Association Between Treatment Complexity and Procedural Fluoroscopic Radiation Exposure in Transarterial Radioembolization using Yttrium-90 Microspheres

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2026 JOINT AAPM | COMP MEETING
JULY 19–22 | VANCOUVER, BC
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Abstract

Purpose: To evaluate the relationship between treatment complexity and fluoroscopic radiation exposure during yttrium-90 (Y-90) transarterial radioembolization (TARE) in patients with hepatocellular carcinoma (HCC).

Methods: A total of 462 TARE procedures using resin (SIR-Spheres®) or glass (TheraSphere™) microspheres were retrospectively reviewed. Treatment complexity was categorized according to treatment scenario (super-selective vs. selective), tumor volume, and the number of Y-90 vials administered. Fluoroscopic radiation exposure metrics were extracted from DICOM Radiation Dose Structured Reports (RDSRs) and correlated with treatment complexity using the Wilcoxon rank-sum test.

Results: Preliminary analysis demonstrated significantly higher fluoroscopic radiation exposure for 77 super-selective procedures than for 385 selective procedures. Increased treatment complexity, including the use of additional Y-90 vials and more selective treatment approaches, was also associated with greater fluoroscopic radiation exposure (p = 0.005).

Conclusion: Increased TARE treatment complexity is associated with higher fluoroscopic radiation exposure. These findings may help establish procedural benchmarks and guide radiation dose optimization during Y-90 radioembolization.

Introduction

TARE, also known as selective internal radiation therapy (SIRT), using Y-90 microspheres is an established treatment for HCC [1]. The TheraSphere Global Dosimetry Steering Committee (DSC) defines five treatment scenarios based on disease extent, tumor characteristics, and treatment intent [2]. More complex disease presentations often require increasingly selective angiographic catheterization and treatment planning, potentially leading to longer fluoroscopy times and greater radiation exposure to both patients and operators. However, the relationship between TARE treatment complexity and fluoroscopic radiation exposure has not been systematically evaluated.

Study Objective

- Develop preliminary fluoroscopic radiation dose benchmarks across different TARE treatment scenarios.
- Quantify the association between TARE treatment complexity and fluoroscopic radiation exposure.
- Determine whether increasing treatment complexity is associated with higher procedural radiation dose.

Figure 1. Y-90 microsphere preparation and procedural setup in the interventional suite

Methods and Materials

A retrospective analysis was performed on 462 Y-90 TARE procedures conducted procedures conducted at a NCI-designated comprehensive cancer center in New York City. Treatment planning data and fluoroscopy records were matched using the MRN and procedure date. Treatment complexity was characterized by treatment selectivity (selective or super-selective) based on target tumor dose [2], perfused volume [3], and the number of Y-90 vials administered (1, 2, 3, or ≥4), which served as a surrogate for procedural complexity (Table 1). Associations between treatment complexity and fluoroscopic radiation exposure were evaluated using the Wilcoxon rank-sum test.

Study Cohort and Analysis

- **Study cohort:** 462 Y-90 TARE procedures (October 2020–October 2025)
- **Treatment dataset:** Derived from Y-90 written directives
- **Fluoroscopy dataset:** Extracted from DICOM Radiation Dose Structured Reports (RDSRs)
- **Data linkage:** Treatment and fluoroscopy datasets matched using MRN and procedure date
- **Complexity classification:** Treatment selectivity and number of Y-90 vials administered.
- **Variables collected:** Pt characteristics, fluoroscopy parameters, and radiation exposure metrics
- **Statistical analysis:** Wilcoxon rank-sum test to compare radiation exposure between groups

Figure 2. Study workflow illustrating cohort identification, fluoroscopy data extraction, and treatment–fluoroscopy dataset matching.

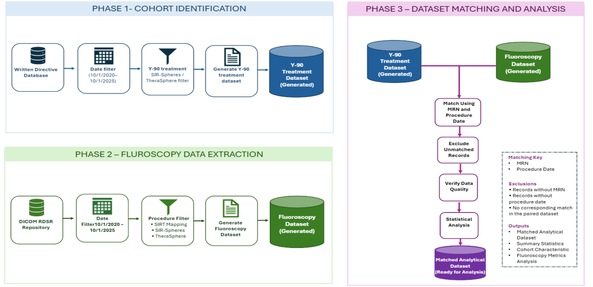


Table 1. Clinical treatment scenarios and determining factors for Y-90 TARE.

Treatment Scenario		S1A*	S1B*	S2A	S2B	S3A	S3B	S4A	S4B
Classification Criteria	Treatment sites (n)	1	1	2	2	3	3	4	4
	Target tumor dose	All Tx sites < 400 Gy	≥1 Tx site ≥400 Gy	All Tx sites < 400 Gy	≥1 Tx site ≥400 Gy	All Tx sites < 400 Gy	≥1 Tx site ≥400 Gy	All Tx sites < 400 Gy	≥1 Tx site ≥400 Gy
	Perfused volume	Any	Same site volume < 38% TLV**	Any	Same site volume < 38% TLV	Any	Same site volume < 38% TLV	Any	Same site volume < 38% TLV

* 'A' scenarios are selective TARE. 'B' scenarios are super-selective TARE (segmentectomy or lobectomy).
** 'TLV' = Total Liver Volume.

Results

Patient size, fluoroscopy technique, and radiation exposure metrics are summarized in Table 2. Across all Y-90 TARE treatment procedures, the median reference air kerma (Ka,r) was 220.9 mGy (IQR: 115.1–438.7 mGy). Median kerma-area product (KAP) was 33.2 Gy·cm² (IQR: 17.7–62.5 Gy·cm²), and median fluoroscopy time was 59.7 s (IQR: 34.7–94.6 s).

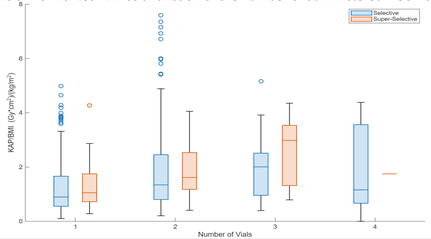
Key Findings

- **Median Ka,r:** 220.9 mGy (IQR, 115.1–438.7 mGy)
- **Median KAP:** 33.2 Gy·cm² (IQR, 17.7–62.5 Gy·cm²)
- **Median fluoroscopy time:** 59.7 s (IQR, 34.7–94.6 s)
- **Treatment selectivity:** Super-selective (B) procedures were associated with significantly higher radiation exposure than selective (A) procedures ($p < 0.05$; Figure 3).
- **Clinical scenarios:** KAP was significantly higher in S2A and S3A than S1A, and in S2B and S3B than S1B ($p < 0.05$).

Table 2. Patient characteristics, fluoroscopy parameters, and radiation exposure metrics.

	Variable	Min	Q1	Median	Q3	Max
Patient Characteristics	BMI (kg/m²)	15.7	22.5	26.6	30.9	55.4
	Patient Thickness(cm)	17.5	21.6	23.8	25.7	33.6
Fluoroscopy Parameters	Fluoro. kVp	60	62	65	72	120
	Fluoro. Tube Current (mA)	30	94	99	102	129
	Total Fluoro. Exposure (mAs)	4.6	2917.1	5308.8	8975.6	54005.1
	Total Fluoro. Exposure Time (s)	0.1	31.8	56.0	88.5	384.7
	Fluoro Field Size at Ref. Point (cm)	7.8	10.7	11.4	17.1	24.0
	Acq. kVp	0	79	85	89	110
	Acq. Tube Current (mA)	0	141	157	262	575
	Total Acq. Exposure (mAs)	0.0	365.9	618.4	1055.6	9178.1
	Total Acq. Exposure Time (s)	0.0	2.3	3.6	5.3	21.4
	Acq. Field Size at Ref. Point (cm)	0.0	11.9	17.7	19.1	24.0
	Focus-Skin-Distance (cm)	73.8	74.9	75.3	75.6	76.9
	Focus-Detector-Distance (cm)	95.0	97.9	101.8	105.4	119.5
Radiation Exposure Metrics	Total Ka,r (mGy)	0.1	115.1	220.9	438.7	2867.2
	Total KAP (Gy*cm²)	0.03	17.7	33.2	62.5	388.9
	Total Exposure Time (s)	0.1	34.7	59.7	94.6	398.1

Figure 3. Normalized KAP as a function of the number of administered Y-90 vials



Discussion

The use of fluoroscopy-guided transarterial radioembolization (TARE) with Y-90 microspheres has increased substantially at our institution. Although internal dosimetry models for Y-90 microsphere therapy are well established and routinely used for treatment planning and dose verification, fluoroscopy-related radiation exposure during catheter navigation and microsphere delivery has been less well characterized. [4–8].

Across the study cohort, no procedure exceeded a cumulative reference air kerma (Ka,r) of 3 Gy, and all kerma-area product (KAP) values were below 400 Gy·cm². These findings suggest that fluoroscopy-related radiation exposure during TARE was generally low and unlikely to result in deterministic skin injury, with minimal incremental lifetime cancer risk. Furthermore, all procedures remained below our institutional threshold for radiation dose follow-up.

Treatment complexity was associated with increased fluoroscopic radiation exposure. Super-selective procedures, which require more distal and technically demanding catheterization of the hepatic arterial vasculature, resulted in significantly greater fluoroscopic radiation exposure than selective procedures ($p = 0.005$). Analysis of 385 selective and 77 super-selective procedures demonstrated that increasing procedural complexity contributes to higher fluoroscopic dose. Within both treatment groups, radiation exposure generally increased with the number of administered Y-90 vials, reflecting the additional catheter manipulations and treatment time required for more extensive procedures.

Further investigation is warranted to better characterize radiation exposure in the relatively small cohort of four-vial treatments and to validate these findings in an independent cohort from a second institution.

Conclusions

Fluoroscopic radiation exposure increased with procedural complexity, particularly for super-selective treatments and procedures involving multiple treatment sites.

Establishing institutional radiation dose benchmarks and optimizing fluoroscopic technique are important strategies for minimizing patient radiation exposure while maintaining procedural efficacy.

These preliminary benchmarks may serve as a reference for quality assurance, radiation dose optimization, and procedural planning during Y-90 TARE, while supporting future multicenter benchmarking and quality improvement initiatives.

Acknowledgement

This research was funded in part through the NIH/NCI Cancer Center Support Grant P30CA008748.

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References

1. Salem R, Padia SA, Lam M, Bell J, Chiesa C, Fowers K, Hamilton B, Herman J, Kappadath SC, Leung T, Portelance L. Clinical and dosimetric considerations for Y90: recommendations from an international multidisciplinary working group. European journal of nuclear medicine and molecular imaging. 2019 Jul 1;46(8):1695-704.
2. Salem R, Padia SA, Lam M, Chiesa C, Haste P, Sangro B, Toskich B, Fowers K, Herman JM, Kappadath SC, Leung T. Clinical, dosimetric, and reporting considerations for Y-90 glass microspheres in hepatocellular carcinoma: updated 2022 recommendations from an international multidisciplinary working group. European journal of nuclear medicine and molecular imaging. 2023 Jan;50(2):328-43.
3. Mise Y, Satou S, Shindoh J, Conrad C, Aoki T, Hasegawa K, Sugawara Y, Kokudo N. Three-dimensional volumetry in 107 normal livers reveals clinically relevant inter-segment variation in size. Hpb. 2014 May 1;16(5):439-47.
4. Marquis H, Ocampo Ramos JC, Carter LM, Zanzonico P, Bolch WE, Laforest R, Kesner AL, MIRD committee. MIRD pamphlet no. 29: MIRDy90—a 90Y research microsphere dosimetry tool. Journal of Nuclear Medicine. 2024 May;65(5):794-802.
5. Opitz M, Zensen S, Ludwig JM, Weber M, Alatzides G, Seifert R, Grüneisen J, Theysohn JM, Bos D, Schaarschmidt BM. Radiation dose aspects and establishment of diagnostic reference levels for 90Y radioembolisation during angiographic procedure. Journal of Radiological Protection. 2022 Sep 1;42(3):031518.
6. Ehrengut C, Vogt J, Leonhardi J, Carabencioiv E, Teske F, Boemmel FV, Berg T, Seehofer D, Lincke T, Sabri O, Gößmann H. Analysis of Periprocedural X-ray Exposure in Transarterial Radioembolization with Glass or Resin Microspheres. Diagnostics. 2023 Dec 6;13(24):3609.
7. Jones AK, Wunderle KA, Fruscello T, Simanowith M, Cline B, Dharmadhikari S, Duan X, Durack JC, Hirschl D, Kim DS, Mahmood U. Patient radiation doses in ir procedures: the american college of radiology dose index registry-fluoroscopy pilot. Journal of Vascular and Interventional Radiology. 2023 Apr 1;34(4):544-55.
8. Jones AK, Wunderle KA, Fruscello T, Simanowith M, Cline B, Dharmadhikari S, Duan X, Durack JC, Hirschl D, Kim DS, Mahmood U. Patient radiation doses in interventional radiology procedures: comparison of fluoroscopy dose indices between the American College of Radiology Dose Index Registry-Fluoroscopy Pilot and the Radiation Doses in Interventional Radiology Study. Journal of Vascular and Interventional Radiology. 2023 Apr 1;34(4):556-62.