Intra-Operative Radiation Therapy using Mobile Linear Accelerators

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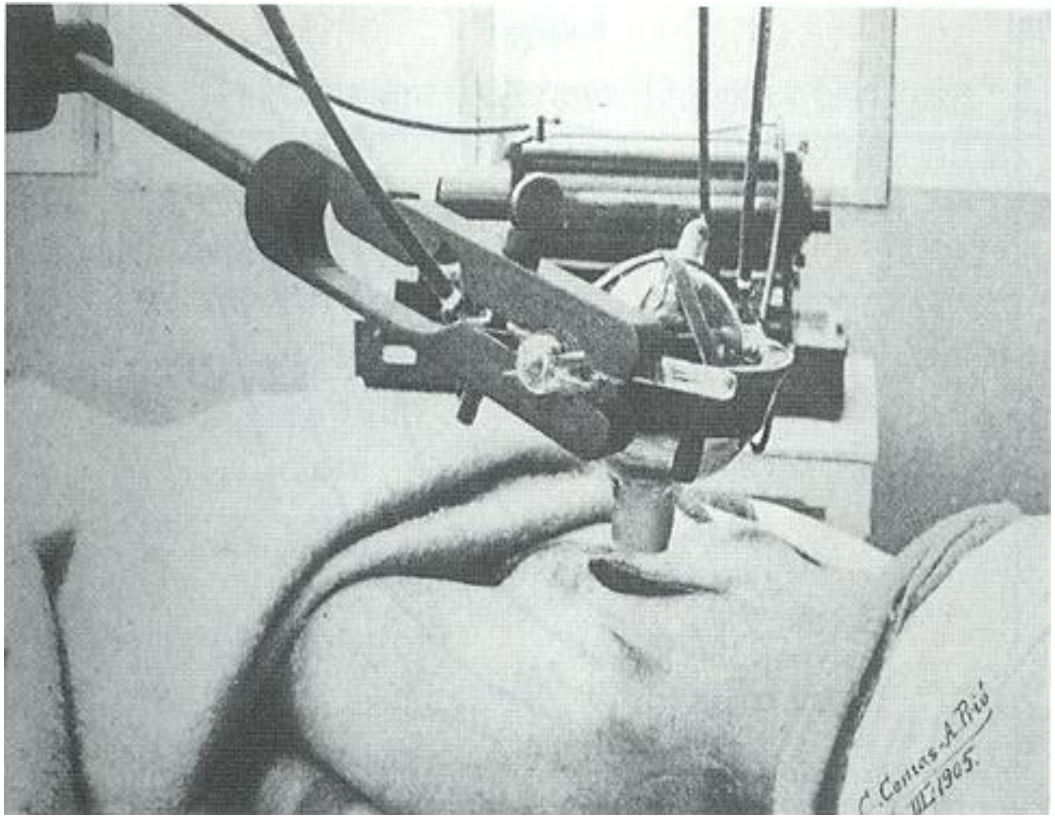
1905 – Carl Beck



History of IORT

- 1st report of IORT in 1907 by Carl Beck
- 1964 Abe in Japan
- 1st US IORT in 1975 @ Howard University
- MGH 1978, NCI 1979, Mayo Clinic 1981, Joint Center 1982, MCO 1983

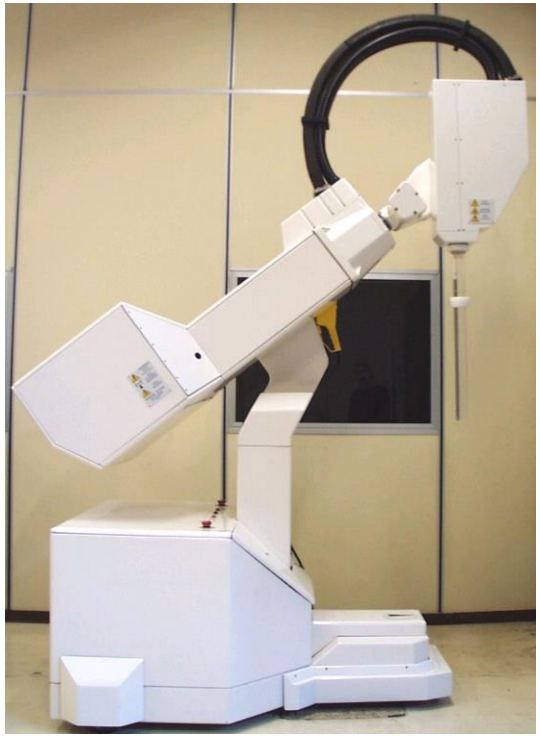
- 1st Mobile LINAC: Novac7 in Italy in 1997
- 1st Mobile LINAC Mobetron prototype in the US: UCSF in 1998
- 1st Commercial Mobetron installed @ University Hospitals of Cleveland in 1999

Before the mobile systems

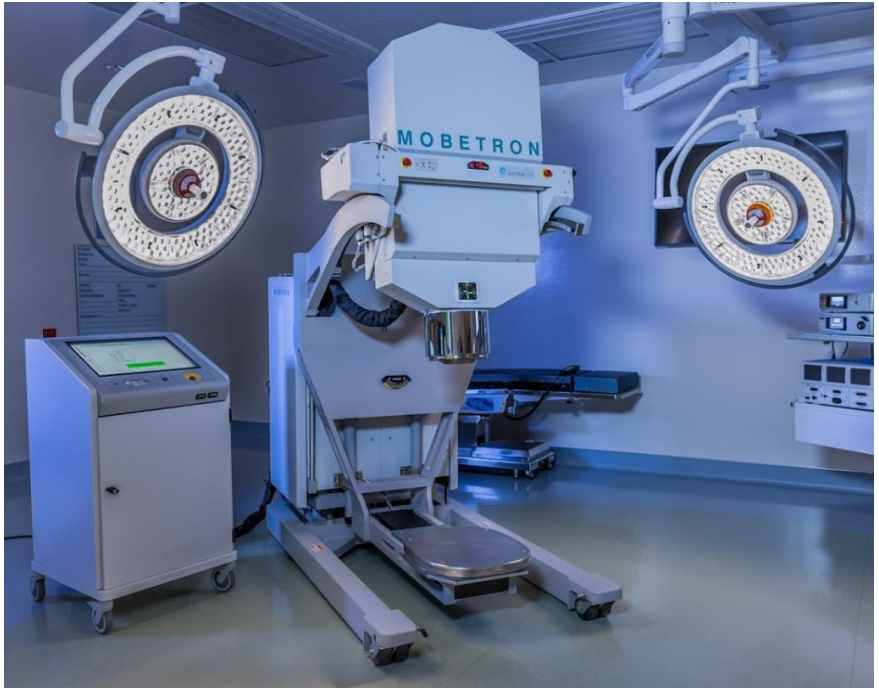
- The tremendous logistics to transport the patient under anesthesia from the OR to radiation oncology deterred many centers from implementing the procedure

- Many centers lost interest after only few cases

Novac 7



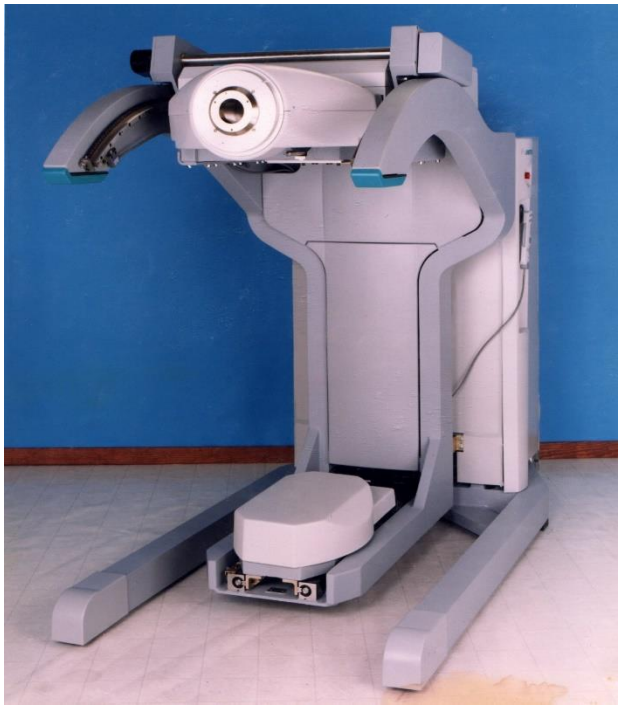
Mobetron 2000



Mobetron 2000

Mobetron 1000

Transport Mode



Treatment Mode

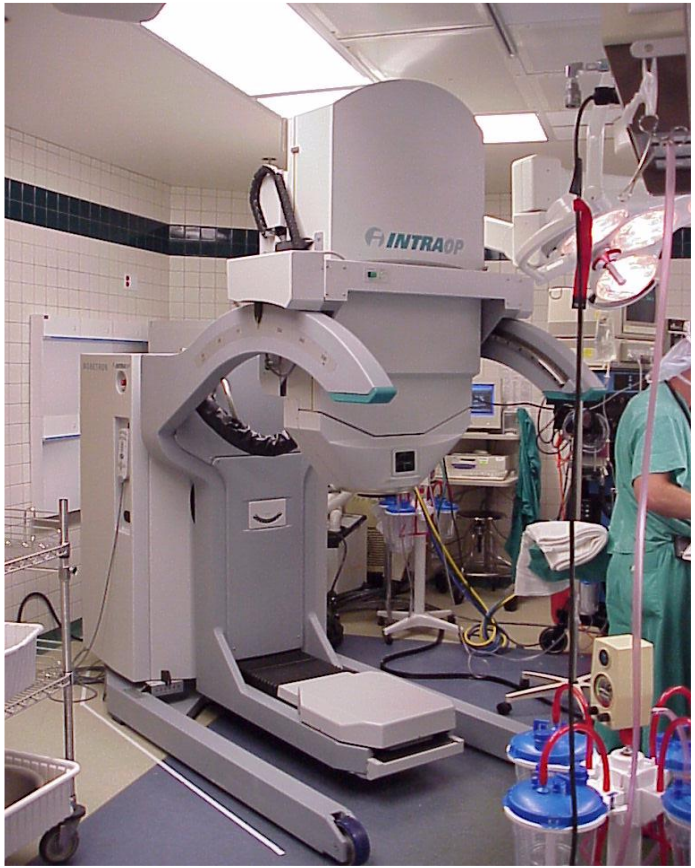
Commissioning – before & after

… It goes around corners

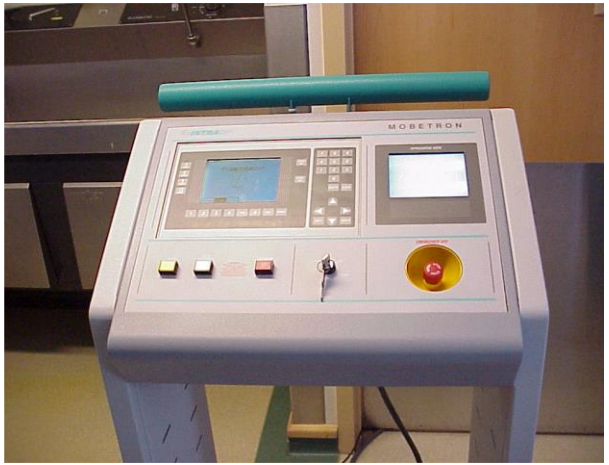
… to the OR floor

…it fits in elevators,
but
can’t walk up stairs yet

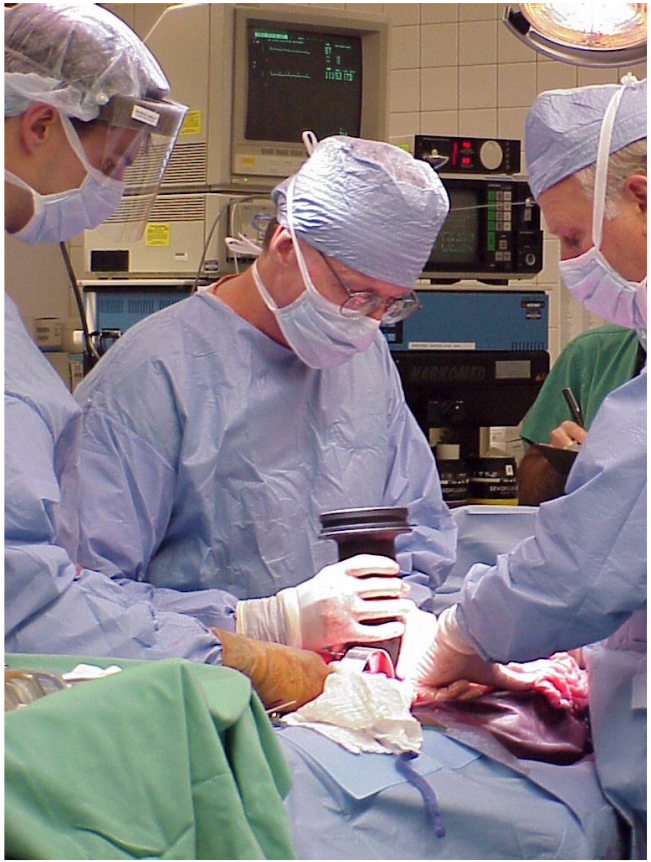
… in the OR

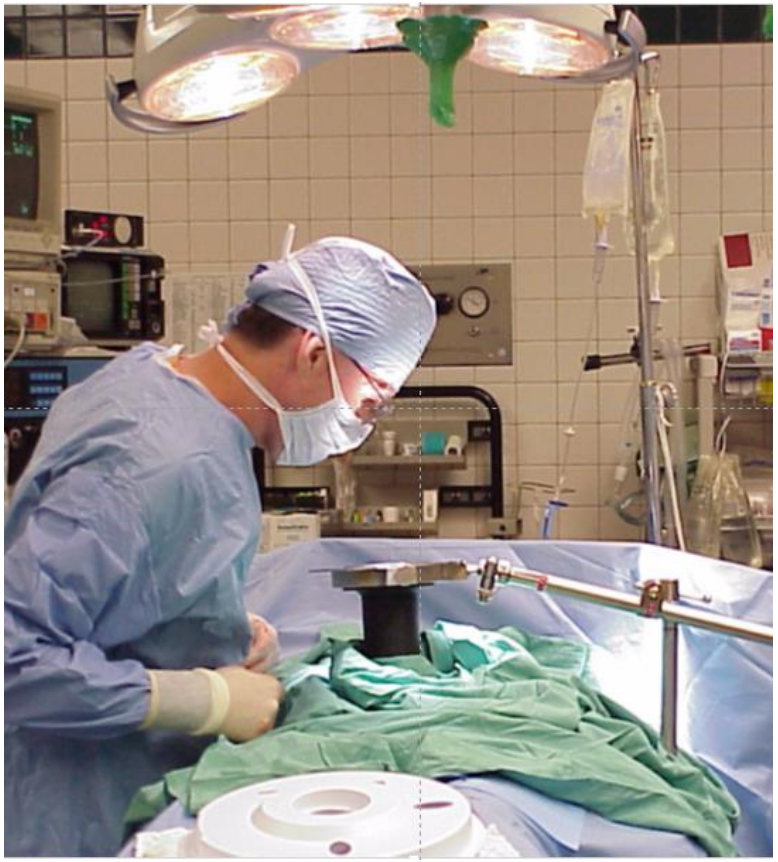


Control console outside the OR



Applicator Placement

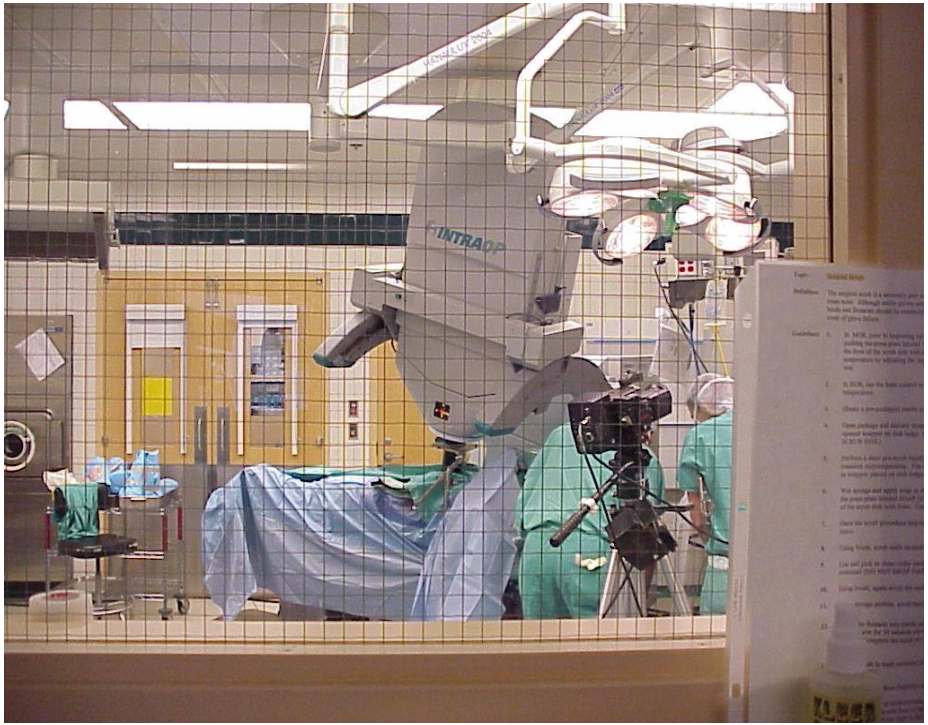




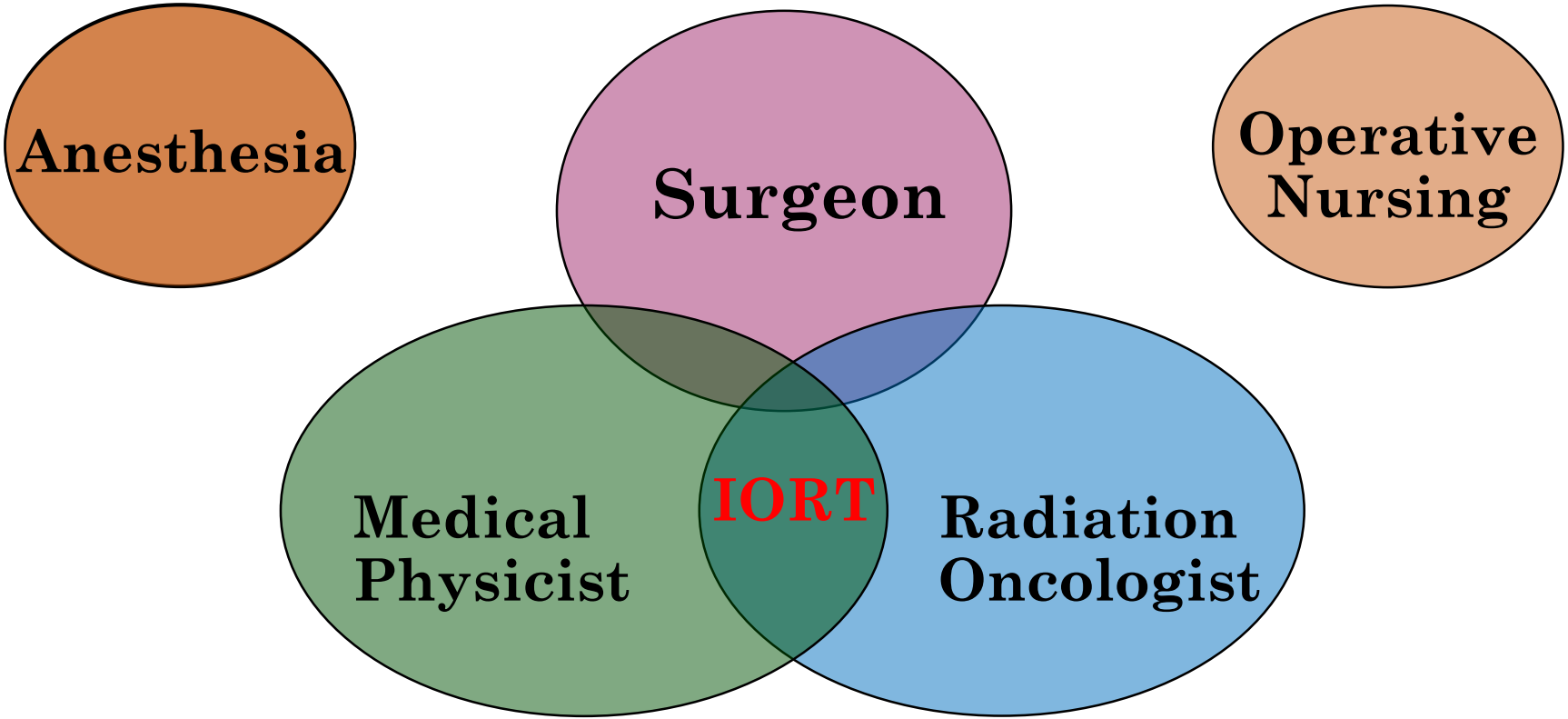
Almost ready to treat

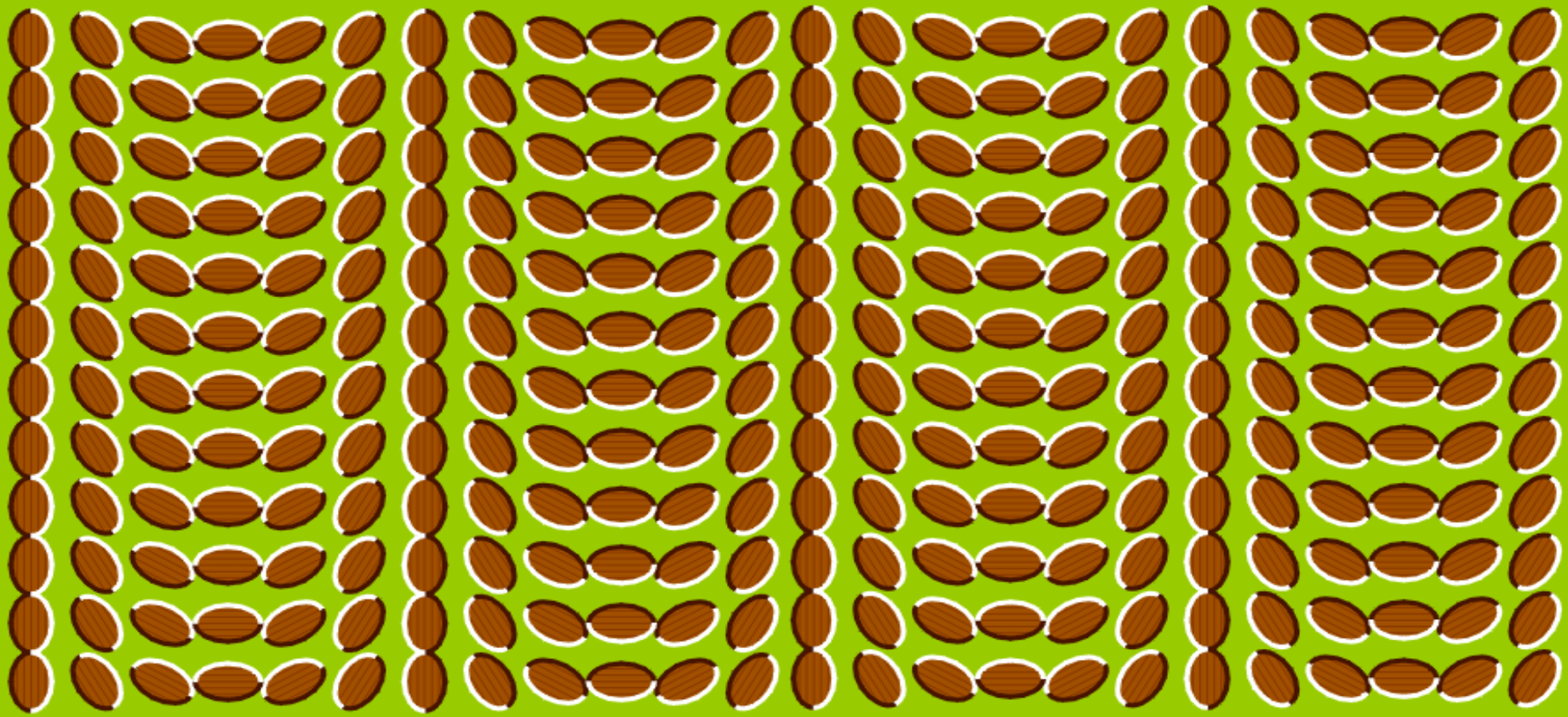
Soft Docking – Laser Alignment System

Treatment Delivery

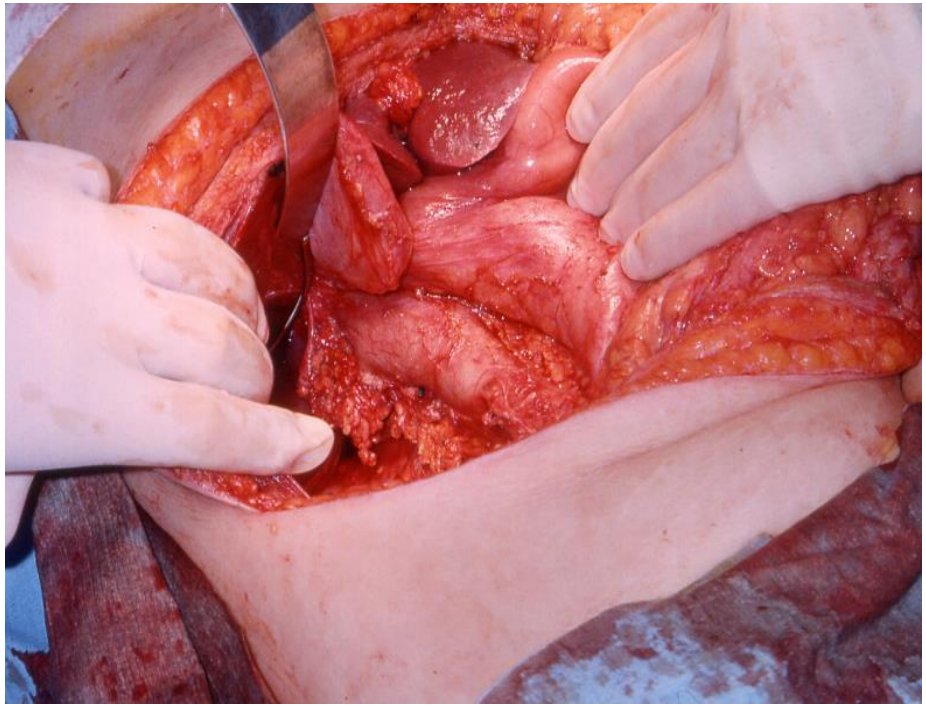


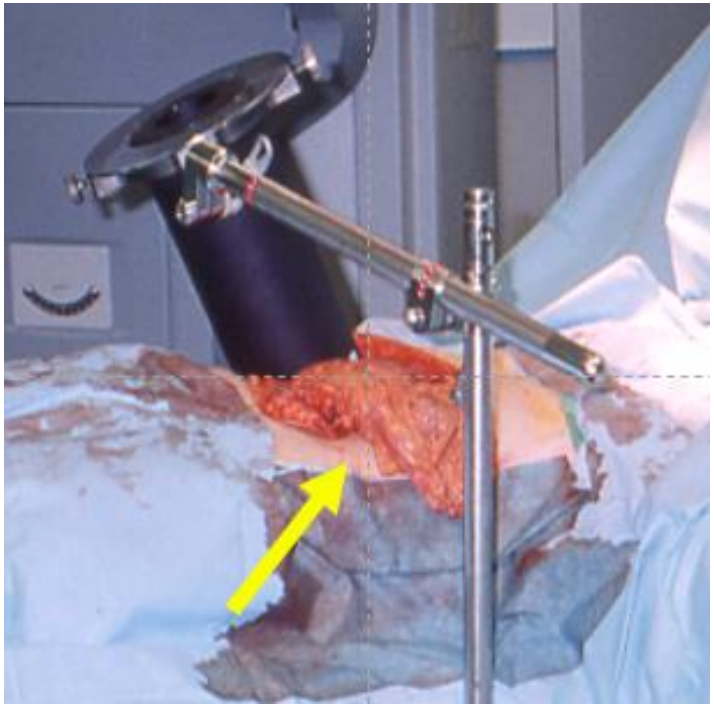
Multidisciplinary: Roles & Team Work





Advantages of IORT

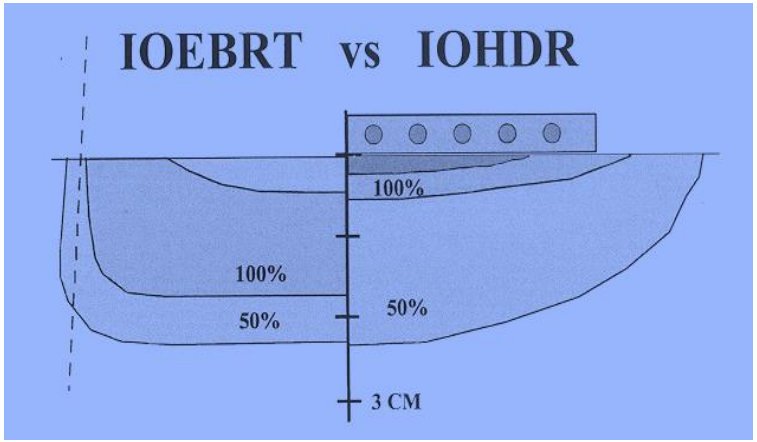


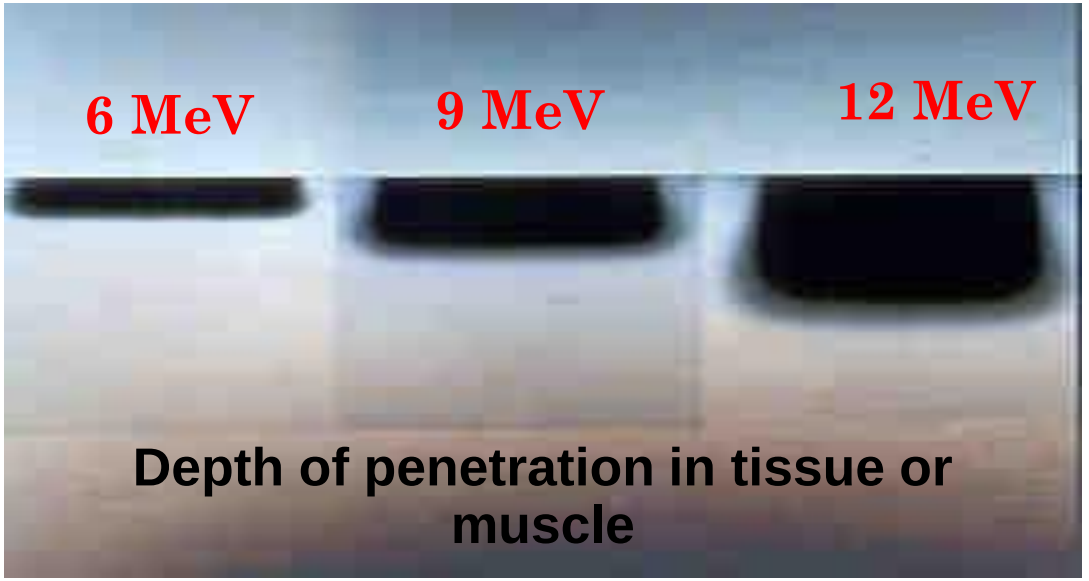


Advantages of IORT

- **Provides a large dose of radiation to the tumor/ tumor bed at the time of surgery, while normal tissues can be displaced from the radiation field**
- **Potentially decreases side effects and complications of radiation therapy**
- **Shortens overall treatment time for the patients by decreasing the number of visits to the Radiation Oncology Department**
- **Social niche (breast cancer)**
  - **poor countries, with no access to breast conservation - an alternative**
  - **rich countries, where patients can’t fit RT treatment into their schedules**

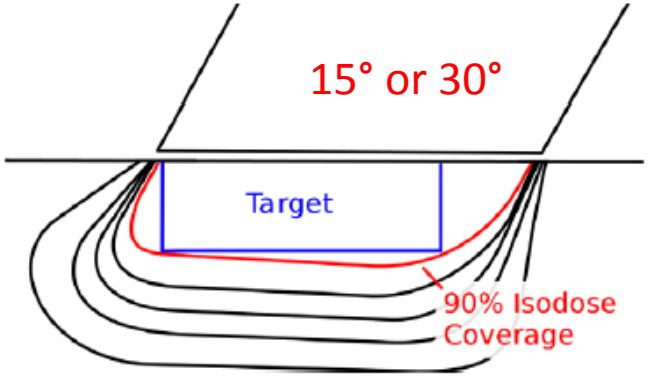
Advantages of IORT





Machine Characteristics

- Electron energies: 4, 6, 9 and 12 MeV with dose rates up to 10Gy/min
- Flat and beveled electron applicators (3.0 to 10.0 cm, 0.5 cm increments)
- Plastic Boluses (0.5 or 1.0 cm)
- Soft-docking system
- 50 cm nominal SSD, non-isocentric
- 6 degrees of freedom (3 transl., 3 rot.)
- Beam stopper tracks the beam (self-shielded)
- No need for shielding in the OR
- Plugs into normal 3-phase electrical outlet / single-phase input



Wootton et. al., 2016

Why No Shielding Requirements?

- Electron Beam Only– Low beam current greatly reduces radiation leakage.
- No Bending Magnet – The most significant source of leakage in a conventional accelerator is eliminated.
- X-ray Contamination – Extremely Low!

A self-shielded accelerator

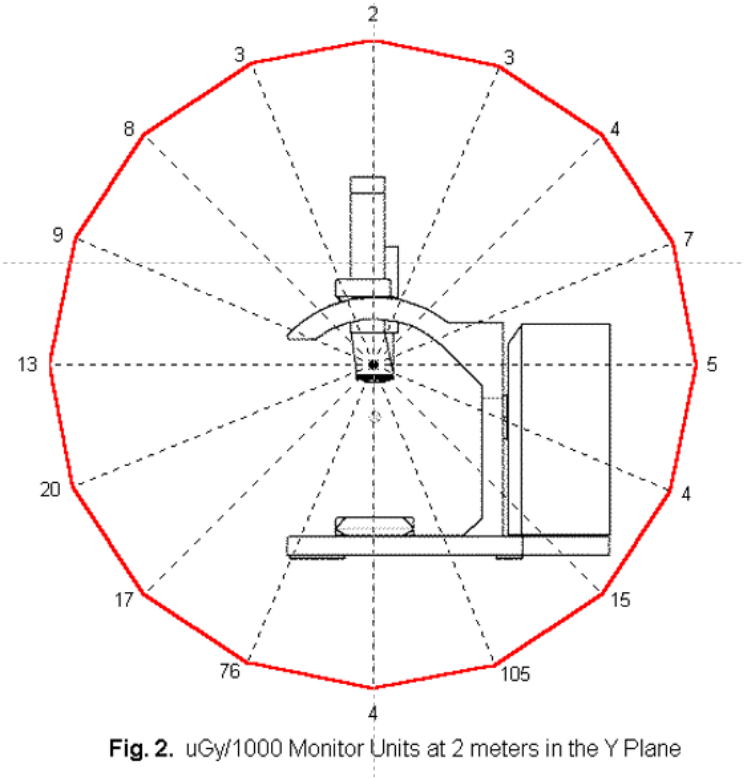


Fig. 2. uGy/1000 Monitor Units at 2 meters in the Y Plane

Mills et. al., 2001

Intraoperative radiation therapy using mobile electron linear accelerators: Report of AAPM Radiation Therapy Committee Task Group No. 72

TABLE OF CONTENTS

I. INTRODUCTION. 1477
II. IORT USING MOBILE VERSUS STATIONARY LINEAR ACCELERATORS. 1477
III. IMPLEMENTATION OF AN IORT PROGRAM WITHIN AN OPERATING ROOM ENVIRONMENT. 1478
IV. RADIATION PROTECTION. 1478
A. Regulatory considerations. 1479
B. Radiation site plan. 1479
1. Treatment operating rooms. 1479
2. Commissioning and annual quality assurance location. 1479
C. Radiation survey. 1479
D. Exposure rate measurements. 1479
V. ACCEPTANCE TESTING AND COMMISSIONING. 1480
A. Acceptance testing measurements. 1480
B. Commissioning and dose measurements. 1482
VI. RECOMMENDED QUALITY ASSURANCE. . . . 1484
A. Previous quality assurance recommendations for medical linear accelerators. 1484
B. Quality assurance for mobile electron accelerators. 1484
VII. CLINICAL ASPECTS OF IORT TREATMENT DELIVERY: DOSE SPECIFICATION. 1486
VIII. RECOMMENDATIONS FOR FUTURE CONSIDERATIONS. 1487

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Additional Slides for References

Disclaimer

I am only providing these additional slides for additional information and educational purposes to complement my personnel presentation and experience using the Mobetron 1000. The slides below were obtained from IntraOp Medical to show the new version of the Mobetron: Mobetron 2000.

The author has no direct affiliation with Intraop Medical, Inc. and received no financial support for the research reported in his work in the past/present or for giving this invited presentation.

The author thanks Derek Descioli, VP Global Sales. IntraOp and Dan Goer, Co-Founder of IntraOp in 1993 and serving currently as its Chief Scientist.

IntraOp Mobetron Treatment Applications

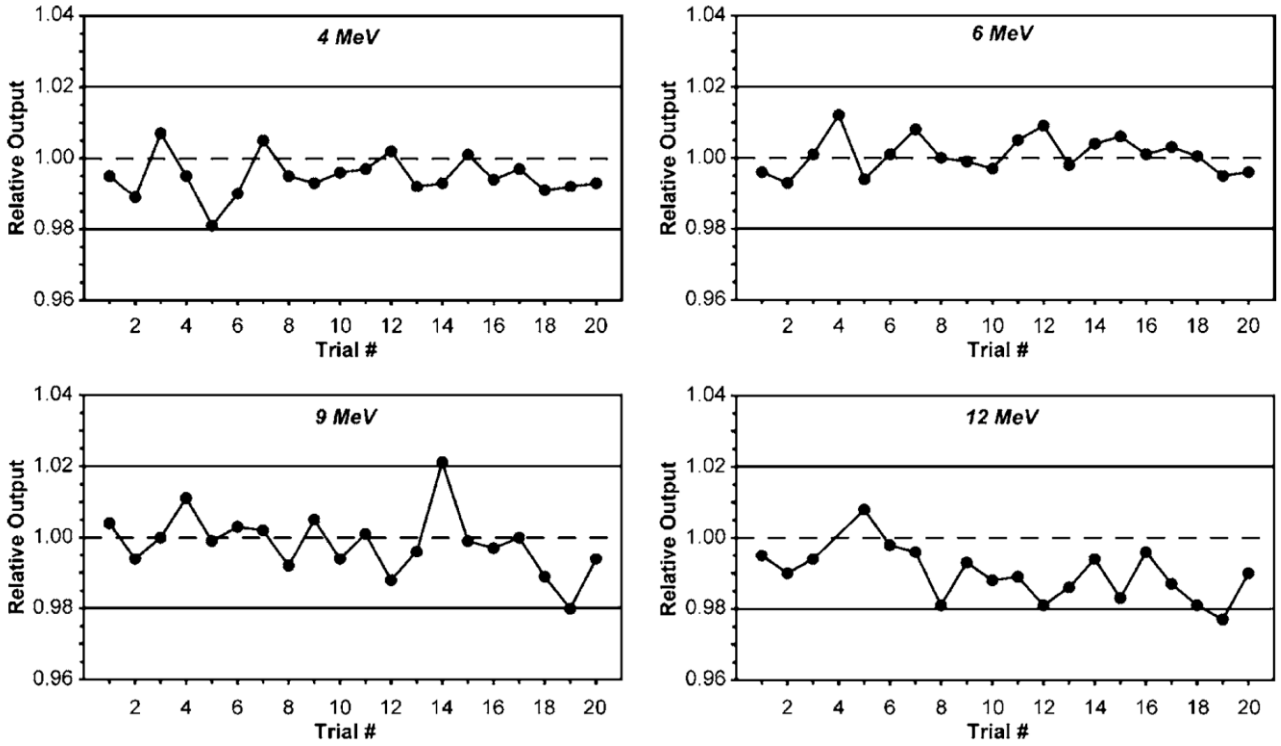
Treatment Application Characteristics

Tumor	Energy [MeV]			Applicator diameter [cm]	Bevel [deg]			½ cm sized applicators
	6	9	12		0	15	30	
Breast	26%	48%	24%	4 – 6 (84%)	53%	31%	15%	35%
Colorectal	35%	50%	10%	4 – 7 (86%)	8%	4%	88%	21%
Pancreas	24%	26%	49%	5 – 7 (77%)	73%	12%	16%	22%
Sarcoma-Extremity	45%	46%	8%	10 (30%)	39%	13%	48%	12%
Sarcoma-RPS	22%	58%	19%	10 (23%)	34%	8%	58%	11%

Source: IntraOp Mobetron User Database

IntraOp Mobetron Output Stability

Mobetron Output Variation for Various Energies



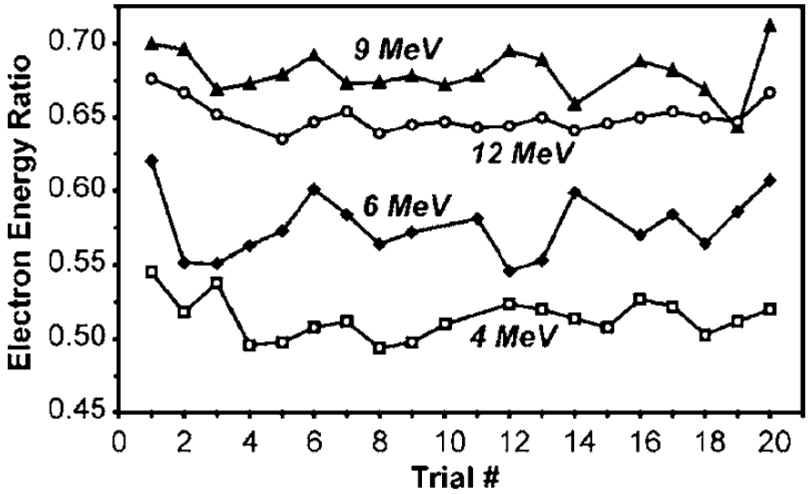
Source: Beddar, et al. 2005

Mobetron Long Term Stability

	Absolute Calibration Output (cGy/MU)			
Electron Energy	4 MeV	6 MeV	9 MeV	12 MeV
Commissioning 1999	0.999	0.997	0.993	1.001
Annual Calibration 2000	0.987	0.993	1.004	1.010
Percent Change (%)	- 1.2 %	- 0.4 %	+ 1.1 %	+ 0.9 %

Source: Beddar, Et al. 2005

Mobetron Energy Ratio Variation



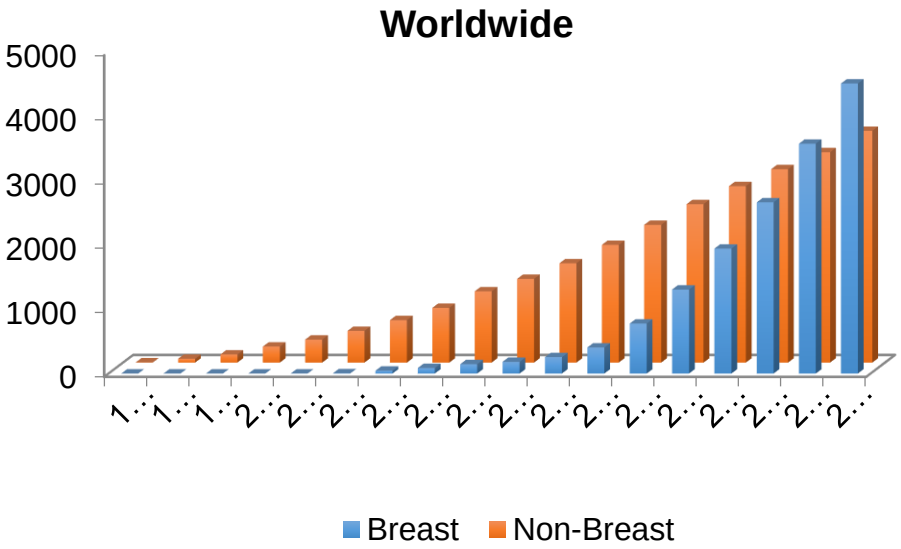
Equivalent PDD Shift	
4 MeV	0.6 mm
6MeV	0.8 mm
9 MeV	0.8 mm
12 MeV	0.4 mm

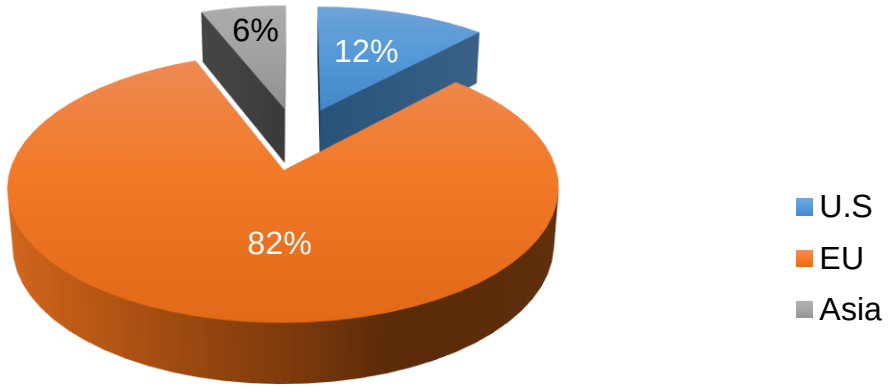
Source: Beddar, et al. 2005

Technical and Clinical Review of Mobetron Usage

Mobetron Treatments Characteristics

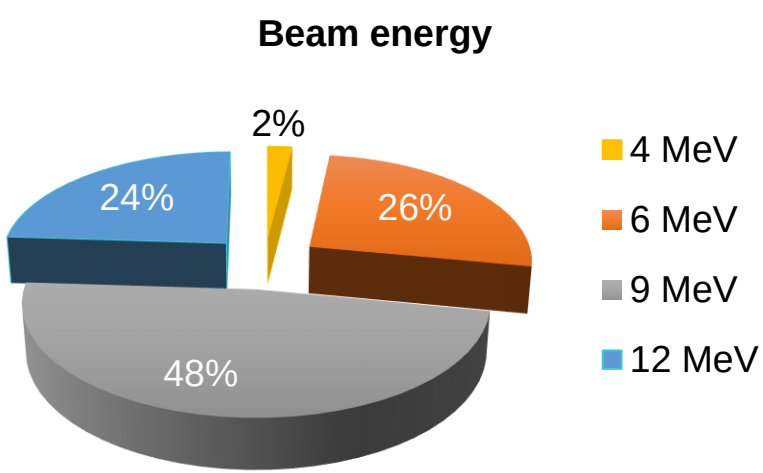
- Worldwide, 56% of Mobetron treatments were for breast cancer (83% in Europe, 20% in the U.S, and 33% in Asia).
- For the non-breast data main sites were: Colorectal (21%), Pancreas (15%), Extremity Sarcomas (22%) and RPS (8%).

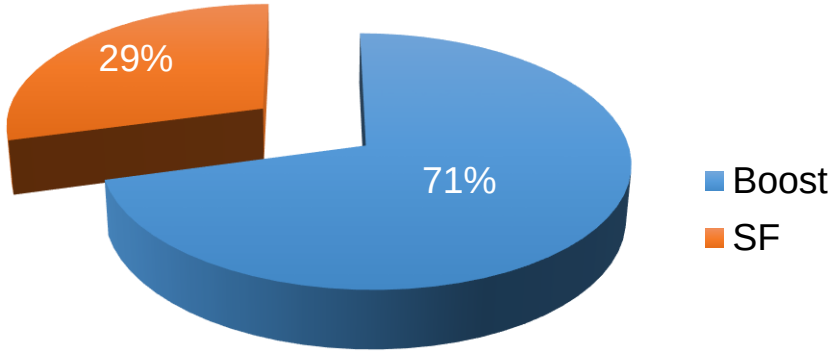




Breast data characteristics

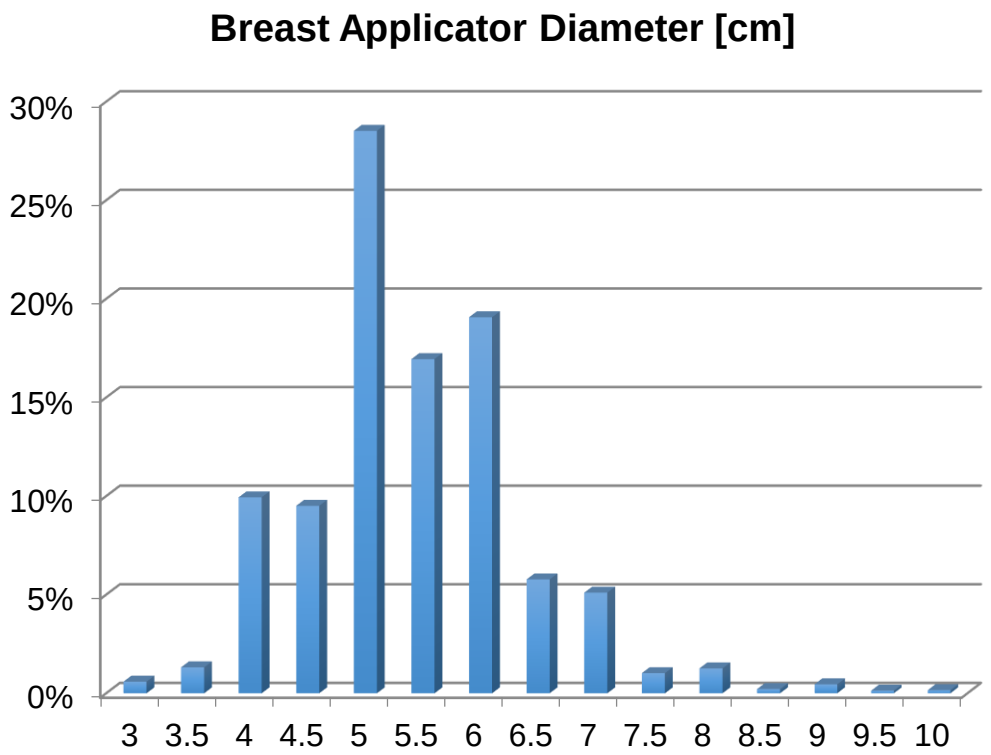
- For the breast data received:
  - 71% of breast patients were treated as a boost (75% EU, 72% U.S., 16% Asia).
  - 29% of boost treatments followed by 3 weeks EBRT.
  - 48% were treated at 9 MeV; 26% at 6 MeV; and 24% at 12 MeV (2% @ 4 MeV).





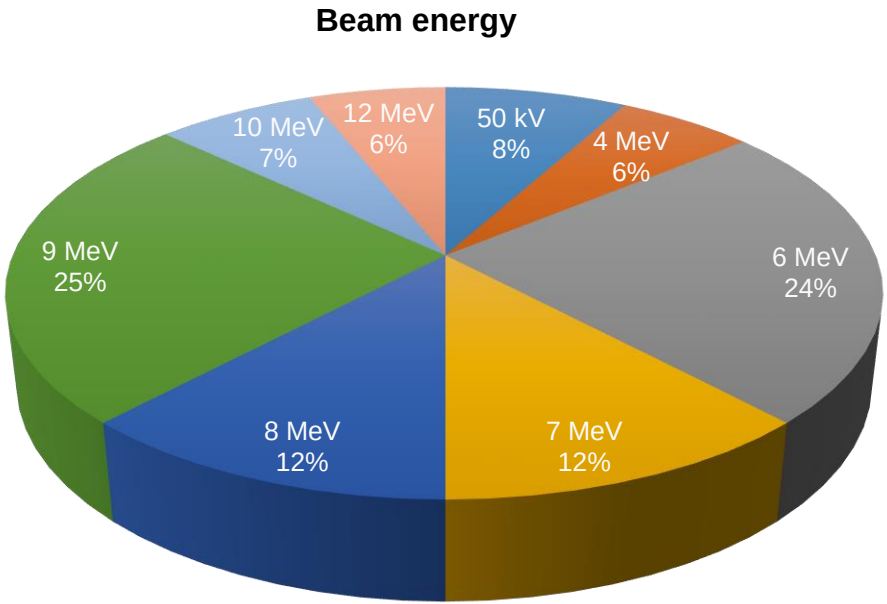
Breast data characteristics (continued)

- For the breast data received:
  - 84% of patients were treated with FS between 4-6 cm.
  - 35% of patients were treated with a ½ cm sized applicator.
  - 3% of patients were treated with a FS > 7 cm.



ISIORT Breast Treatments Characteristics

- 42 Collaborating Centers
- 8,075 Breast cancer patients
  - Median age 61 years (16 – 90)
  - 81.8% T1 and 16.1% T2
  - 96.5% Ductal carcinoma; 3.5% Lobular
  - 52.2% Surgery + IORT
  - 47.8% Surgery + IORT + EBRT
  - CT in 13.2% of cases



Courtesy of Marco Krengli

APBI Single Fraction Treatment Clinical Results

Single Fraction Clinical Results

					ASTRO Suitable			ESTRO Good		
Reference	**Median FU (yrs)**	**Total # pts**	**# LR**	**LR (%)**	**# pts ASTRO Suitable**	**#LR**	**LR (%)**	**# pts ESTRO Good**	**#LR**	**LR (%)**
ELIOT [1]	5.8	585	34	5.8%	135	2	1.5%	-	-	-
ELIOT Out Trial [2,3]	3.5*	1822	75	4.1%	294	3	1.0%	573	7	1.2%
U. of Verona [4,5]	5	226	4	1.8%	128	1	0.8%	160	3	1.9%
Brussels [6]	2	204	1	0.5%	87	1	1.1%	151	1	0.7%
Japan [7]	6	32	0	0%	16	0	0%	28	0	0%
Brazil [8]	4.3	152	5	3.2%	48	0	0%	92	2	1.9%
Naples [9]	4	13	0	0%	7	0	0%	13	0	0%
China [11]	4.3	36	2	5.6%	2	0	0%	6	0	0%
Stanford [10]	6.8	64	1	1.6%	-	0	0%	-	0	0%
Total		**3134**	**122**		**717**	**7**		**1023**	**13**	

Source: Horst et al., Presented at 2016 ASCO Annual Meeting

5 yr LR of <2% for Low Risk Patients

Updated ASTRO APBI Guidelines Affirm the use of Electron IORT

- 2016 ASTRO APBI Consensus Guidelines update removes experimental status for electron IORT in suitable patients
- Citing Evidence from Multivariate analysis on randomized trial with median follow up of 5.8 years
- More than 3,000 patients receiving single treatment electron IORT have been studied in the literature
- Electron IORT is the only single treatment option recognized by the updated ASTRO guidelines

ASTRO Suitable Criteria

AGE:	50 years or older
SIZE:	≤2 cm
NODAL STATUS:	pN0
HISTOLOGY:	IDC/Favorable
MARGINS:	Negative (≥2mm)
ESTROGEN RECEPTOR:	Positive
LVSI:	Negative
DCIS :	Low to intermediate ≤ 2.5 cm
DCIS MARGIN:	Negative (≥ 3 mm)
SYSTEMIC THERAPY:	No neoadjuvant
GRADE:	Any