Co-60 sources. Journal of Gynecologic Oncology. 2018 Jul 23;29(5):e86.
17. Yadav S, Singh OP, Choudhary S, Saroj DK, Yogi V, Goswami B. Estimation and comparison of integral dose to target and organs at risk in three-dimensional computed tomography image-based treatment planning of carcinoma uterine cervix with two high-dose-rate brachytherapy sources: 60: Co and: 192: Ir. Journal of Cancer Research and Therapeutics. 2021 Jan 1;17(1):191-7.
18. Zolciak-Siwinska A, Kowalczyk A, Sikorska K, Bijok M, Michalski W, Gruszczynska E. Comparison of computed tomography with magnetic resonance imaging for imaging-based clinical target volume contours in cervical cancer brachytherapy. Brachytherapy. 2018 Jul 1;17(4):667-72.
19. Srivastava S, Venugopal AK, Singh MN. Effect of model-based dose-calculation algorithms in high dose rate brachytherapy of cervical carcinoma. Reports of Practical Oncology and Radiotherapy. 2024;29(3):300-8.
20. Horeweg N, Creutzberg CL, Rijkmans EC, Laman MS, Velema LA, Coen VL, Stam TC, Kerkhof EM, Kroep JR, de Kroon CD, Nout RA. Efficacy and toxicity of chemoradiation with image-guided adaptive brachytherapy for locally advanced cervical cancer. International Journal of Gynecological Cancer. 2019 Feb 1;29(2):257-65.