

Chat with the Faculty

April 3rd, 2026

**Individualized Patient Dosimetry for
Radiopharmaceutical Therapy:
Emerging Career Opportunities in Medical Physics***

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*** *References not cited but available upon request***

Key Reference: Jacene, Urbain, Lewis et al. Radiopharmaceutical therapy: Rapid growth, rising challenges, and the critical need for expertise. J Nucl Med 66:1871–1879, 2025.

Hypothesis

**Dramatic advances in and
increased utilization of
radiopharmaceutical therapy
(RPT)**

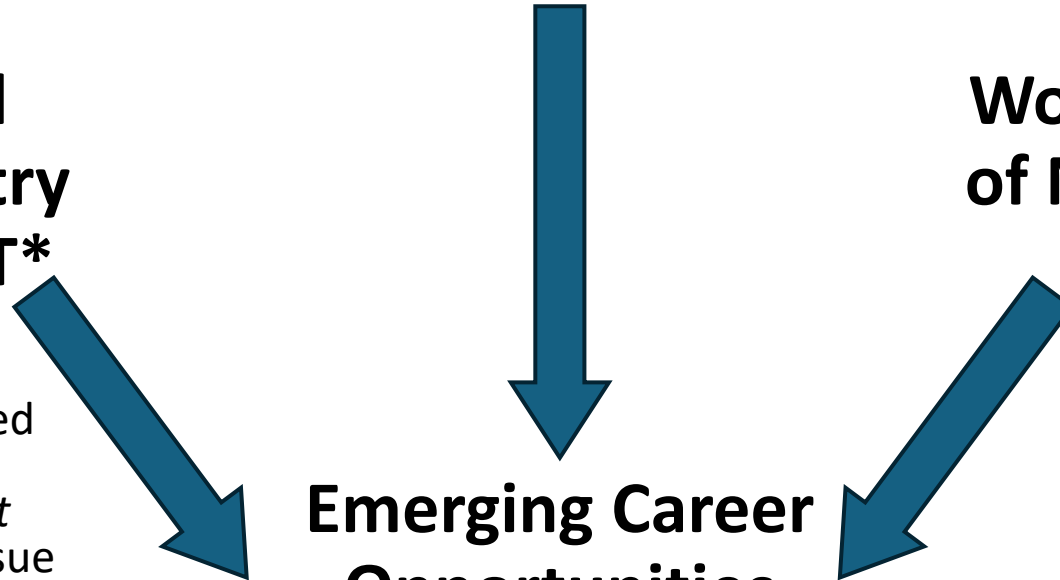
aka
“Theranostics”

**Individualized
patient dosimetry
to optimize RPT***

* Maximize administered activity and therefore lesion dose(s) *without* exceeding normal-tissue maximum tolerated doses (MTDs)

**Worsening shortage
of Nuclear Medicine
Physicists**

**Emerging Career
Opportunities
in Nuclear Medicine
Physics**



Currently Approved Therapeutic Radiopharmaceuticals

Therapeutic radiopharmaceutical	Year of initial approval (FDA; EMA)	Approved PET/SPECT diagnostic companion(s)	Therapeutic radiopharmaceutical indication(s)	Data
^{131}I -sodium iodide	Before 1982; 1971*	^{131}I -sodium iodide; ^{123}I -sodium iodide	Treatment of selected cases of differentiated thyroid carcinoma	Low-risk thyroid cancer (15); metastatic thyroid cancer (16,17)
^{89}Sr -chloride	1993; 1993*	$^{99\text{m}}\text{Tc}$ -bisphosphonates (e.g., $^{99\text{m}}\text{Tc}$ -medronate, $^{99\text{m}}\text{Tc}$ -oxidronate, $^{99\text{m}}\text{Tc}$ -pyrophosphate)	Relieve bone pain in patients with painful osteoblastic skeletal metastases	Pain response rates higher in ^{89}Sr vs. placebo groups; myelosuppression occurs, with delayed nadirs between 12 and 16 wk
^{153}Sm -EDTMP [†]	1997; 1998	$^{99\text{m}}\text{Tc}$ -bisphosphonates (e.g., $^{99\text{m}}\text{Tc}$ -medronate, $^{99\text{m}}\text{Tc}$ -oxidronate, $^{99\text{m}}\text{Tc}$ -pyrophosphate)	Relieve bone pain in patients with multiple painful osteoblastic skeletal metastases	Patients who respond generally experience onset of pain relief within 1 wk after treatment; relief of pain may persist for 4 wk up to 4 mo (18); by 4 wk, improvement in pain score and opioid use vs. control group (19)
^{90}Y -ibritumomab tiuxetan [†]	2002; 2004	^{111}In -ibritumomab tiuxetan	Relapsed or refractory, low-grade, or follicular B-cell NHL; previously untreated patients with follicular NHL who achieve PR or CR to first-line chemotherapy	ORR, 80% vs. 56% for rituximab alone (CR in 30% vs. 16%); median duration of response, 14.2 mo vs. 12.1 mo; durable response ≥ 6 mo in 64% vs. 47% (11); clinical benefit seen in various combination settings (20–24)

Currently Approved Therapeutic Radiopharmaceuticals *cont*

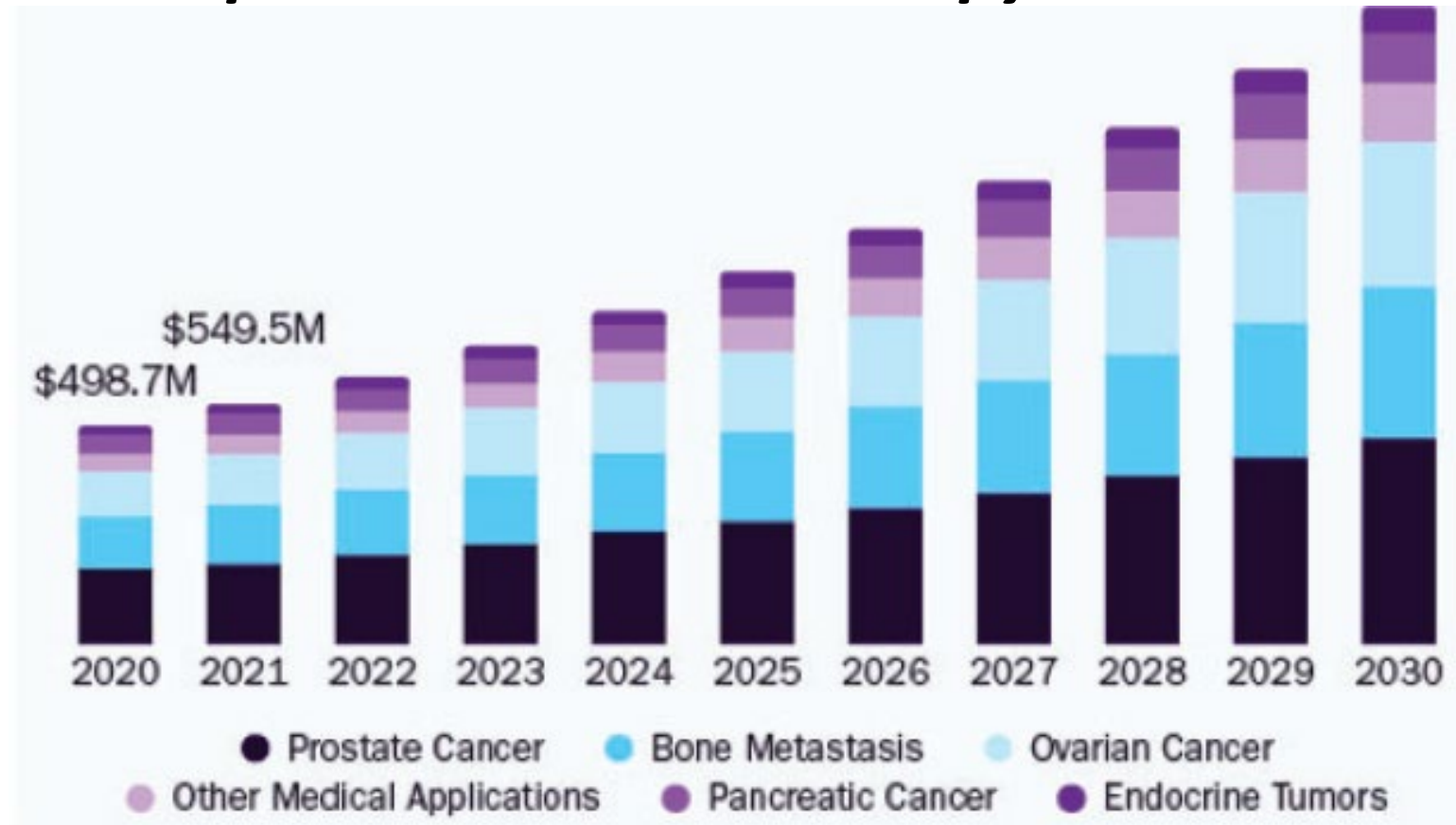
Therapeutic radiopharmaceutical	Year of initial approval (FDA; EMA)	Approved PET/SPECT diagnostic companion(s)	Therapeutic radiopharmaceutical indication(s)	Data
¹³¹ I-tositumomab [‡]	2003; 2003	¹³¹ I-tositumomab	CD20-positive relapsed or refractory, low-grade, follicular, or transformed NHL after progression during or after rituximab therapy	ORR, 49%–64%; median duration of response, 13–16 mo (25,26)
¹³¹ I-ioibenguane (or MIBG) ⁵	1994; 2018* (27)	¹²³ I-ioibenguane	Treatment of adults and adolescents age 12 y or older with rare tumors of adrenal gland (pheochromocytoma or paraganglioma) who are positive for norepinephrine transporter	22% of patients treated achieved PR; 53% of responders experienced durable tumor response ≥ 6 mo; median OS, 36.7 mo (12)
²²³ Ra-dichloride Xofigo™	2013; 2013		Adults with CRPC, symptomatic bone metastases, and no known visceral metastases	Median OS, 14.9 mo vs. 11.3 mo; increased time to first SSE; increase in pain control and QoL (14,28,29)
¹⁷⁷ Lu-DOTATATE (¹⁷⁷ Lu-[DOTA ⁰ ,Tyr ³] octreotate) Lutathera™	2018; 2017	⁶⁸ Ga-DOTATATE (United States); ⁶⁴ Cu-DOTATATE (United States); ⁶⁸ Ga-DOTATOC (European Union)	Treatment of somatostatin receptor positive gastroenteropancreatic neuroendocrine tumors	Median OS, 48.0 vs. 36.3 mo; increase in QoL; true difference in OS likely underestimated because 36% crossed over from control group (30)
¹⁷⁷ Lu-vipivotide tetraxetan (PSMA-617) Pluvicto™	2022; 2022	¹⁸ F-piflufolastat (DCFPyL); ⁶⁸ Ga-gozetotide (PSMA-11); ¹⁸ F-flotufolastat	Treatment of metastatic CRPC who have been treated with androgen receptor pathway inhibition and taxane-based chemotherapy	ORR, 29.8 vs. 1.7%; increased time to first SRE; high-grade adverse effect rate, 52.7% vs. 38.0% (32)

Rapid Growth of Radiopharmaceutical Therapy...

- In 2022, 41,500 patients with neuroendocrine tumors and prostate cancer eligible for 1.5 million cycles of RPT, with up to 300 centers needed to deliver such treatments.
- >Half a million doses of PSMA RPT per year would be needed to treat more than 158,000 patients with Stage-4 metastatic castration-resistant prostate cancer.
- Total sales of therapeutic radiopharmaceuticals projected to grow from \$7.3B in 2022 to \$13.5B in 2032, at an annual growth rate of >23%.
- >80 therapeutic radiopharmaceuticals currently in clinical trial.
- Trend to use RPT in *earlier-stage* disease → Far more RPT treatments.

*Rapid Growth of **Alpha-Particle*** Radiopharmaceutical Therapy*

Annual growth rate of 11.4% from 2024 to 2030, with total sales >\$1B by 2030.



- * Technical challenges - Short range ($<100\ \mu\text{m}$) $\rightarrow$ Localized dose distributions / No cross-fire effect
- Low administered activities ($\sim 100\ \mu\text{Ci}$) $\rightarrow$ Imaging feasible?
- High LET ($\sim 100\ \text{keV}/\mu\text{m}$) $\rightarrow$ High RBE $\rightarrow$ Bioeffect modeling?

Radiopharmaceutical Therapy is routinely delivered on a “one-size-fits-all” - fixed-administered activity - basis

- **$^{223}\text{Ra-RaCl}_2$ (Xofigo™) for skeletal disease in castrate-resistant prostate cancer: $1.49 \mu\text{Ci/kg } \bar{q}$ 4 weeks x 6.**
- **$^{177}\text{Lu-DOTATATE}$ (Lutathera™) for somatostatin receptor-positive neuroendocrine tumors: $200 \text{ mCi } \bar{q}$ 8 weeks x 4.**
- **$^{177}\text{Lu-PSMA-617}$ (Pluvicto™) for PSMA-positive metastatic castration-resistant prostate cancer: $200 \text{ mCi } \bar{q}$ 6 weeks x 6.**

Dosimetry (Likely) Essential for Optimum Radiopharmaceutical Therapy

¹⁷⁷Lu-DOTA-JR11 Clinical Trial @ MSKCC: Dosimetry Results to Date

Patient	Activity (mCi)		Actually Administered		Absorbed Dose to Index Lesion (Gy)	
	1.5 Gy to Marrow	23 Gy to Kidneys			per mCi	for 200-mCi Administered
						for MTA
1	789	861	200		0.22	44
2	618	522	200		0.15	30
3	965	467	200		0.36	72
4	841	901	200		0.23	46
5	626	412	200		0.12	25
6	582	482	200		0.48	95
Mean	737	608			0.26	52
SD	152	215			0.14	27

On average, patients can be safely treated with 3x the “standard” 200-mCi activity

Courtesy of Drs. Joseph O'Donoghue and Wolfgang Weber, MSKCC

Dosimetry (Likely) Essential for Optimum Radiopharmaceutical Therapy cont

^{177}Lu -DOTATATE

7.4 GBq Q8W, four total treatments

- **~18% objective response rate**
- Grade 3-4 toxicity: 1% thrombocytopenia, 3% neutropenia, 2% leukopenia, 3% renal failure

Kidneys: 0.3 to 1.9 Gy/GBq [1]

(6-fold range)

Marrow: 2 to 19 cGy/GBq [2]

(10-fold range)

Based on Kidney MTD of 23 Gy and Marrow MTD of 1.5 Gy, many (most?) patients are under-treated BUT a finite percentage of patients are over-treated

^{177}Lu -PSMA-617

7.4 GBq Q6W, four to six total treatments

- **~30% overall response rate**
- Grade 3-4 toxicity: 9% thrombocytopenia, 4.5% neutropenia, 7% leukopenia, 1% kidney failure

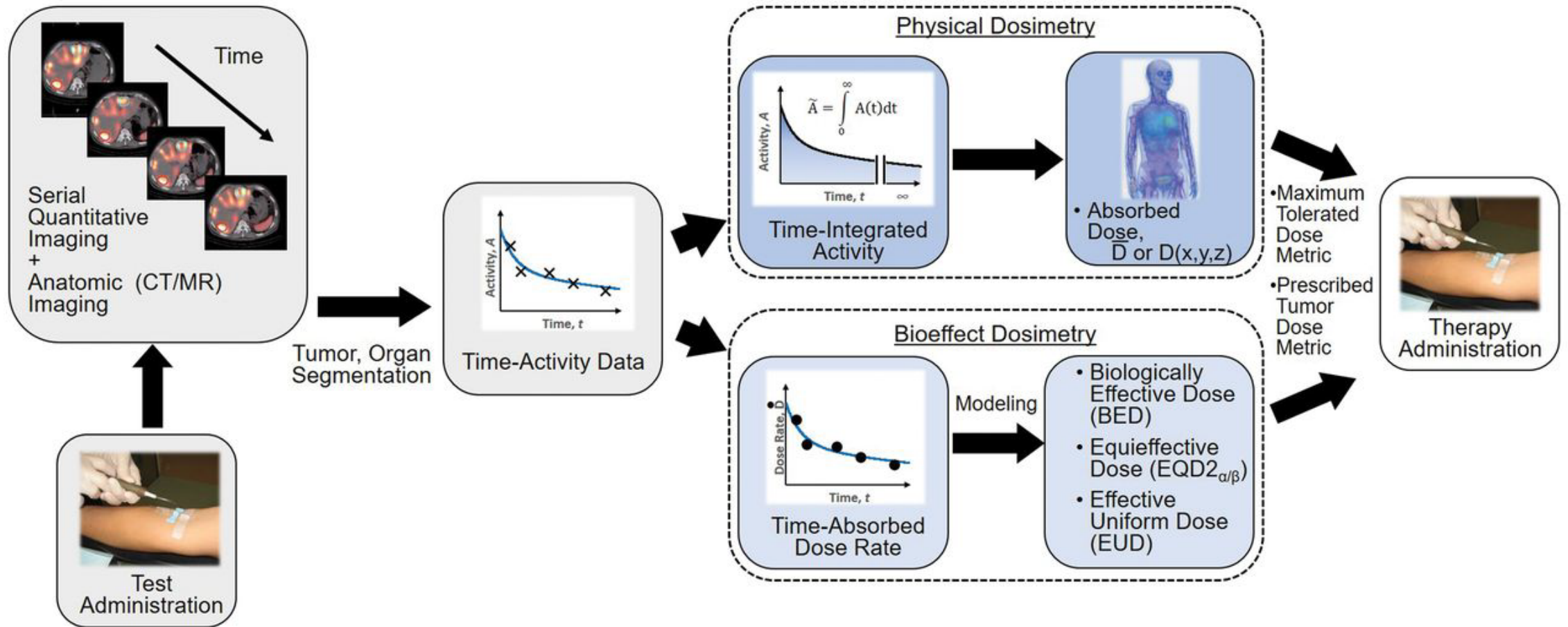
Kidneys: 0.1 to 1.4 Gy/GBq [3]

(14-fold range)

Marrow: 0.4 to 11 cGy/GBq [4]

(25-fold range)

Patient-Specific Radiation Dosimetry for Optimized Radiopharmaceutical Therapy: Basic Workflow



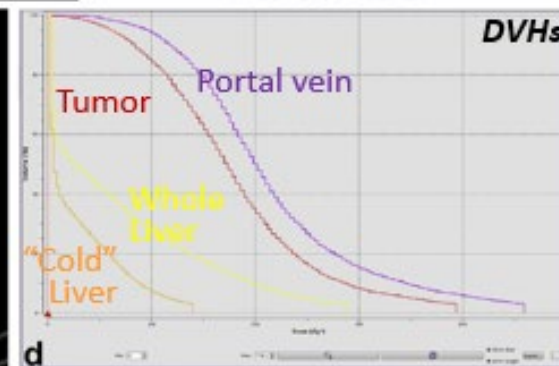
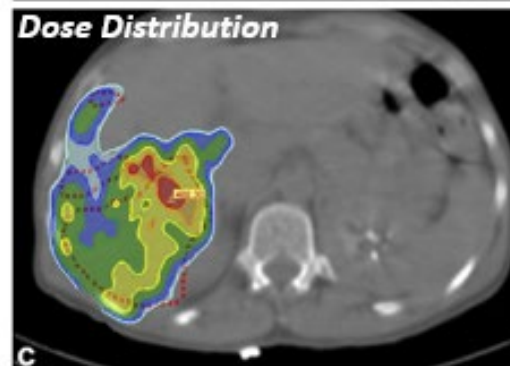
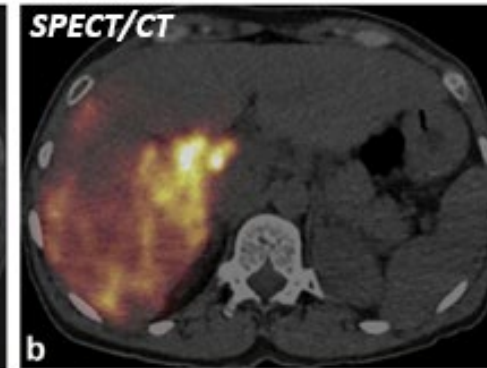
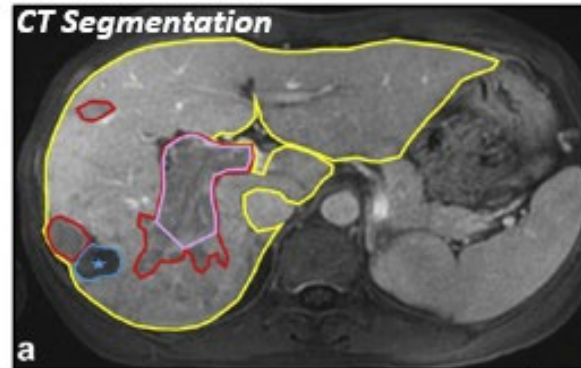
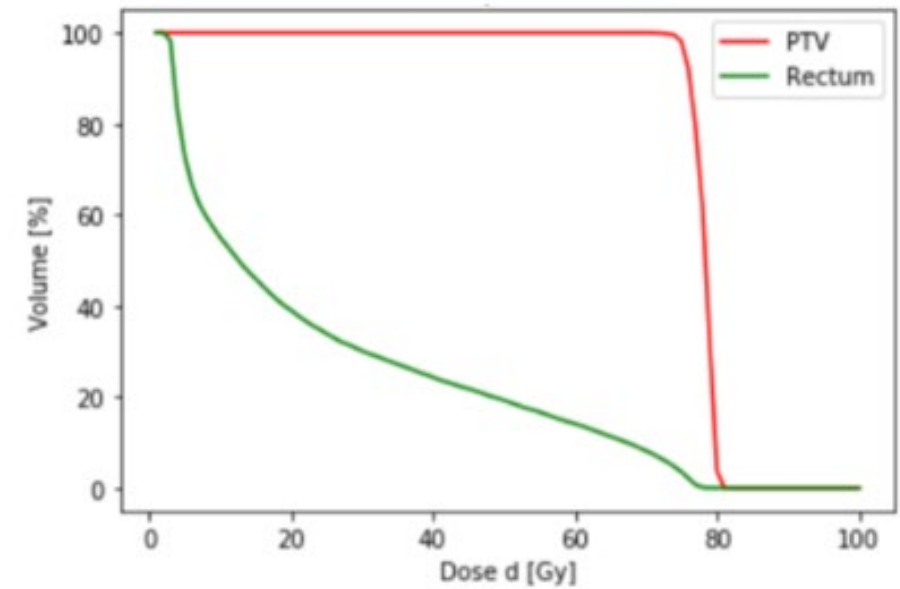
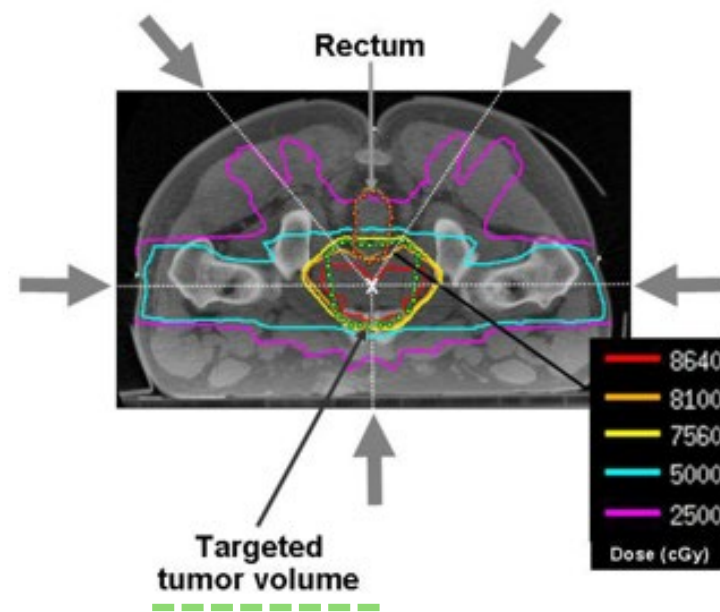
Technical Expertise Required for RPT Dosimetry - as Provided by Nuclear Medicine Physicists

- Quantitative planar imaging, SPECT, and PET
 - Alignment of serial image sets
 - Organ / tumor segmentation (activity-based?)
- Organ / tumor time-activity data
- Scintillation well counting → Blood / urine / CSF time-activity data
 - Kinetic analyses of time-activity data → Time-integrated activities
 - Internal dosimetry → Organ / tumor absorbed doses
 - Bioeffect modeling - to account for time-varying and spatially non-uniform doses → BED, EUD etc

***Uniformity
of Dose
in XRT***

VS

***Non-Uniformity
of Dose
in RPT***



**^{90}Y -
microspheres**

Qualified Medical Physicists (QMPs) in Nuclear Medicine Practicing in US

ABR- or ABNM-certified
and/or licensed Nuclear
Medicine Physicist

➤ CRCPD

- QMP NM workforce has grown from 340 in 2014 to 405 in 2022
- Median years of experience remains high (approximately 10% certified prior to 1970), suggesting true workforce may be **~364 QMPs**

➤ AAPM

- 53% survey response rate (2,868 out of 5,390)
- 134 indicate NM certification, therefore total is estimated to be $134/.53 = \text{~252 QMPs}$ (down from 340 in 2014)
- 31 indicate NM as primary discipline (23%, down from 29% in 2014)

➤ ACR, TJC allow for qualified status based on training pathways outside of certification.

- CRCPD and AAPM numbers are likely underestimated by ~20%

- **Best estimate: ~350 ± 50 practicing QMPs in US**
~160 practicing Nuclear Medicine QMPs (?)

*Only a minority
identify Nuclear
Medicine as
primary area of
practice*

The Nuclear Medicine Physics workforce is aging!

<i>All Degrees and Certification – 2012 Professional Survey</i>		
<i>Degree/Certification</i>	<i>#</i>	<i>Median Yrs Experience</i>
MS-ABR(NM)	49	28
MS-ABSNM	20	19
MS-ABR(Radiologic)	16	36
PhD-ABR(NM)	64	30
PhD-ABSNM	24	25
PhD-ABR(Radiologic)	33	37
MS-ABR Diagnostic	200	22
PhD-ABR Diagnostic	199	22
Total ABR(NM)	162	
Total ABSNM	44	
Total NM Certified ^a	206	

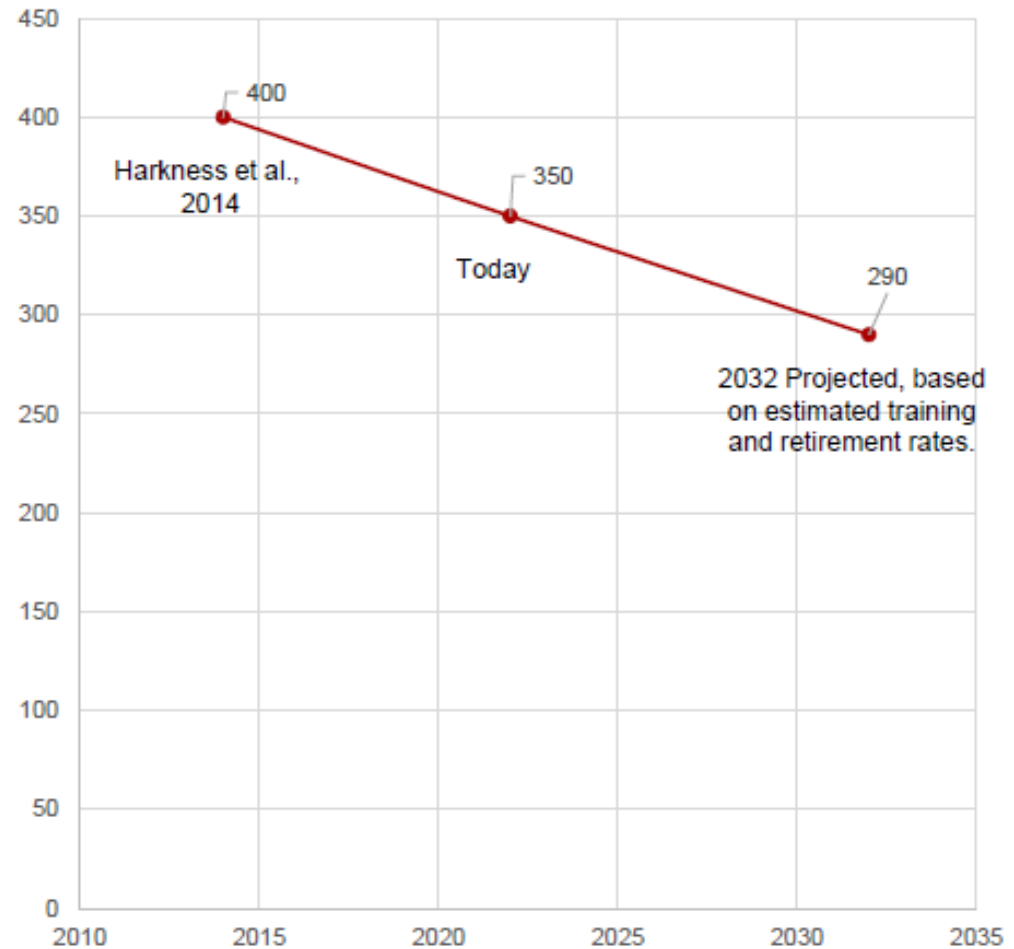
^a The sum of all ABR(NM) and ABSNM

Source: Harkness BA, Allison JD, Clements JB et al. AAPM/SNMMI Joint Task Force: Report on the current state of nuclear medicine physics training. J Appl Clin Med Phys 16:3-13, 2015

<i>Working Primarily in Nuclear Medicine AAPM 2012 Professional Survey</i>			
<i>Degree</i>	<i>Certified</i>	<i>#</i>	<i>Yrs Experience</i>
MS	No	5	7
MS	Yes	5	25
PhD	No	18	20
PhD	Yes	31	23
Total		59	

Projected Shortage of Nuclear Medicine QMPs in US

- Based on a projected shortfall of 60 trainees (~12 per year over 5 years) the number of practicing QMPs may fall from ~350 to ~290 over the next 5-10 years.
- It will be difficult to avoid this trend unless existing Dx/NM residencies increase trainee throughput, and/or those already eligible seek certification.



Nuclear Medicine Physicist Workload: Current and Projected

- ~20 million nuclear medicine procedures performed annually in the U.S.*
- >40,000 procedures/yr per NM physicist
- If therapy rises to be 5% of the total procedure count, and 20% of those cases require physicist-supported dosimetry, this would be >500 cases per physicist per year. Likely a doubling of NM physics workforce would be needed to support. In practice, diagnostic physicists, RO physicists, and technologists will be necessarily be involved, due to modest NM physics training pipeline

Summary

- Current training programs in Medical Physics are largely directed towards Radiation Oncology and Diagnostic Radiology and *not* Nuclear Medicine.
- The number of Medical Physicists certified in Nuclear Medicine Physics are marginally adequate to meet current demand and appear *inadequate* to address any significant increase in demand, as the number of certified Nuclear Medicine Physicists has remained flat.
- The **aging of the Nuclear Medicine Physics workforce** will exacerbate any increased demand.
- The **growth in radiopharmaceutical therapy**, if delivered on a patient-specific dosimetric basis, would substantially increase the demand for Nuclear Medicine Physicists, which may be filled *part-time* by Radiation Oncologist Physicists.

Closing Comment

“The recent rapid growth of imaging and therapeutic radiopharmaceutical applications may create a rapid increase in demand for nuclear medicine physicists, and it is unclear whether the current education and training pipeline would be able to fulfill such demand with QMPs.”

Sources: Jordan DW, Newhauser WD, and Mills MD. Current state of the imaging physics workforce and financial model. J Appl Clin Med Phys 22:4-6, 2021

Conclusion

**Dramatic advances in and
increased utilization of
radiopharmaceutical therapy
(RPT)**

**Individualized
patient dosimetry
to optimize RPT**

**Worsening shortage
of Nuclear Medicine
Physicists**

**Emerging Career
Opportunities
in Nuclear Medicine
Physics**

