

IORT Techniques

Mobile Electron Accelerator

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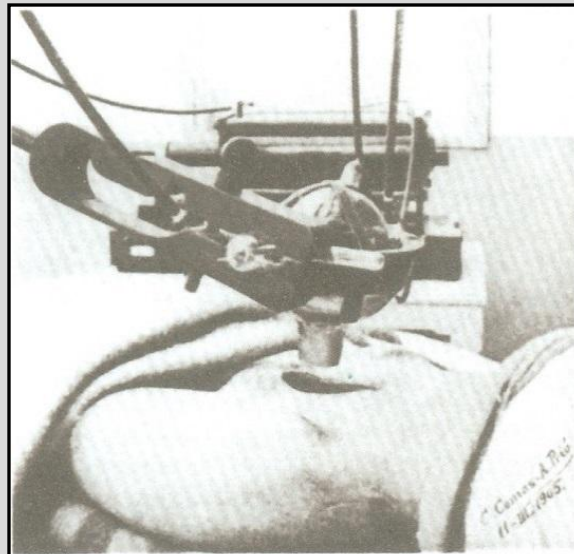


Fig. 1. Photographic document of the case report during roentgen treatment. Notice in the right-lower corner of the figure the note with the picture date: 11th March, 1905.

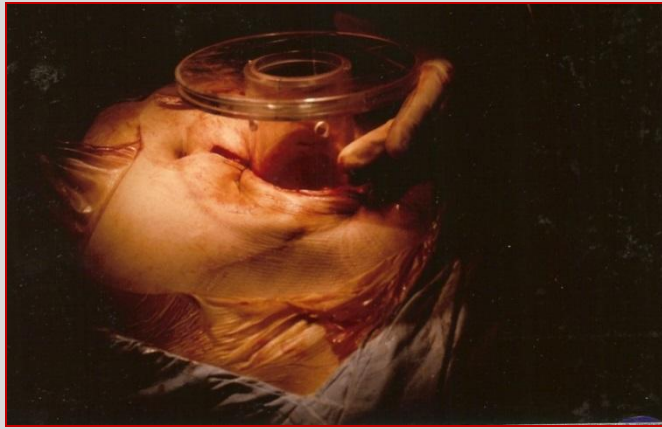


IOERT

- Introduction
- Radiation safety
- PBI treatments
- Surgical technique
- Specific technique
- Thoracic shield
- In vivo dosimetry
- IOERT PTV
- Advantages and disadvantages of IOERT
- Jules Bordet experience
- Results
- Conclusions

IOERT

- Introduction
 - Historical background (late 80's)



IOERT

- Introduction

- **MOBETRON system**

- Mobile linear accelerator self shielded and 'light' (1,2 T)
 - Operate with 9 instead of 3 GHz
 - Accelerated electrons beam of 4, 6, 9 and 12 MeV
 - Dose rate: 10 Gy/min



IOERT

- Introduction

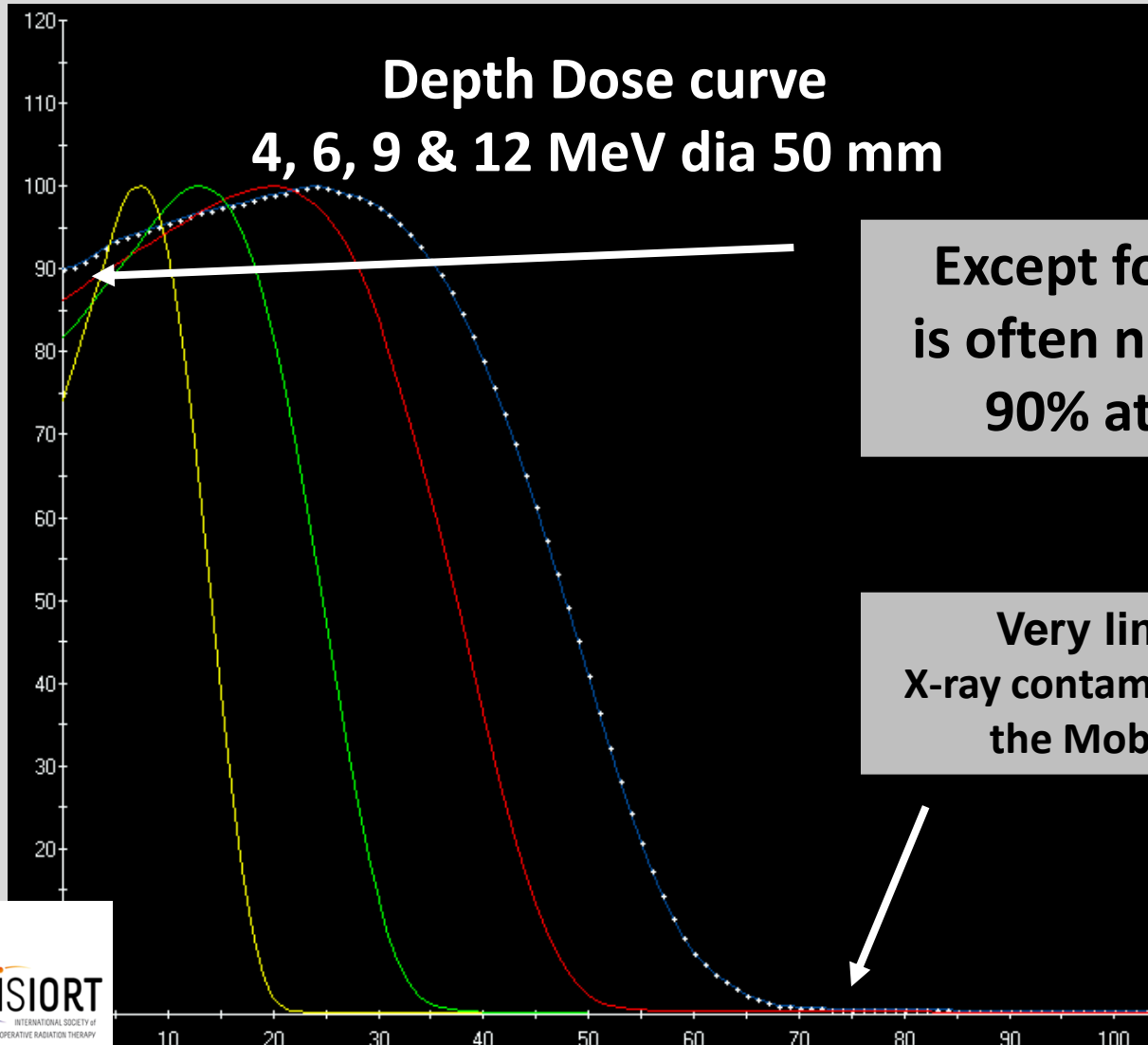
- **MOBETRON system**

- Aluminum applicators of 3 to 10 cm diameter
- 3 tips: flat or beveled (15° and 30°)
- boluses of 5 or 10 mm for every applicator



IOERT

- Technical parameters/Radiation safety



Except for the 12 MeV, a bolus is often needed in order to have 90% at the beam entrance

Very limited braking radiation
X-ray contamination is significantly lower in the Mobetron Beam (0,7 % vs 2 %)

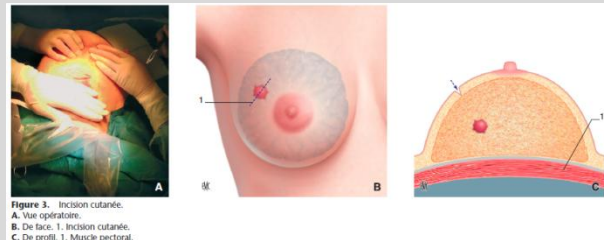
IOERT

- PBI treatments
 - Principles
 - Breast cancer cells: more sensitive to shorts bursts of intense radiation than to small doses fractionated over several weeks
 - Numerous studies: higher radiation doses over shorter treatments periods
 - Emergence of techniques targeting the « at-risk » portion of the breast
 - Assess the risk of recurrence

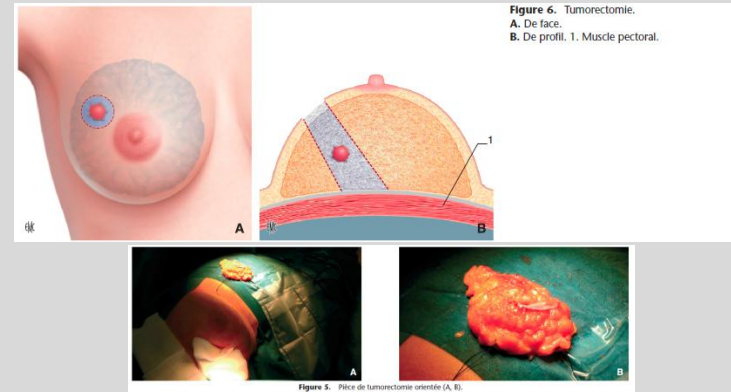
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- Surgical technique

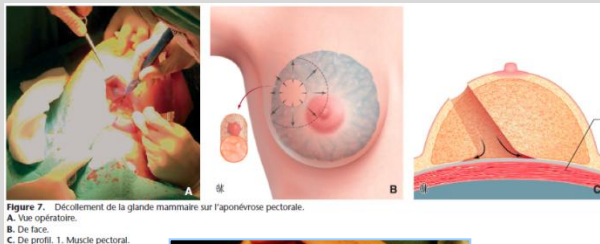
Surgical incision



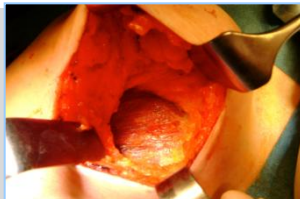
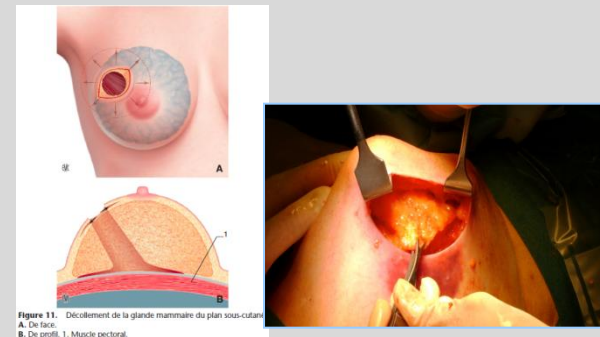
Lumpectomy



Tumour resection till the muscle



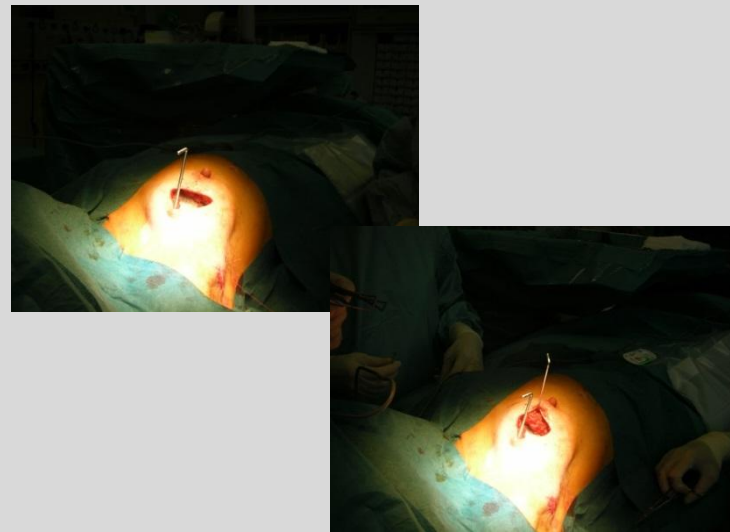
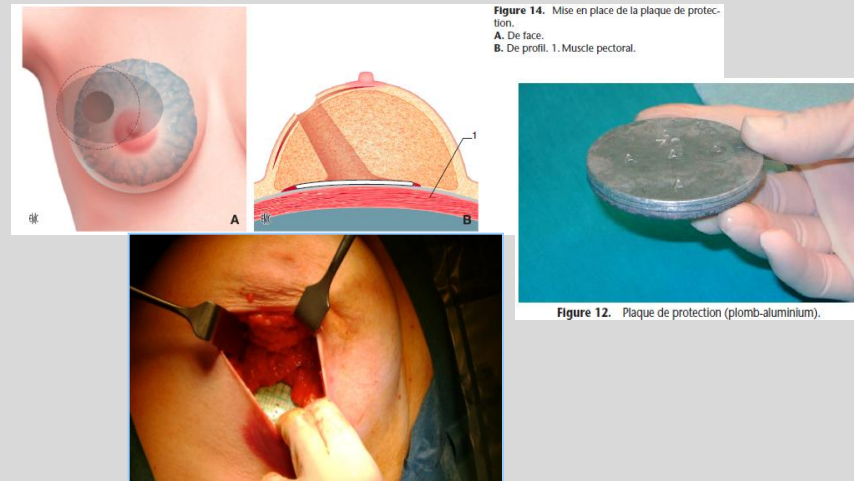
Detachment of the gland



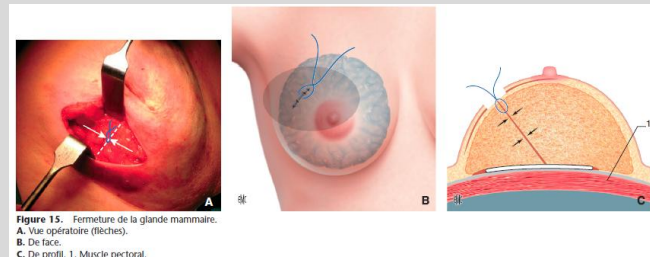
IOERT

- Surgical technique

Shield positioning on the muscle



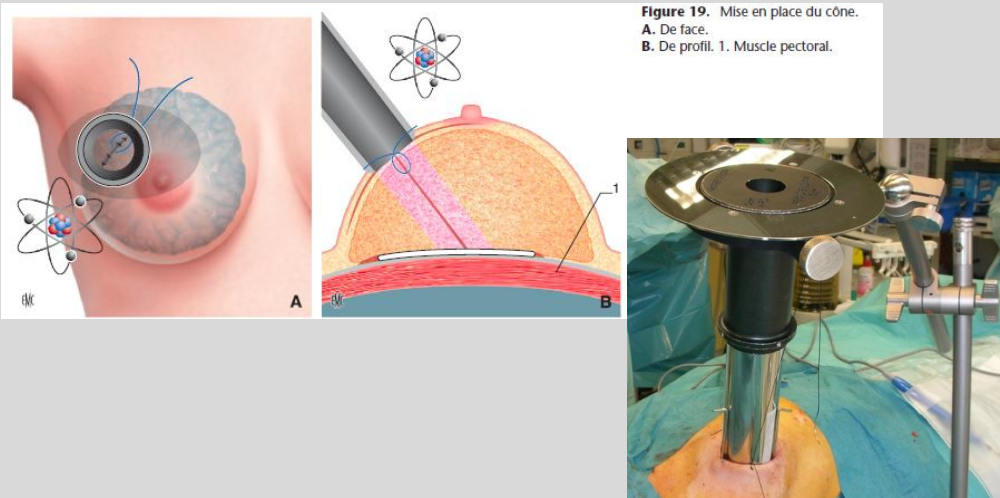
Suture of the tumour bed



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- Surgical technique

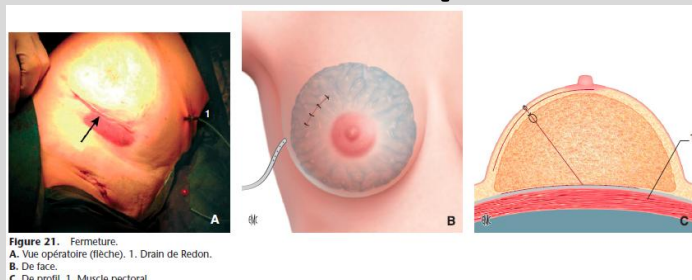
Applicator positioning



Soft docking



Shield extraction, oncoplastic surgery



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- Specific technique
 - **Margins**
 - 10 to 20 mm (except ant & post)
 - Peroperative analysis: margin
 - **Applicator diameter**
 - 40 to 45 mm bigger than the tumour size (perop)
 - **Safety margin**
 - Surgery + IOERT: at least 35-40 mm around the tumour bed

IOERT

- Specific technique – Target volume
 - **Thoracic shield**
 - Diameter: 10 to 15 mm bigger than the applicator (shield coverage)
 - Shield coverage perfect with our new system
 - **Energy choice**
 - In function of the maximum target tissue thickness (measured with a needle)

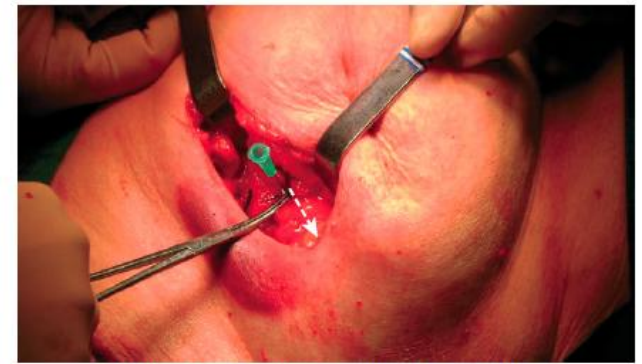
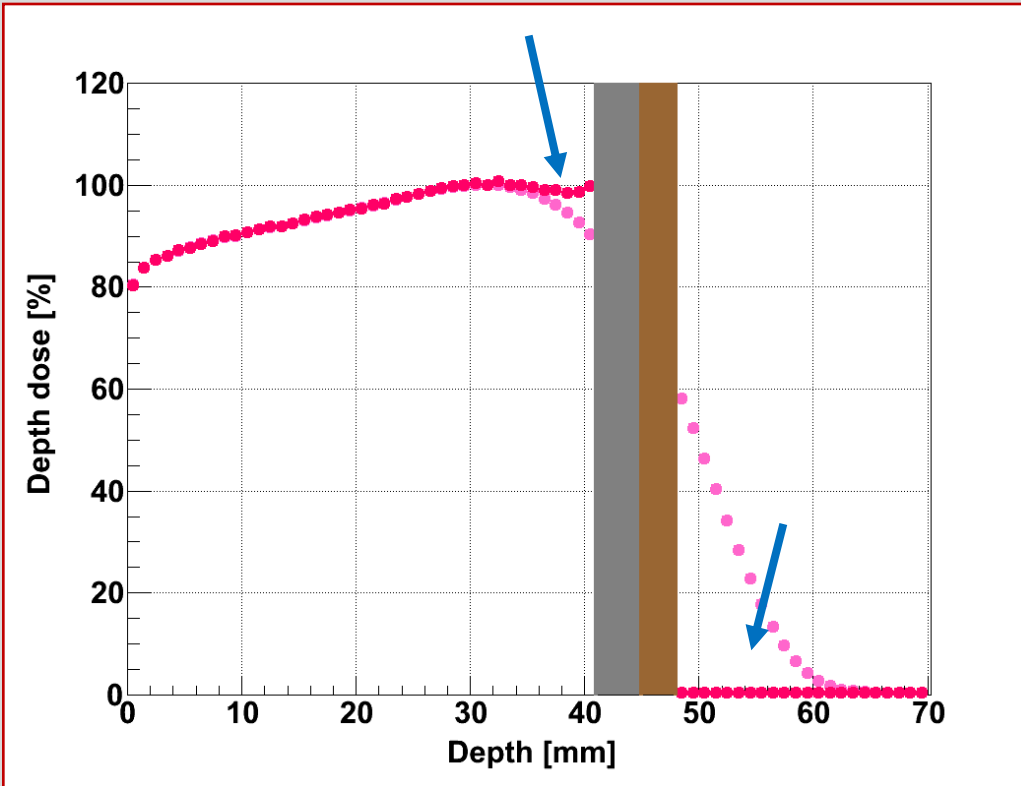


Figure 16. Mesure de l'épaisseur de la glande.

IOERT

- Dosimetric Thoracic Shield assessment



12 MeV PDD curve
Monte Carlo Simulation, with
and without the shield placed at
the depth of the 90% isodose line

Local **10%** dose increase

Range of backscattered electrons:
4 to 11 mm

Almost **no influence** on D_{\max}

4 X 1 mm
Aluminum

3 X 1 mm
Lead



IOERT

- In Vivo Dosimetry

	APBI X-rays Dose (cGy)		
	Thyroid	Breast	Gonads
Mean	0.83	0.41	0.14
St. Dev.	0.59	0.23	0.11
Min.	0.08	0.02	0.01
Max.	3.87	1.97	1.19
Nb	488	481	485



LiF TLD with Build-Up Caps

IOERT

- In Vivo Dosimetry

6 MeV (cGy)

	Thyroid	Breast	Gonads
Mean	0.36	0.25	0.08
St. Dev.	0.17	0.11	0.03
Min.	0.08	0.10	0.04
Max.	0.85	0.81	0.19
Nb	51	51	52

9 MeV (cGy)

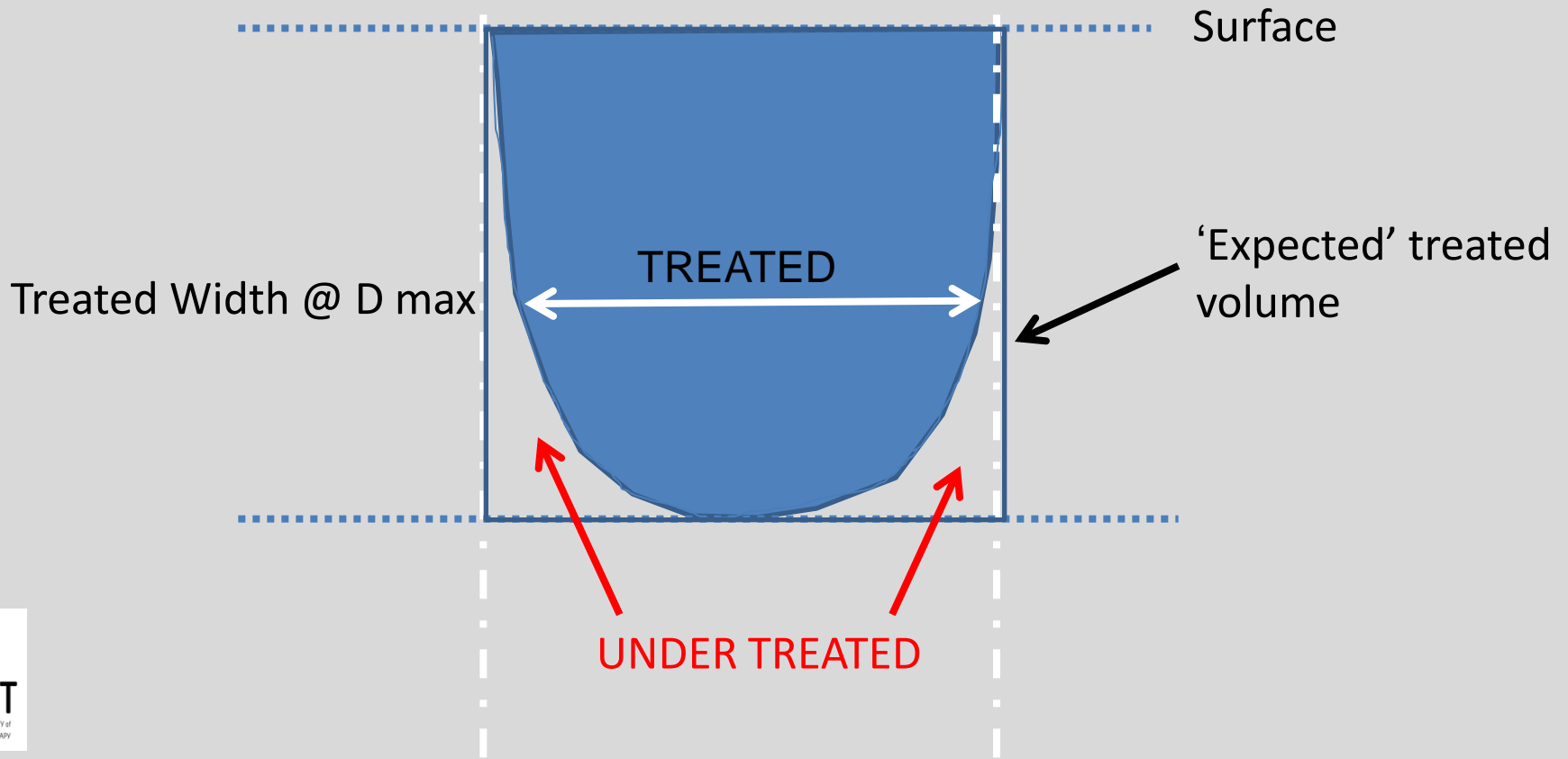
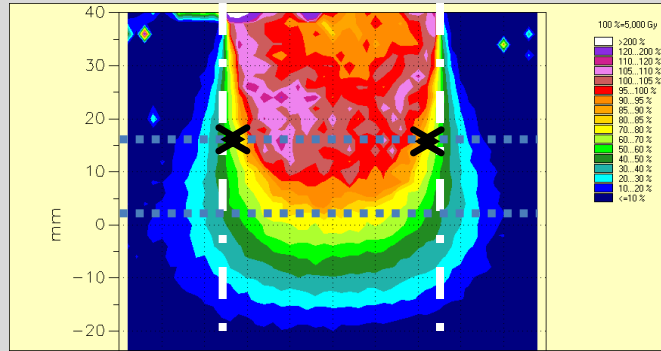
	Thyroid	Breast	Gonads
Mean	0.69	0.37	0.12
St. Dev.	0.49	0.15	0.10
Min.	0.12	0.02	0.01
Max.	3.05	0.91	1.19
Nb	228	227	226

12 MeV (cGy)

	Thyroid	Breast	Gonads
Mean	1.09	0.49	0.17
St. Dev.	0.63	0.29	0.12
Min.	0.21	0.04	0.02
Max.	3.87	1.97	0.63
Nb	208	202	206

IOERT

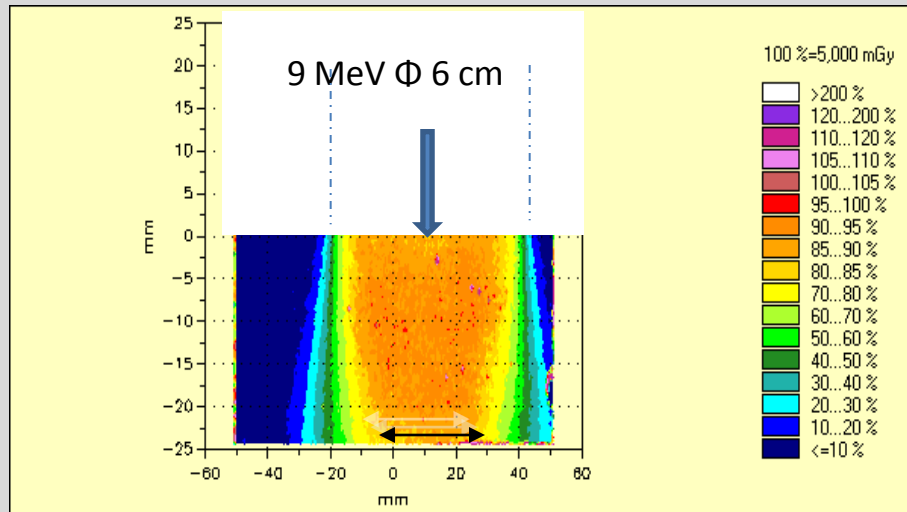
- IOERT PTV



IOERT

- IOERT PTV

Influence of thoracic shield



Increase of treated PTV at 90% isodose depth

IOERT

- Advantages & disadvantages of IOERT
 - **Advantages**
 - High ballistic precision
 - High dose in a single fraction in more sensitive oxygenated cells
 - Dose homogeneity
 - Healthy organs perfectly protected
 - Less side effects
 - **Disadvantages**
 - Ignorance of the final pathological results
 - Technique not available in all radiotherapy centers

IOERT

- Jules Bordet Inclusion criteria
 - More than 40 years old
 - Ductal invasive carcinoma (preoperative biopsy)
 - pT less than 20 mm (peroperative analysis)
 - Free margins (peroperative analysis)
 - Unicentric (MRI)
 - Unifocal (MRI)
 - All HR
 - All grade
 - pN0 (peroperative analysis)
 - No EIC or LVI (preop biopsy)

IOERT

- Jules Bordet Experience
 - February 2010 till February 2014
 - 425 patients (8 bilateral IOERT)
 - Dose 21 Gy on the 90% isodose
 - Follow-up: median 23.6 months



IOERT

- Jules Bordet Experience

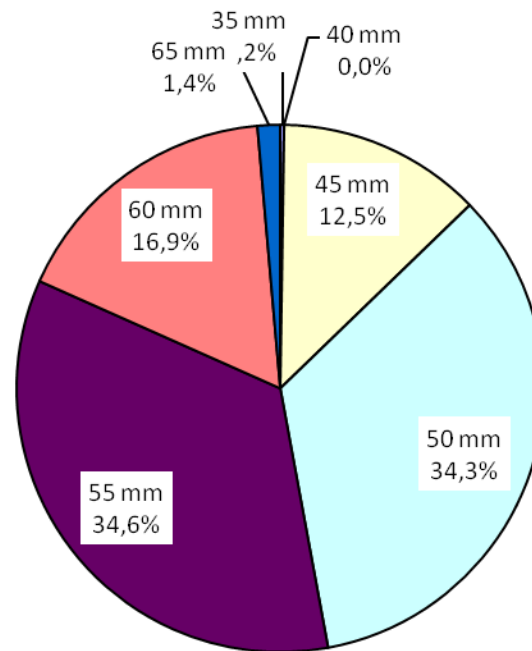
Age distribution			
Age	40-49	50-60	>60
Nb	47	155	223
%	11,1	36,5	52,5

Stage				
T	T1a	T1b	T1c	Total
Nb	19	164	250	433
%	4,4	37,9	57,7	100

IOERT

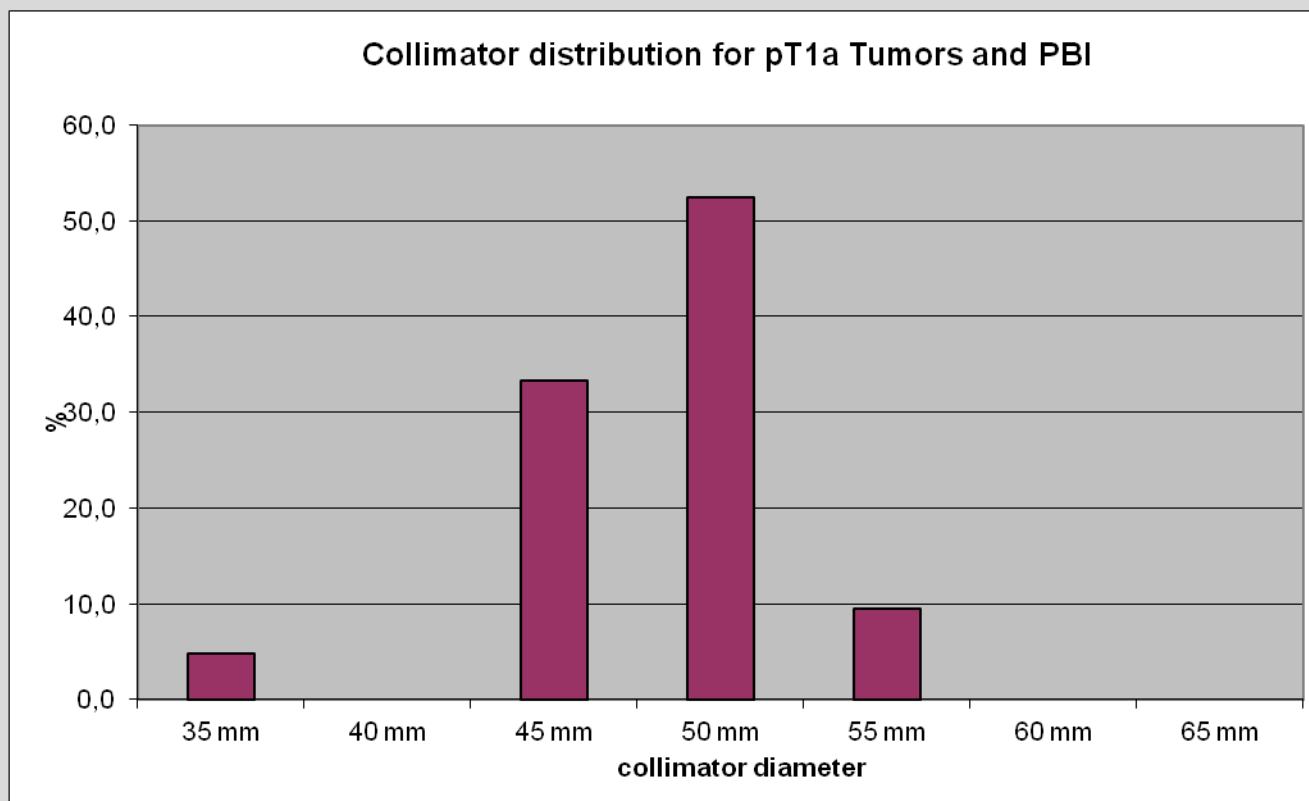
- Jules Bordet Experience

Collimator size distribution



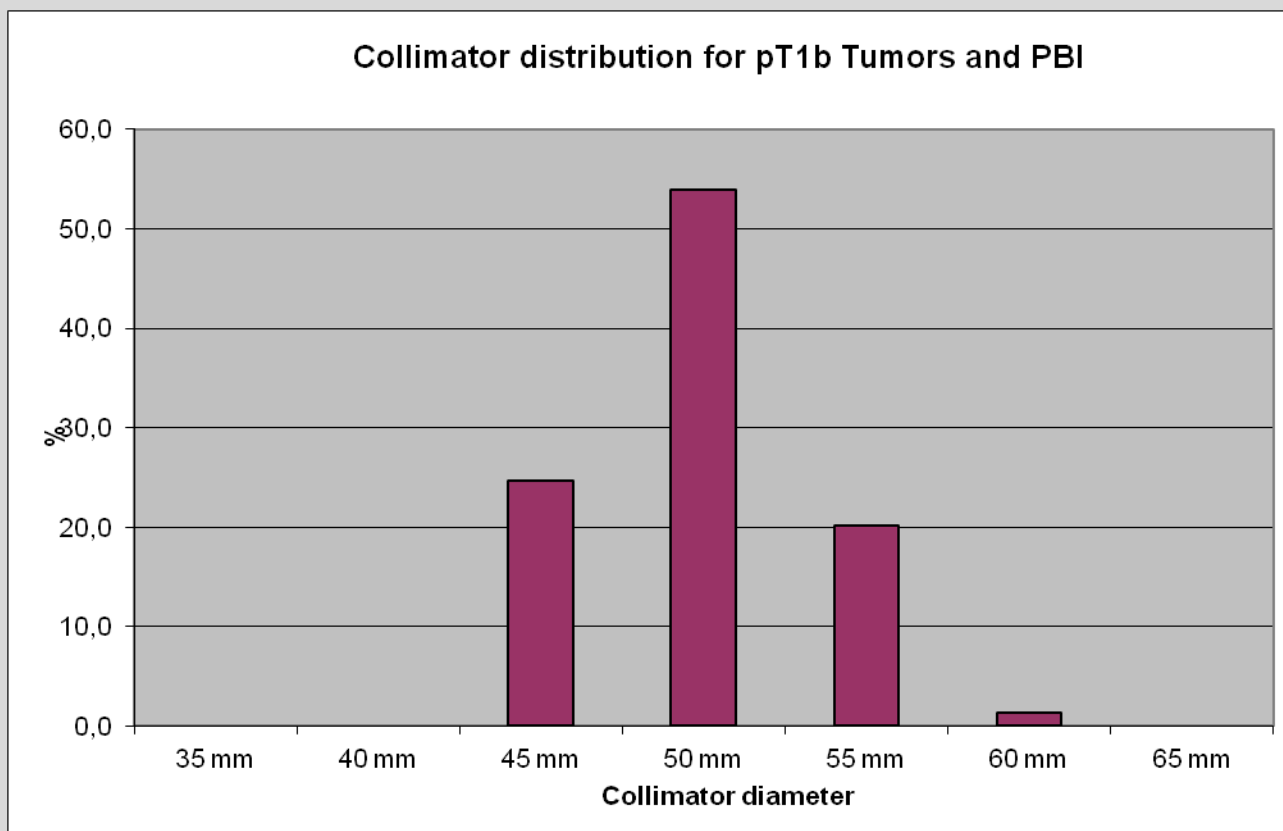
IOERT

- Jules Bordet Experience
 - Collimator distribution for pT1a, pT1b, pT1c



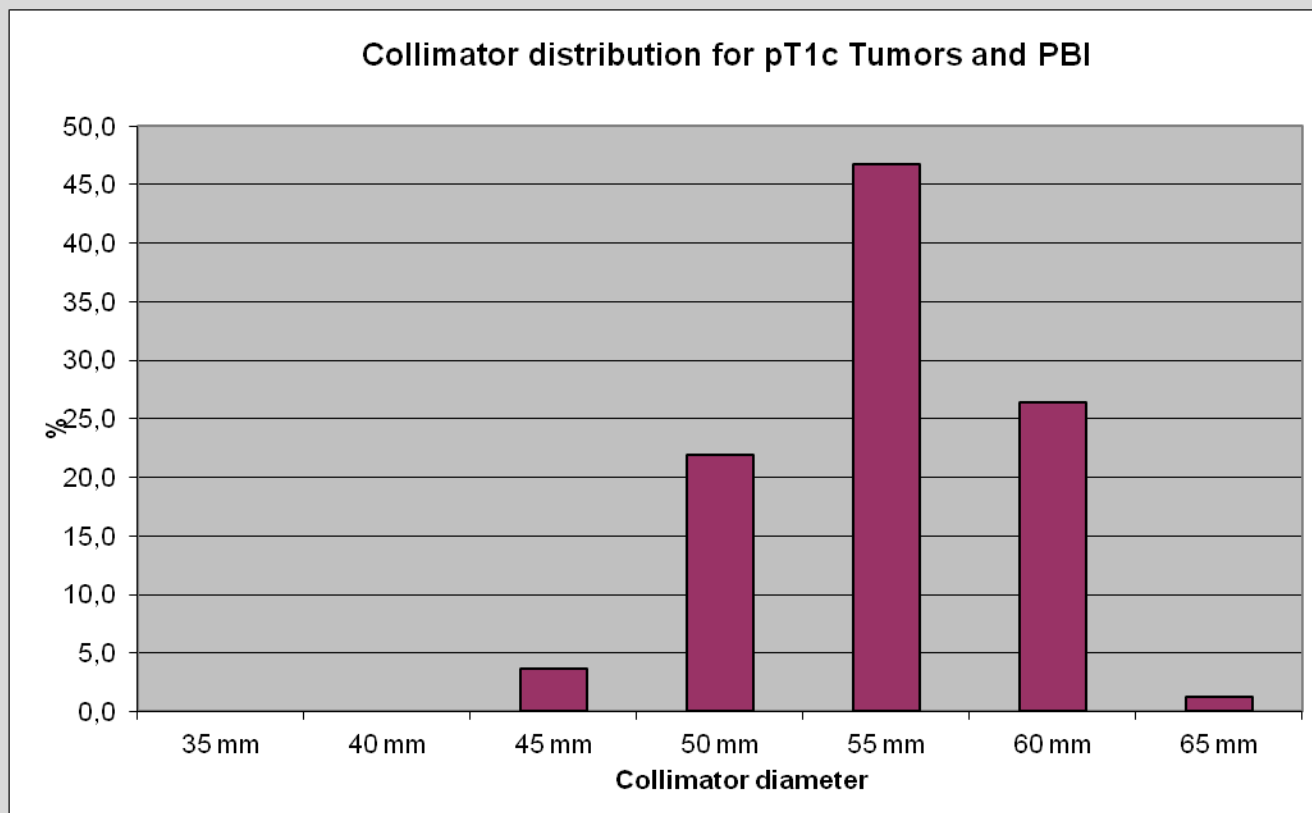
IOERT

- Jules Bordet Experience
 - Collimator distribution for pT1a, pT1b, pT1c



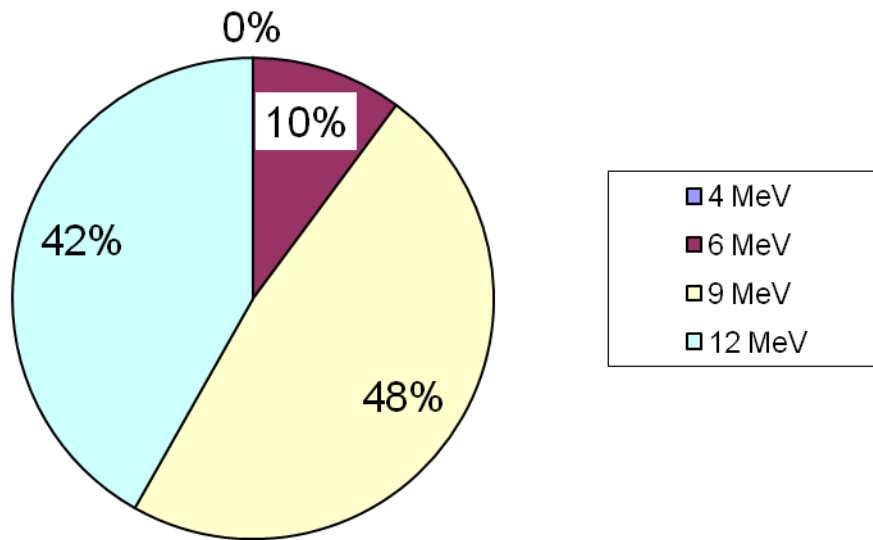
IOERT

- Jules Bordet Experience
 - Collimator distribution for pT1a, pT1b, pT1c



IOERT

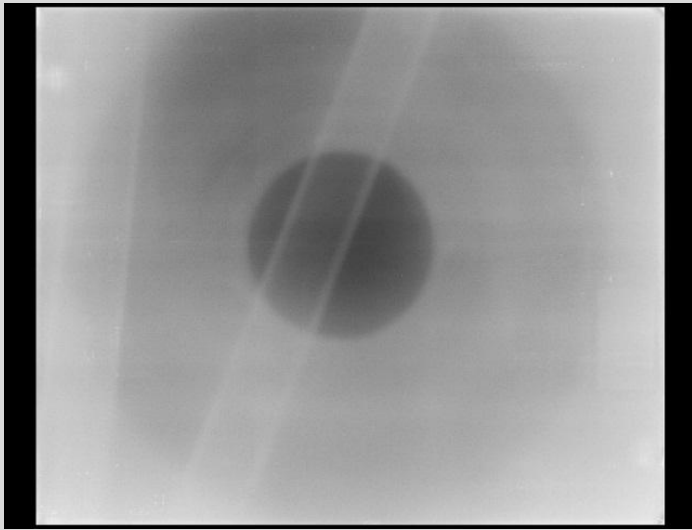
- Jules Bordet Experience
 - Energy distribution & treated thickness



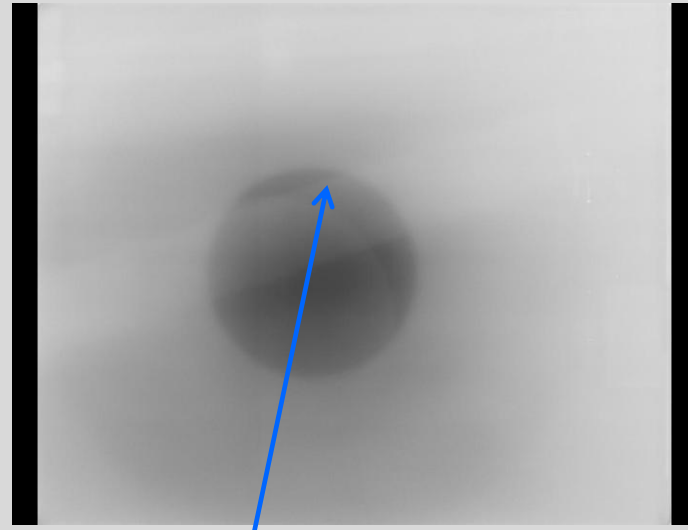
Thickness	mm
Min	7
Max	42
Mean	21

IOERT

- Jules Bordet Experience
 - Shield coverage



Perfect coverage



Partial (80%) coverage

	Mean coverage (%)	% with coverage $\geq 90\%$	% with total coverage
Old shield system	94	81	51
New system, with 3 rods	99.6	100	88

IOERT

- Jules Bordet Experience

Pathology							
AP	Ductal	Lobular	Mixed	Mucinous	Medullary	Papillary	Total
Nb	413	8	5	5	1	1	433
%	95,4	1,8	1,2	1,2	0,2	0,2	100

Nodes				
Stage	pN0	pN1mic	pN1a	Total
Nb	409	13	11	433
%	94,5	3,0	2,5	100

IOERT

- Jules Bordet Experience
 - Histology: molecular subtypes & grade

	Nb	%
Luminal A	299	69,1
Luminal B	76	17,5
Triple negative	29	6,7
HER2/neu +	26	6
Unknown	3	0,7
Total	433	100

	I	II	III
Nb	179	175	79
%	41.4	40.4	18.2

IOERT

- Jules Bordet Experience
 - Adjuvant treatments

HT \ CT (%)	YES	NO	Total
YES	14,8	75,5	90,4
NO	7,5	2,1	9,6
Total	22,4	77,6	100,0

IOERT

- Jules Bordet Experience
 - Acute Toxicities

	GRADE 1 (%)	GRADE 2 (%)	GRADE 3-4-5 (%)
Infection	0,0	0,7	0
Heamatoma	0,7	0,5	0
Delayed Cicatrisation	1,2	1,8	0
Local Inflammation	0,2	0,2	0
Delayed Cicatrisation+Inf.	0,0	1,2	0
Total	2,1	4,4	0

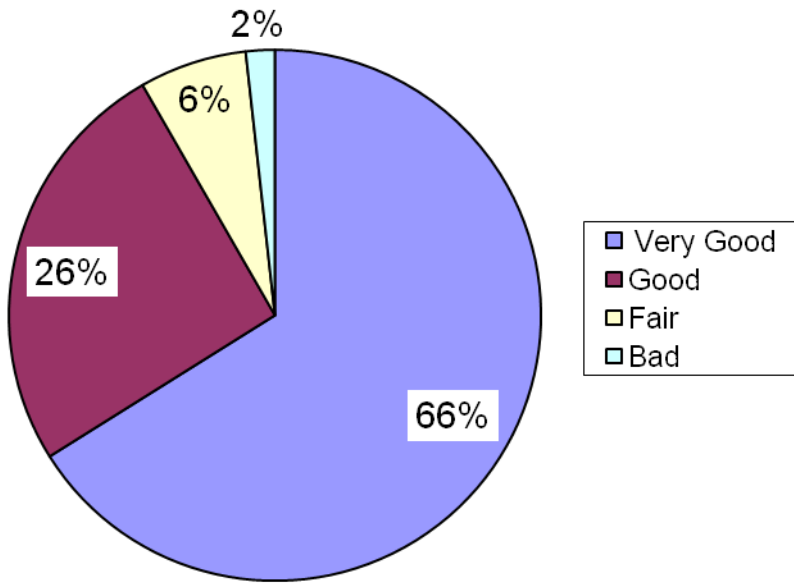
IOERT

- Jules Bordet Experience
 - Late toxicity

	GRADE 0 (%)	GRADE 1 (%)	GRADE 2 (%)	GRADE 3-4 (%)
Fibrosis	92,2	5,5	2,3	0
Atrophy	95,6	4,2	0,2	0
		9,7	2,5	0

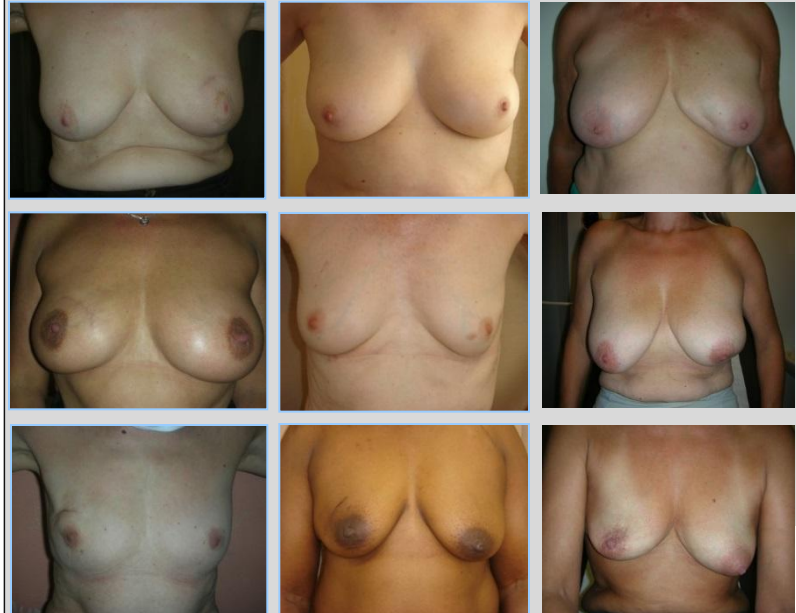
IOERT

- Jules Bordet Experience
 - Cosmesis results



- G0: no effects
- G1: minimal asymmetry or scar prominence
- G2: asymmetry $\leq 1/3$ of the gland
- G3: asymmetry $> 1/3$ of the gland

Beal et al, 2007



IOERT

- Jules Bordet Experience

- **Positive margin management**

- 7/433 (1,6%): surgical revision

- **pN1mic, pN1a management**

	Nodes			
Stage	pN0	pN1mic	pN1a	Total
Nb	409	13	11	433
%	94,5	3,0	2,5	100

pN1mic: no CAND*

pN1a: 11/433 (2,5%)

CAND: 10/11: 2/10 presence of other N+

8/10 absence of other involved nodes

IOERT

- Jules Bordet Experience

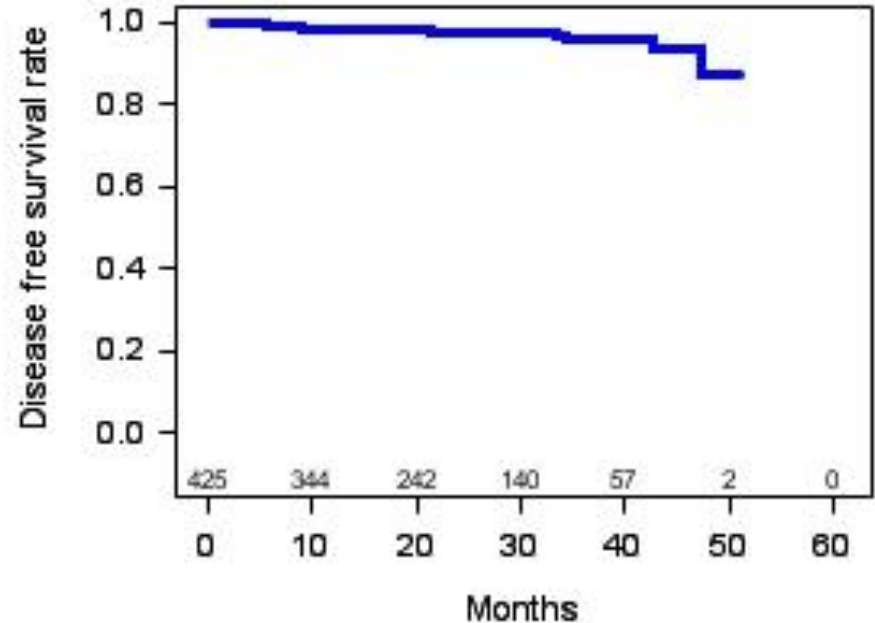
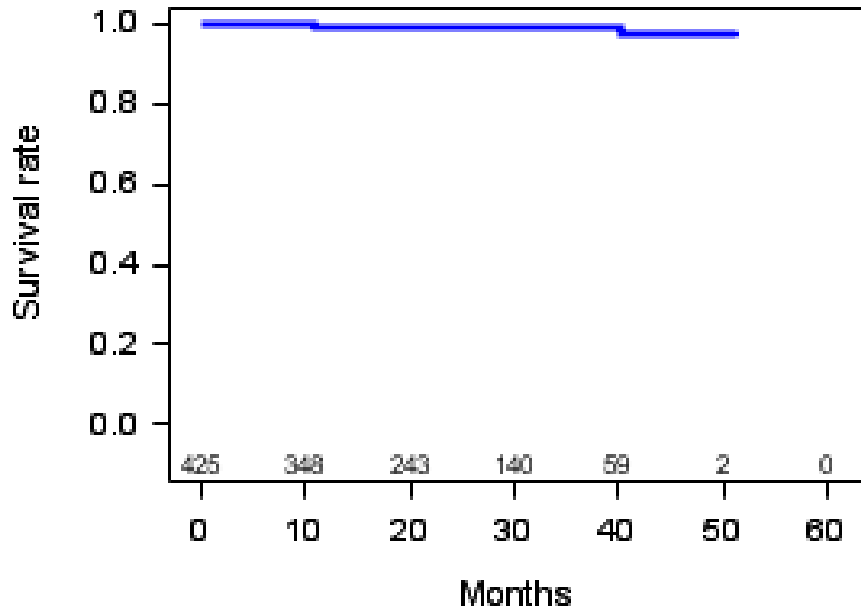
- Results

- 2 local relapses (out-quadrant)
 - 3 metastatic patients
 - 5 other cancers
 - 5 deaths without relation with breast cancer

 - Median FU: 23.6 months
 - Crude recurrence rate = 2/425: 0.5%
 - Actuarial recurrence rate after 23.6 months: 0.4%
 - DFS at 23.6 months: 97.9%
 - OS at 23.6 months: 98.8%
 - Cancer SS: 99.1%
 - BC SS: 100%

IOERT

- Jules Bordet Experience
 - Results



IOERT

- Jules Bordet Experience
– Results

	Patient #1	Patient #2	ASTRO suitable	ESTRO good
Age	63 y	81 y	≥ 60 y	≥ 50 y
Histology	IDC	IDC	IDC*	IDC*
Tumor size (mm)	8	18	≤ 20	≤ 30
Nodal status	0/2	0/3	pN0	pN0
ER/PR status	ER 8/8, PR 8/8	ER 8/8, PR 8/8	Positive	Any
Ki67	10%	10%	NS	NS
Her2/neu	Negative	Negative	NS	NS
Margin	Negative	Negative	Negative	Negative
Grade	G1	G3	Any	Any
Time to relapse	18 months	43 months	–	–

IOERT

- Jules Bordet Experience
 - Results

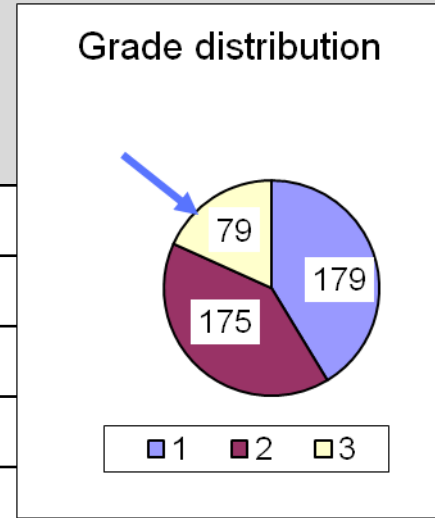
	Patient #1	Recurrence
Age	63 y	64 y
Localisation	Central	UIQ
Histology	IDC	IDC
Tumor size	8 mm	6 mm
Nodal status	0/2	0/5
ER status	8/8	7/8
PR status	8/8	5/8
Ki67	10%	10%
Her2/neu	negative	negative
Margin status	negative	negative
Grade	G1	G2
Treatment	HT (Tamoxifen)	Mastectomy + HT (Letrozole)

Technical parameters: 45mm applicator, 12 MeV

IOERT

- Jules Bordet Experience
 - Results

	Patient #1	Patient #2	Recurrence
Age	81 y	85 y	85 y
Localisation	UOQ	UOQ	Ext Jct
Histology	IDC	IDC	IDC
Tumor size	18 mm	18 mm	3 mm
Nodal status	0/3	0/3	–
ER status	8/8	8/8	8/8
PR status	8/8	8/8	0/8
Ki67	10%	10%	10%
Her2/neu	negative	negative	negative
Margin status	negative	negative	negative
Grade	G2	G3	G2
Treatment	HT (Letrozole)	HT (Letrozole)	Mastectomy + HT (Aromasin)



Technical parameters: 50mm applicator, 9 MeV

IOERT

- Jules Bordet Experience

- Conclusions

- Importance of preoperative Work-Up
 - Importance of surgical procedure
 - IOERT PTV adapted to the pT
 - Acute and late toxicity rates very low
 - Maximal protection of normal tissues
 - No evident relation between molecular subtype and local relapse

IOERT

- Jules Bordet Experience

- Conclusions

- Necessity of a multidisciplinary team
- Importance concept Local control & Survival with ratio 4:1
 - \simeq 20% local recurrence at 5 y
 - \simeq 5% death rate at 15 y
- Median Follow-up too short
- Necessity of a significant initial investment
- Gain in quality of life

IORT Techniques Mobile Linear Accelerator Electrons beams

C. Philippon & S. Simon

*THANK YOU FOR YOUR
ATTENTION*