Advances in permanent source implantation for LDR brachytherapy of various anatomical sites

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2020 Improving Health QUALITY. Increasing Global IMPACT. JULY 12–16 VIRTUAL EASTERN TIME [GMT-4] JOINT AAPM | COMP MEETING

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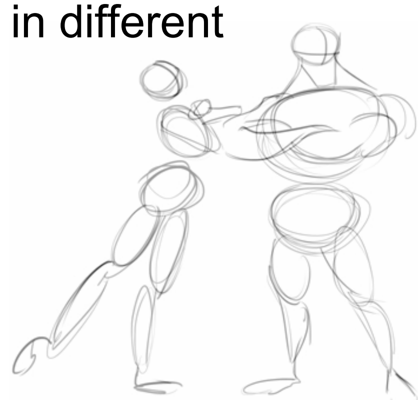
2nd Talk: Learning Objectives

1. Understand the evolution of PSI radionuclides and grasp their dosimetric differences.

2. Learn various techniques used for PSI in different anatomical sites.



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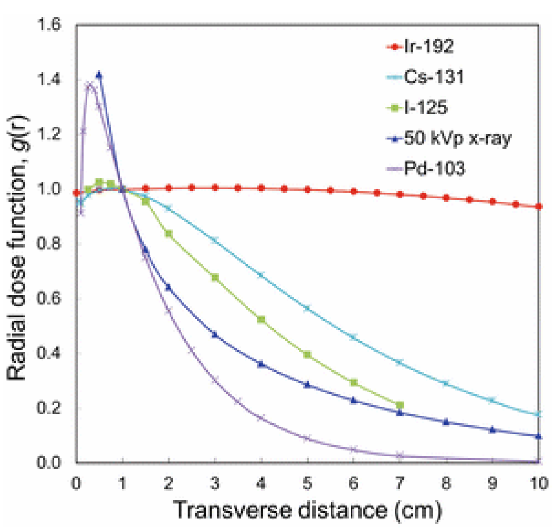
Evolution of PSI Radionuclides

- sources initially developed using radiochemical separation: ^{226}Ra and ^{222}Rn

- later with nuclear activation (atomic age) and radiochemistry: ^{191}Ir(n,γ)^{192}Ir, ^{197}Au(n,γ)^{198}Au
  ^{124}Xe(n,γ)^{125}Xe=>^{125}I, ^{103}Rh(p,n)^{103}Pd, ^{130}Ba(n,γ)^{131}Ba=>^{131}Cs
  electron capture radiochemistry

- development trend has been for:
  a) low energy: safe for personnel and public, easily shieldable
  b) shorter half-life: increased BED, combination with EBRT
  c) capsule standardization: equipment compatibility

PSI General Dosimetry



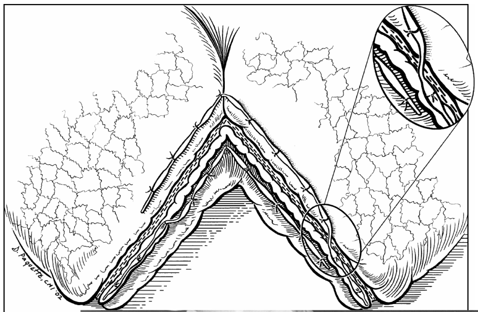
- low-E PSI sources exhibit higher dose falloff and larger dose gradients than ^{192}Ir

- low-E PSI dosimetry is more sensitive to positioning variations (initially and during decay)

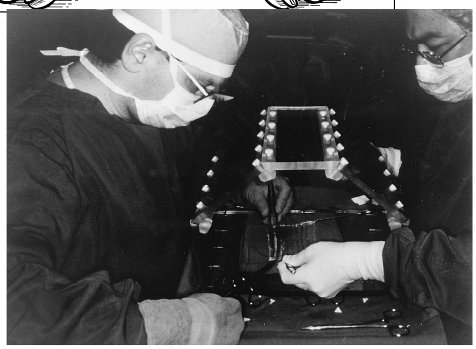
- these factors influence various anatomic sites differently

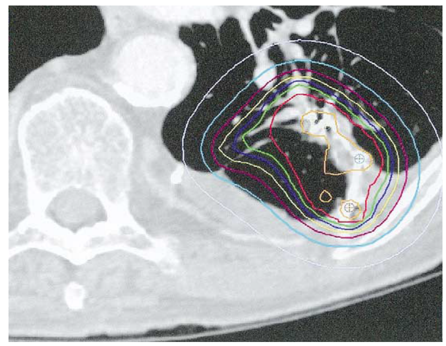
SJ Park & DH Thomas (2017) General Physics Principles in Brachytherapy.
in: J Mayadev, S Benedict, M Kamrava (eds) *Handbook of Image-Guided Brachytherapy*. Springer

PSI for Lung Cancer



- stranded ^{125}I seeds sutured to lobectomy surgical margin
- required high surgical skill
- subject to high/low dose regions

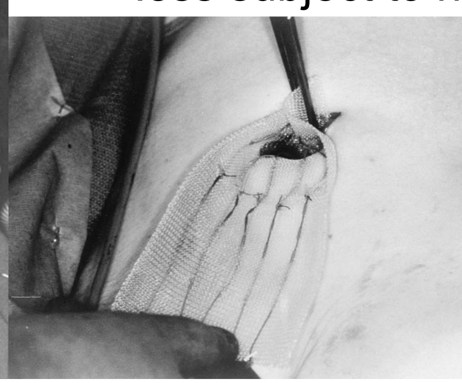


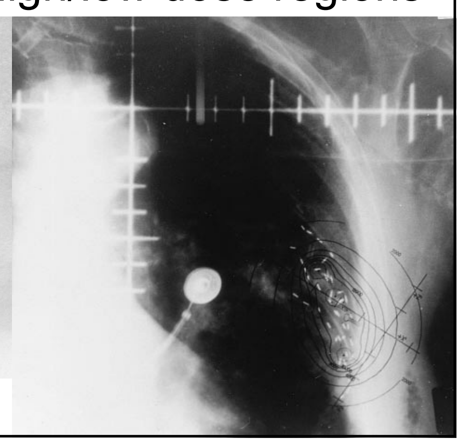


Lee et al. Ann Thorac Surg 75: 237-243 (2003).

PSI for Lung Cancer

- ^{125}I seeds in vicryl mesh sutured to lobectomy surgical margin
- requires less surgical skill
- less subject to high/low dose regions





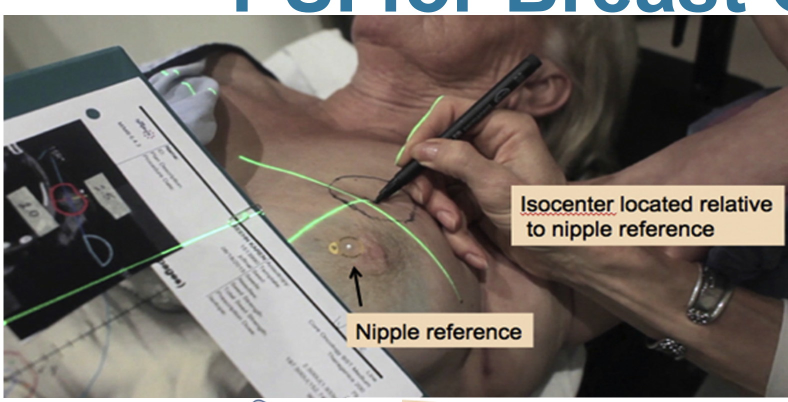
Chen, et al. IJROBP 44: 1057-1063 (1999).

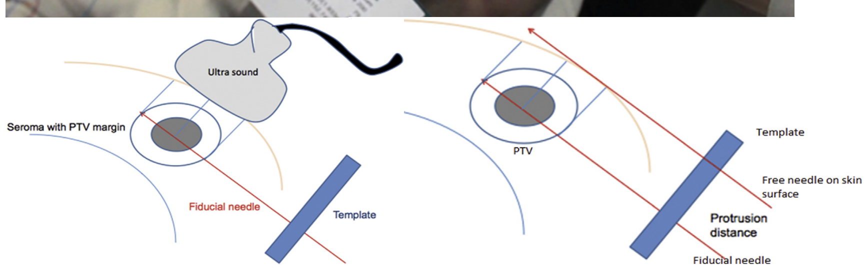
PSI for Breast Cancer

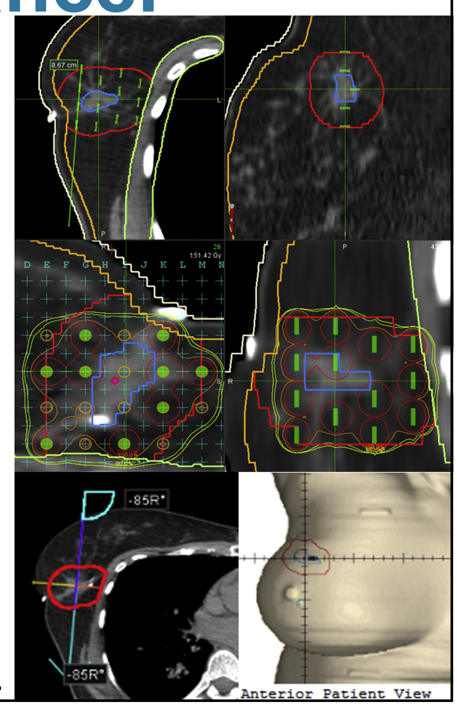
- CT-based pre-implant treatment plan performed for PSI (^{103}Pd) ordering 2 weeks prior to OR
- seroma cavity with PTV margin is delineated under US, needle entry paths determined to guide subsequent surgery
- OR setup concerns for arm position, muscle tension, template position, and fiducial needle position located via US
- post-implant CT dosimetry performed same day as implant

Crook et al. Brachytherapy 18: 510-520 (2019).

PSI for Breast Cancer

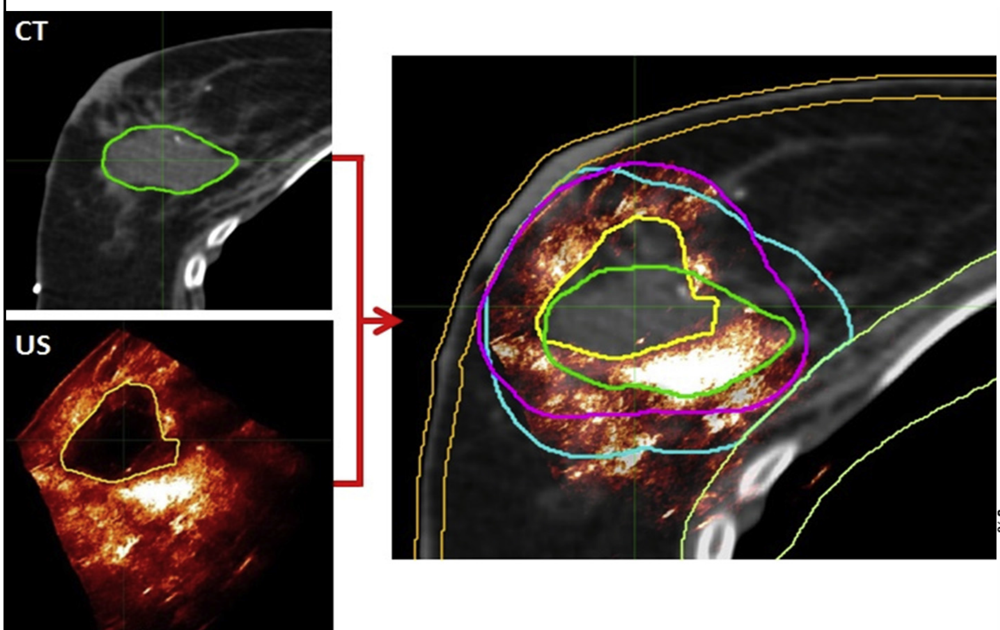


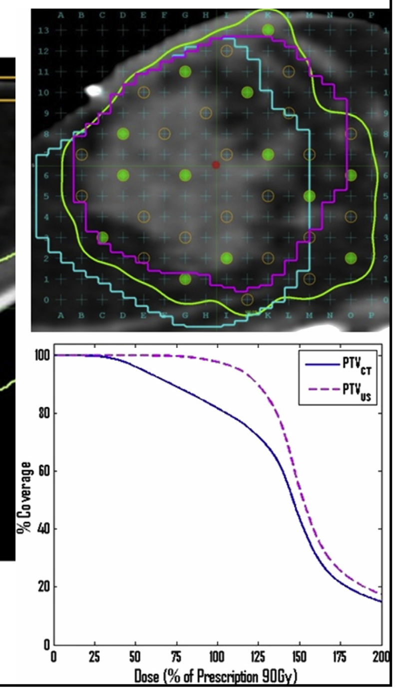




Crook et al. Brachytherapy 18: 510-520 (2019).

PSI for Breast Cancer





Morton et al. Brachytherapy 16: 167-173 (2017).

PSI for Brain Cancer

- historically implanted few ^{125}I seeds during tumor resection
- many single institutional studies, promising alternative to WBRT
- Wernicke and colleagues researched ^{131}Cs in the past decade
- stranded seeds and devices are now being used

Schwarz et al. Rad Oncol 7: 30 (2012).
Chitti et al. J. Contemporary Brachytherapy 12: 67-83 (2020).

PSI for Brain Cancer

TABLE III. Summary of dose conversion for fast growing tumors. D(Au, I, Pd) is the reference dose for a given isotope (Au-198, I-125, Pd-103), and D(Cs-Au, I, Pd) is the Cs-131 dose converted from the corresponding isotope dose.

D(Au, I, Pd) (Gy)	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160
D(Cs-Au) (Gy)	22	31	39	46	53	59	64	68	72	76	78	80				
D(Cs-I) (Gy)				7	14	20	28	36	44	53	63	73	85	97	110	123
D(Cs-Pd) (Gy)		19	32	45	59	73	88	103	119	135	152	169	187			

TABLE IV. Summary of dose conversion for slow growing tumors. D(Au, I, Pd) is the reference dose for a given isotope (Au-198, I-125, Pd-103), and D(Cs-Au, I, Pd) is the Cs-131 dose converted from the corresponding isotope dose.

D(Au, I, Pd) (Gy)	10	20	30	40	50	60	70	80	90	100	110	120	130	140	150	160
D(Cs-Au) (Gy)	11	19	28	38	47	58	68	80	91	103	115	128				
D(Cs-I) (Gy)		13	22	31	41	51	61	71	82	93	103	114	126	137	149	162
D(Cs-Pd) (Gy)		25	38	51	64	77	90	103	116	129	141	154	166			

Luo et al. Med Phys 41: 024101 (2014).

PSI for Brain Cancer

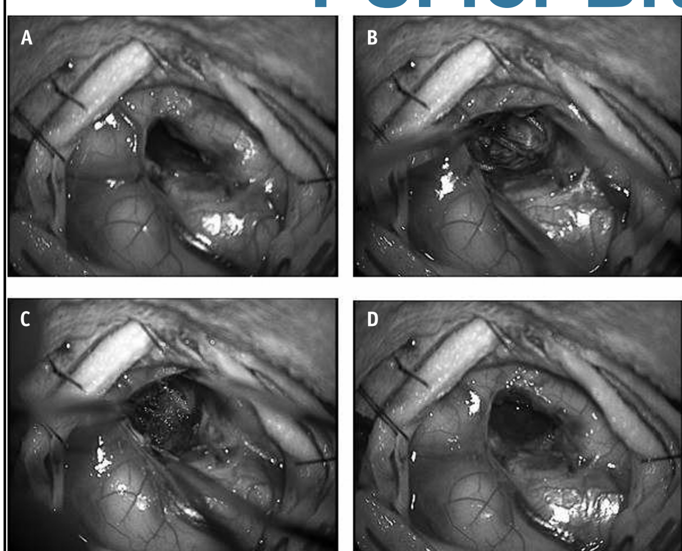


Fig. 1. Surgical technique for applying ^{131}Cs brachytherapy to the cavity of a resected brain metastasis. (A) Resected brain metastasis showing a resection cavity prepared for ^{131}Cs implantation. (B) Resection cavity lined with ^{131}Cs seeds in a pattern similar to barrel staves or parallel tracks. (C) The resected cavity lined with ^{131}Cs seeds and covered with Surgicel. (D) Resected cavity lined with ^{131}Cs seeds and filled with fibrin glue (TISSEEL).

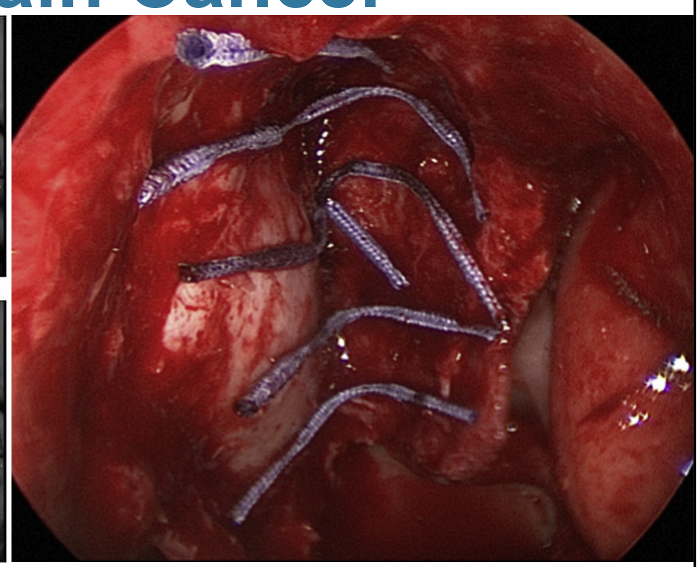
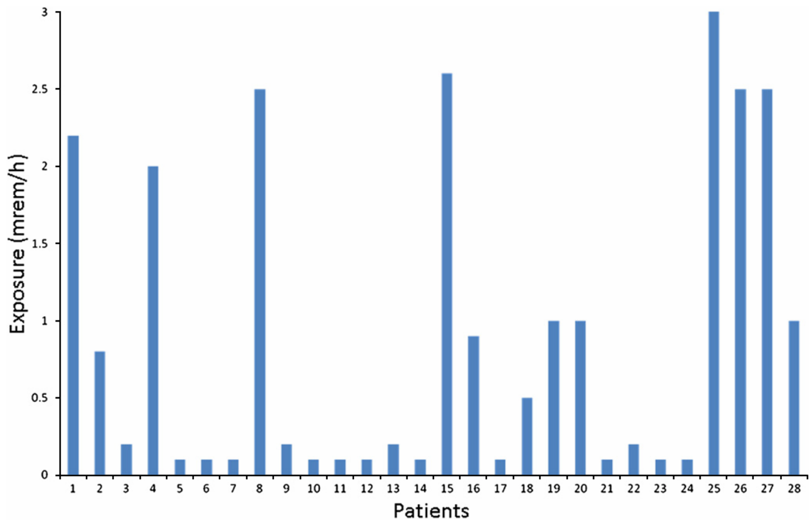


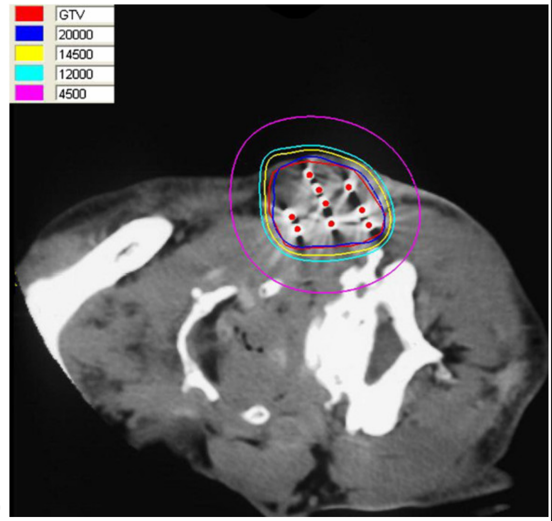
Fig. 2. Resection cavity after neurosurgical resection of tumor and Cs-131 seed implantation. After tumor resection, Cs-131 stranded seeds (IsoRay, Richland, WA) with 3–5 mCi activity were implanted with a planned dose of 80 Gy to a 5 mm depth from the resection cavity surface based on our institutional physics nomogram. Cs-131 suture-stranded seeds delivered as strings of 10 seeds were cut into smaller lengths and placed along the cavity in a tangential pattern to maintain a 7–10 mm spacing between seeds. The cavity is lined like "barrel staves" or "parallel tracks" and covered with Surgicel (Ethicon) and Tisseel (Baxter) to prevent seed migration and limit cavity shrinkage.

Wernicke et al. IJROBP 98: 1059-1068 (2017).

Mahase et al. Brachytherapy 18: 258-270 (2019).

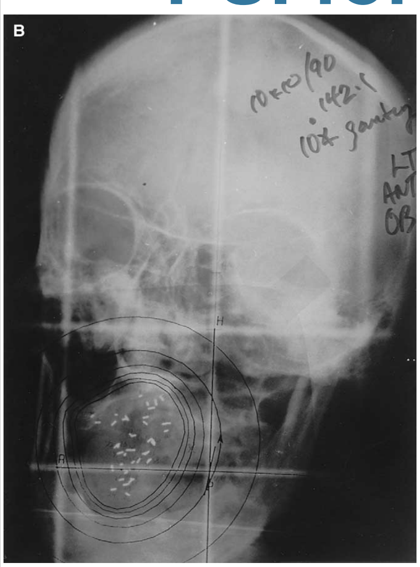
PSI for Head & Neck Cancer

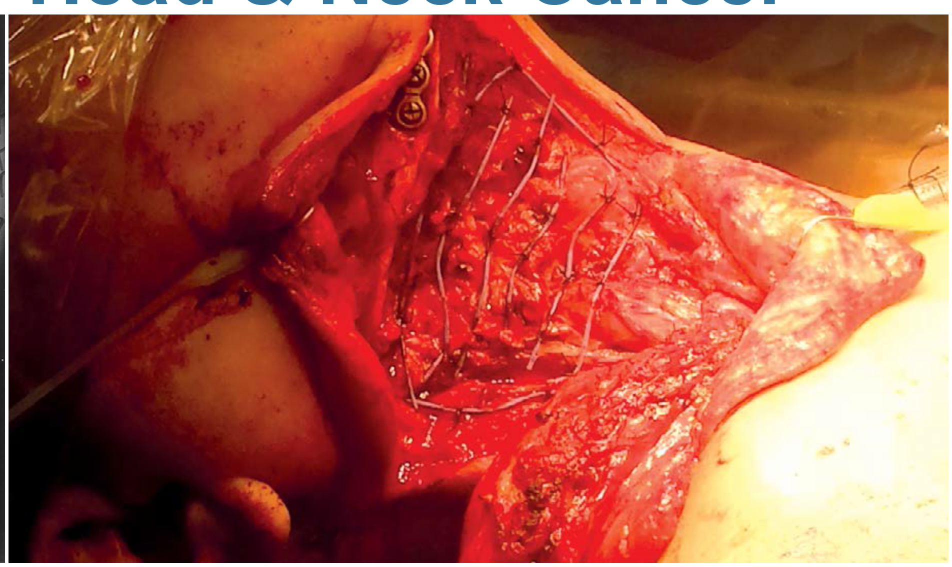




Parashar et al. Brachytherapy 10: 508-513 (2011).
Zhu et al. World J Surg Oncol 11: 60 (2013).

PSI for Head & Neck Cancer





Ashamalla et al. Brachytherapy 1: 161-166 (2002).
Pham et al. J. Contemporary Brachytherapy 7: 445-452 (2015).

Conclusions

- PSI has been used successfully for many years for a variety of anatomic sites
- surgical techniques are more streamlined, using CT/MRI/US for pre-implant planning
- newer radionuclides and source assemblies can improve dose distributions

Related Reading: Lung

- Chen et al. Intraoperative ^{125}I brachytherapy for high-risk stage I non-small cell lung carcinoma. IJROBP 44: 1057-1063 (1999).
- Lee et al. Limited resection for non-small cell lung cancer: Observed local control with implantation of I-125 brachytherapy seeds. Ann Thorac Surg 75: 237-243 (2003).
- Johnson et al. Dosimetric and technical aspects of intraoperative I-125 brachytherapy for stage I non-small cell lung cancer. Phys Med Biol 52:1237-1245 (2007).
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- Fernando et al. Analysis of longitudinal quality-of-life data in high-risk operable patients with lung cancer: Results from the ACOSOG Z4032 (Alliance) multicenter randomized trial. J Thorac Cardiovasc Surg 149: 718-725; discussion 725-726 (2015).
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Related Reading: Breast

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- Pignol et al. Tolerance and acceptance results of a palladium-103 permanent breast seed implant Phase I/II study. IJROBP 73: 1482-1488 (2009).
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- Pignol et al. Report on the clinical outcomes of permanent breast seed implant for early-stage breast cancers. IJROBP 93: 614-621 (2015).
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- Crook et al. Permanent breast seed implant for partial breast radiotherapy after partial mastectomy for favorable breast cancer: Technique, results, and applications to various seroma presentations. Brachytherapy 18: 510-520 (2019).

Related Reading: Brain

- McDermott et al. Interstitial brachytherapy for malignant brain tumors. Semin Surg Oncol 14: 79-87 (1998).
- Huang et al. Surgical resection and permanent iodine-125 brachytherapy for brain metastases. J Neurooncol 91: 83-93 (2009).
- Ruge et al. Stereotactic ^{125}Iodine brachytherapy for treatment of singular brain metastases: Closing a gap? Neurosurgery 68: 1209-1218 (2011).
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- Luo P et al. Determination of prescription dose for Cs-131 permanent implants using the BED formalism including resensitization correction. Med Phys 41: 1-8 (2014).
- Pham et al. Neurocognitive function and quality of life in patients with newly diagnosed brain metastasis after treatment with intra-operative cesium-131 brachytherapy: A prospective trial. J Neurooncol 127: 63-71 (2016).
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- Chitti et al. The role of brachytherapy in the management of brain metastases: a systematic review. J Contemporary Brachytherapy 12: 67-83 (2020).

Related Reading: Head & Neck

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