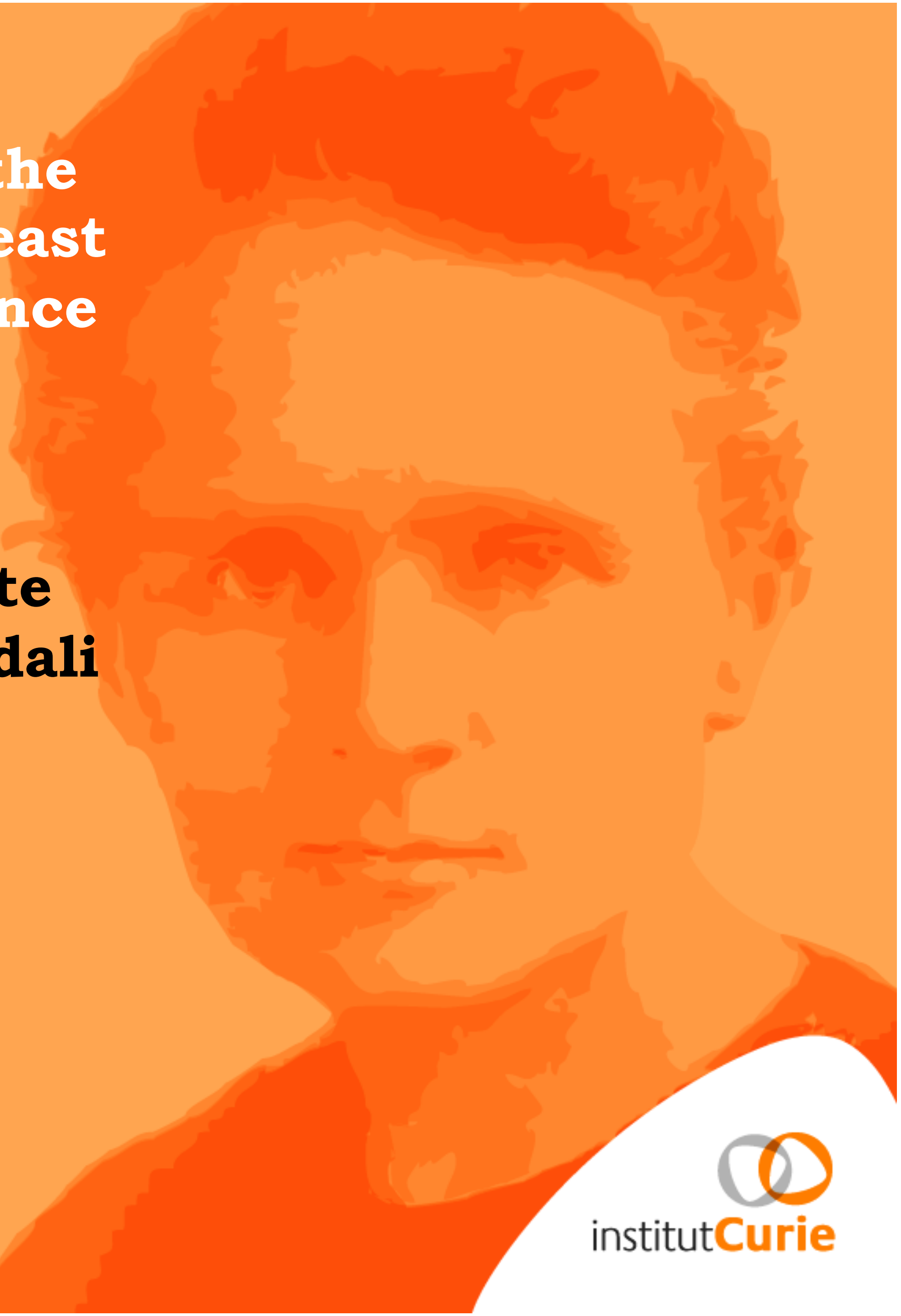
Practical implications of the Helical Tomotherapy in breast cancer treatment: Experience of the Institut Curie

RT della mammella/parete toracica e stazioni linfonodali con tomoterapia



Youlia M. Kirova, MD
Radiation Oncology

youlia.kirova@curie.fr

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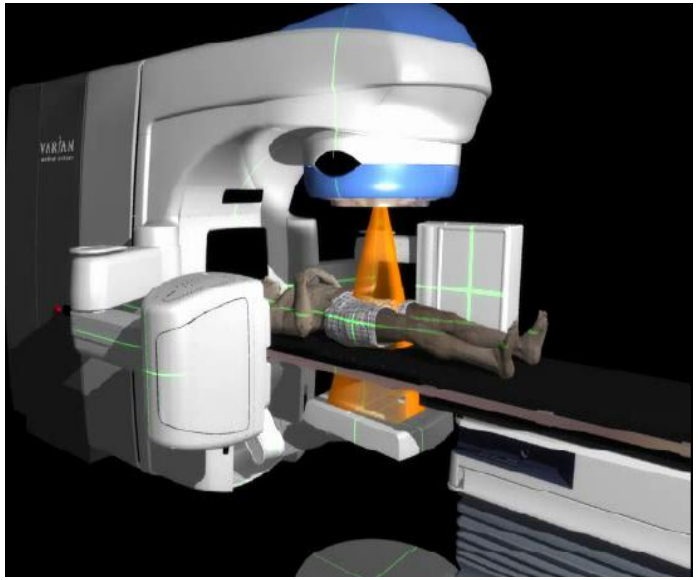
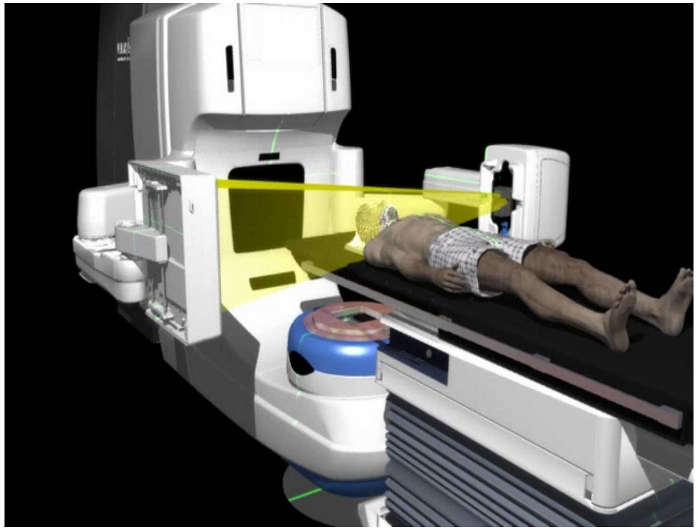
9 linacs





Courtesy of Varian (+ Elekta, Siemens,…)

J. Pouliot, Dirk Verellen

2 Tomotherapies:

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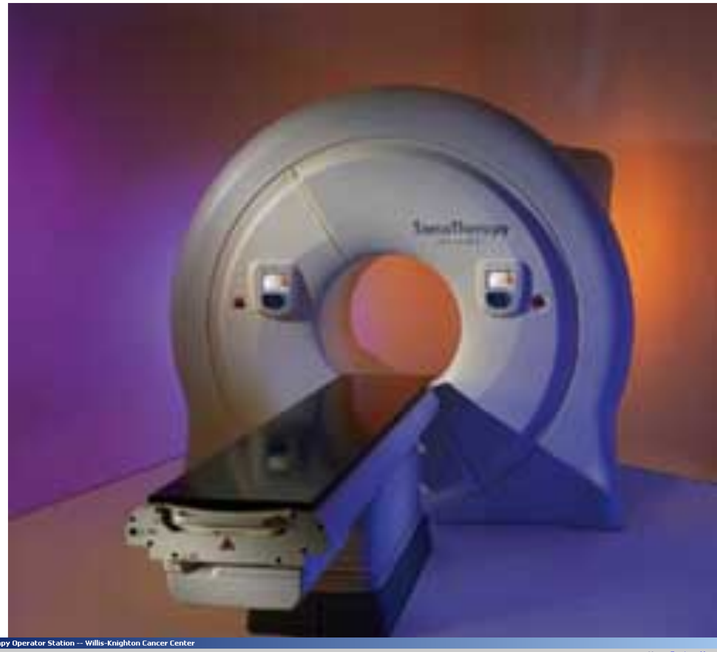

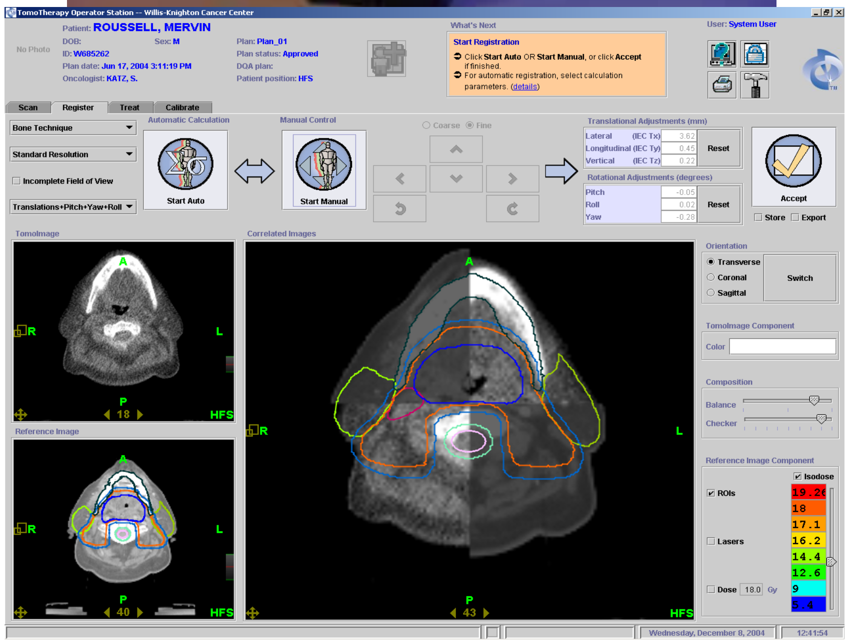

R.Mackie, G. Olivera, Tomotherapy

Year 2011. Patients

- External Beam Radiotherapy

	No. of pts	
Paris	**2240**	5 linacs, 2 Tomo, 1 Low E
Saint-Cloud. René Huguenin	**1700**	4 linacs
Orsay- ICPO	**420**	1 Cyclotron, 3 rooms
	4360	

- Brachytherapy: 400 pts

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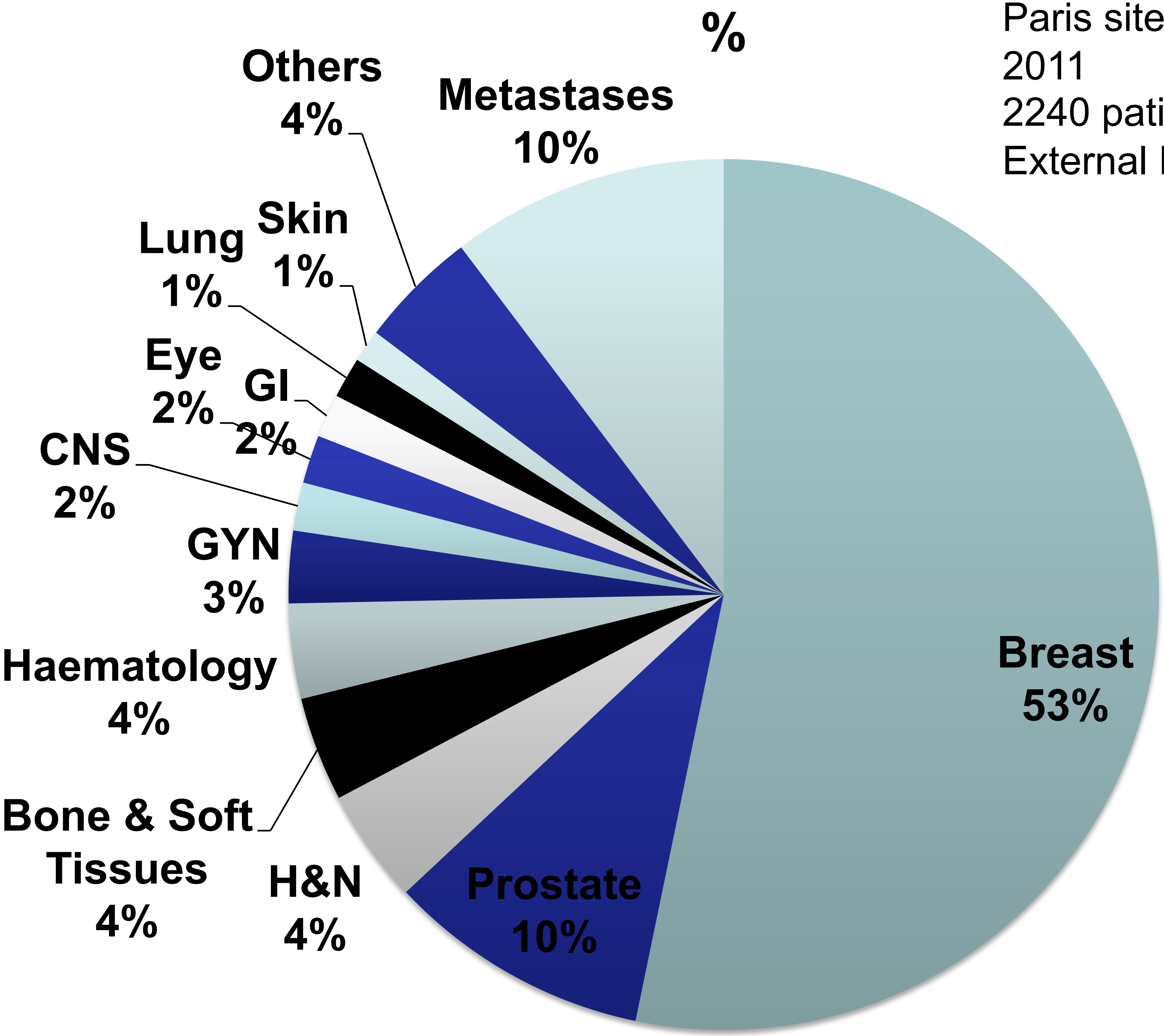
Institut Curie
Paris site
2011
2240 patients
External Radiation Therapy



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Int. J. Radiation Oncology Biol. Phys., Vol. 56, No. 1, pp. 89–105, 2003

0360-3016/03/$–see front matter

doi:10.1016/S0360-3016(03)00090-7

3D-CRT

IMAGE GUIDANCE FOR PRECISE CONFORMAL RADIOTHERAPY

Thomas Rockwell Mackie, Ph.D.,[*†‡] Jeff Kapatoes, Ph.D.,[‡] Ken Ruchala, Ph.D.,[‡] Weiguo Lu, Ph.D.,[‡] Chuan Wu, M.S.,[†] Gustavo Olivera, Ph.D.,[†‡] Lisa Forrest, V.M.D.,[§] Wolfgang Tome, Ph.D.,[*†] Jim Welsh, M.D.,[*] Robert Jeraj, Ph.D.,[†] Paul Harari, M.D.,[*] Paul Reckwerdt, B.S.,[‡] Bhudatt Paliwal, Ph.D.,[*†] Mark Ritter, Ph.D., M.D.,[*†] Harry Keller, Ph.D.,[†] Jack Fowler, Ph.D.,[*†] and Minesh Mehta, M.D.[*]

Departments of *Human Oncology and †Medical Physics, Medical School, and §College of Veterinary Medicine, University of Wisconsin, Madison, WI; ‡TomoTherapy Inc., Madison, WI.

Conclusion: Image-guided precision conformal radiotherapy can be used as a tool to treat the tumor yet spare critical structures. Helical tomotherapy has been designed from the ground up as an integrated image-guided intensity-modulated radiotherapy system and allows new verification processes based on megavoltage CT images to be implemented. © 2003 Elsevier Inc.

Tomotherapy : Concept

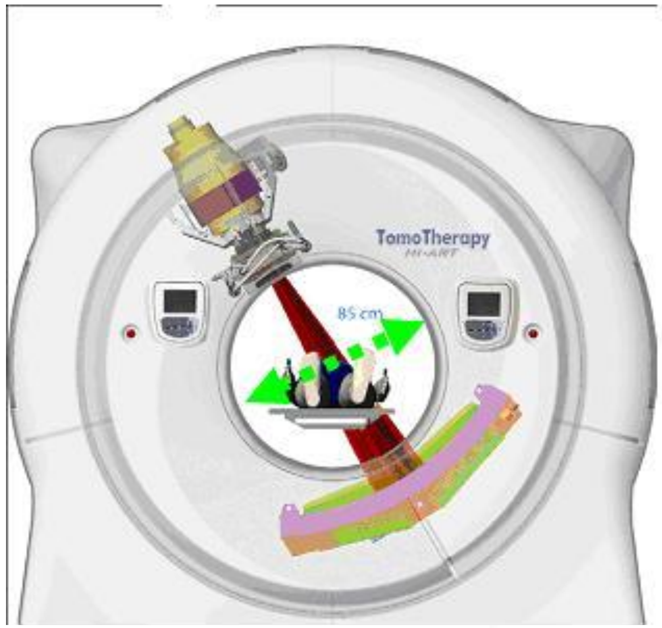
Tomotherapy: How does Helical Tomotherapy work ?

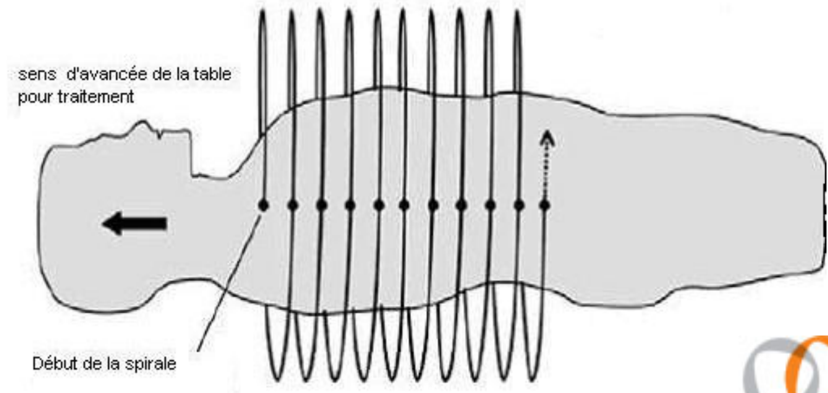
A short 6 MV linac is collimated by jaws and a binary multileaf collimator.

The treatment head rotates on a gantry in the x/z plane while a patient is continuously translated through the bore of the machine in the y-direction – the therapy analogue of spiral CT.

Beam is collimated to a fan beam. The jaw width is held constant (typically 1 or 2.5 cm) for the entire treatment delivery.

- Tomotherapy is rotational IMRT.





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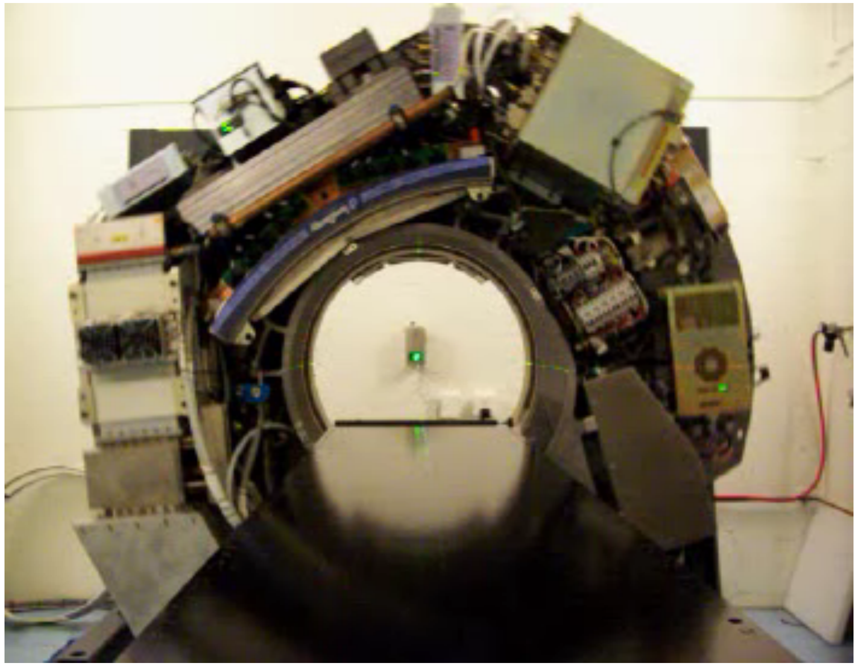
Tomotherapy: The MACHINE



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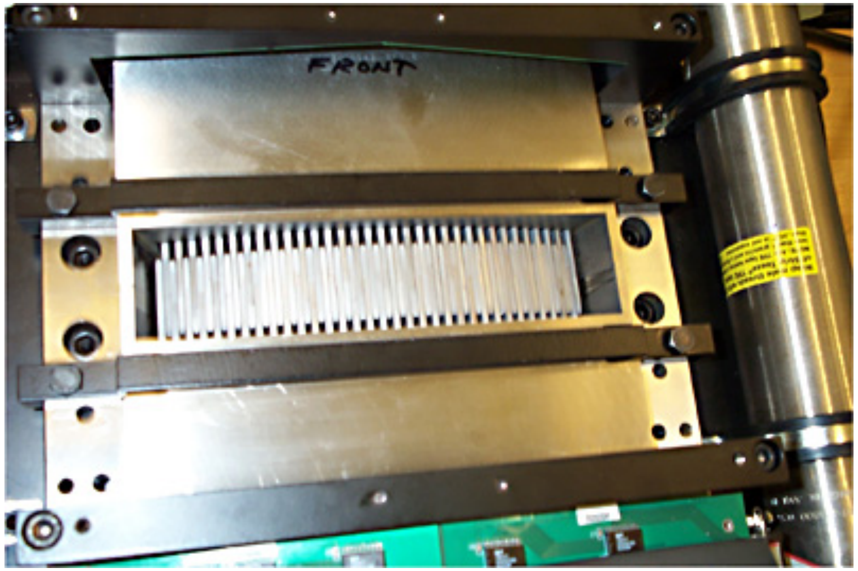
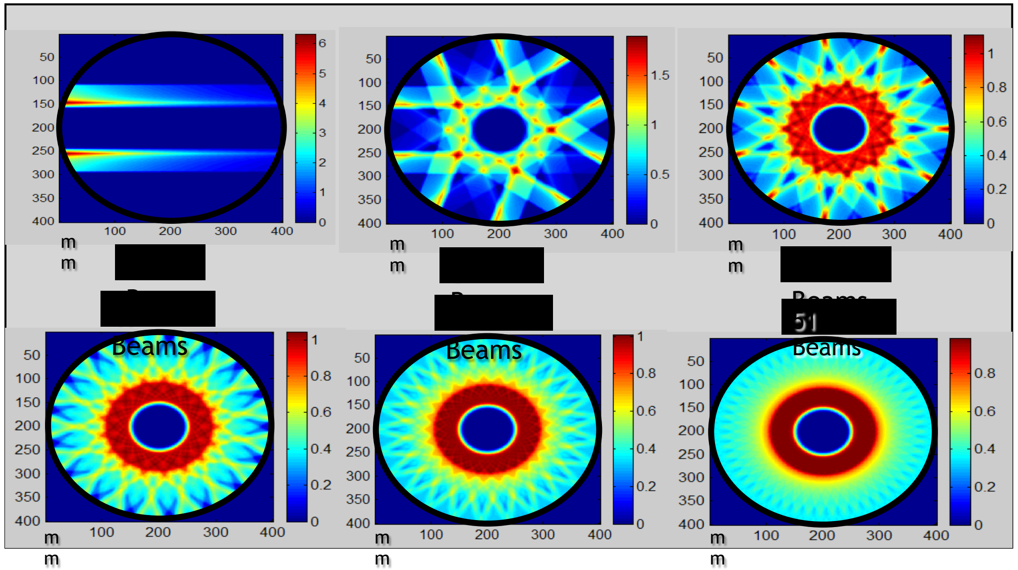
Binary Modulating Collimators

Tomotherapy, Inc.



Laterally the beam is modulated using a binary MLC, which consists of 64 leaves each of width .625 cm for a total possible beam length at isocenter of 40 cm.



TomoTherapy

- Control using CT scan images (MVCT)

- No image of the irradiation field

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Helical Tomotherapy in the treatment of breast cancer

Early stage breast cancer

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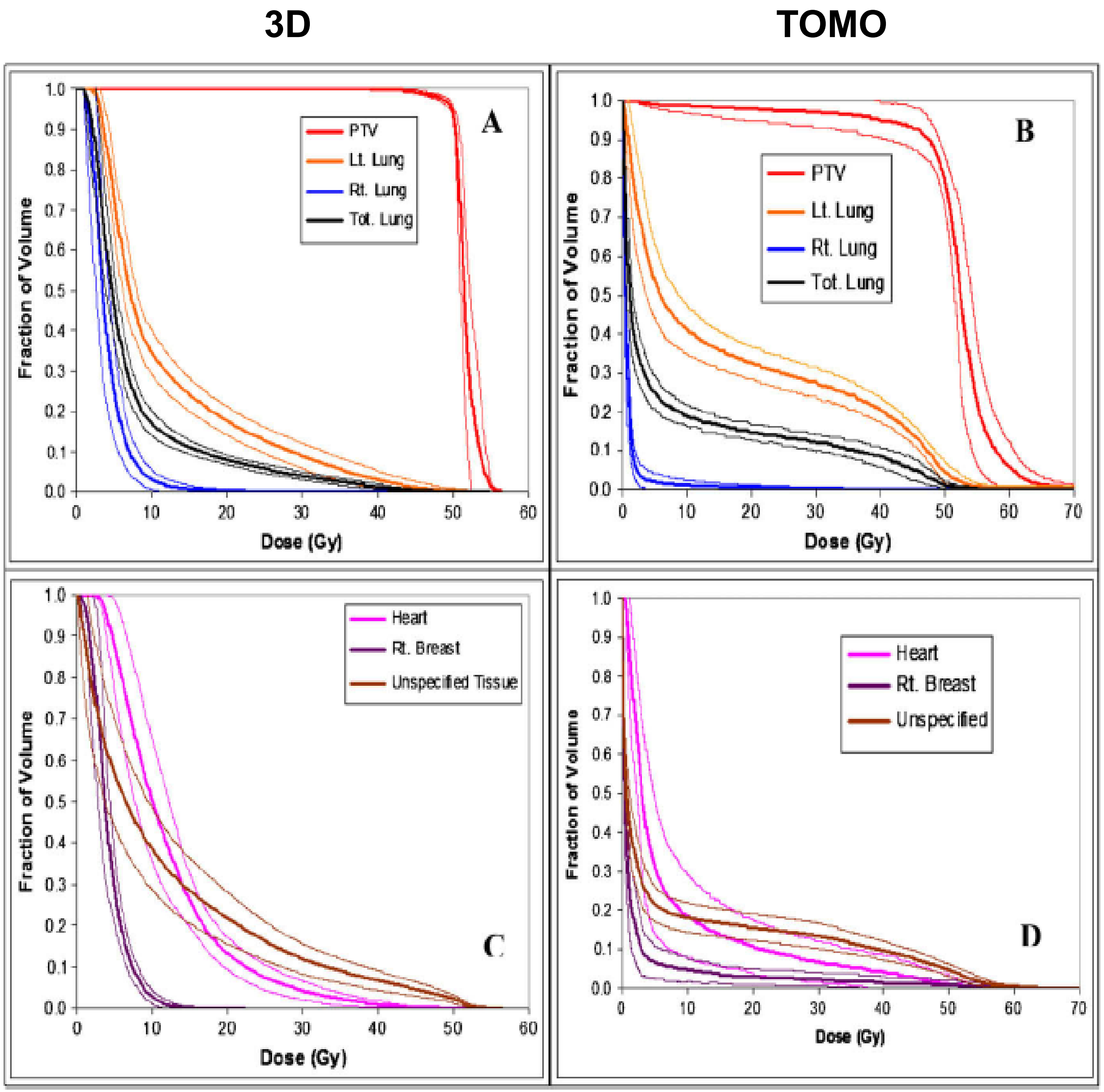
Breast and LN irradiation, Initially only MSKCC and Ontario dosimetric studies. Same protocole

- 10 left side breast cancer
- pN+
- Irradiation of the breast and/or chest wall
- Dosimetriques comparaisons

    3D conformal RT *vs*.

    IMRT using TomoTherapy

MSKCC
Goddu et al.



Radiotherapy and Oncology 94 (2010) 300–306

Contents lists available at ScienceDirect

Radiotherapy and Oncology

journal homepage: www.thegreenjournal.com

Simultaneous integrated boost

Simultaneous integrated boost in breast conserving treatment of breast cancer: A dosimetric comparison of helical tomotherapy and three-dimensional conformal radiotherapy

Tarek Hijal [a,*], Nathalie Fournier-Bidoz [b], Pablo Castro-Pena [a], Youlia M. Kirova [a], Sophia Zefkili [b], Marc A. Bollet [a], Rémi Dendale [a], François Campana [a], Alain Fourquet [a]

[a] *Department of Radiation Oncology; and* [b] *Department of Medical Physics, Institut Curie, Paris, France*

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Hijal et al, Dosimetric analysis, Radiother Oncol, 2010

- **Dosimetric comparative analysis**
- 13 patients
- RT:

Breast:	50.7 Gy/28f de 1.81 Gy
Boost :	64.4 Gy/28f de 2.3 Gy

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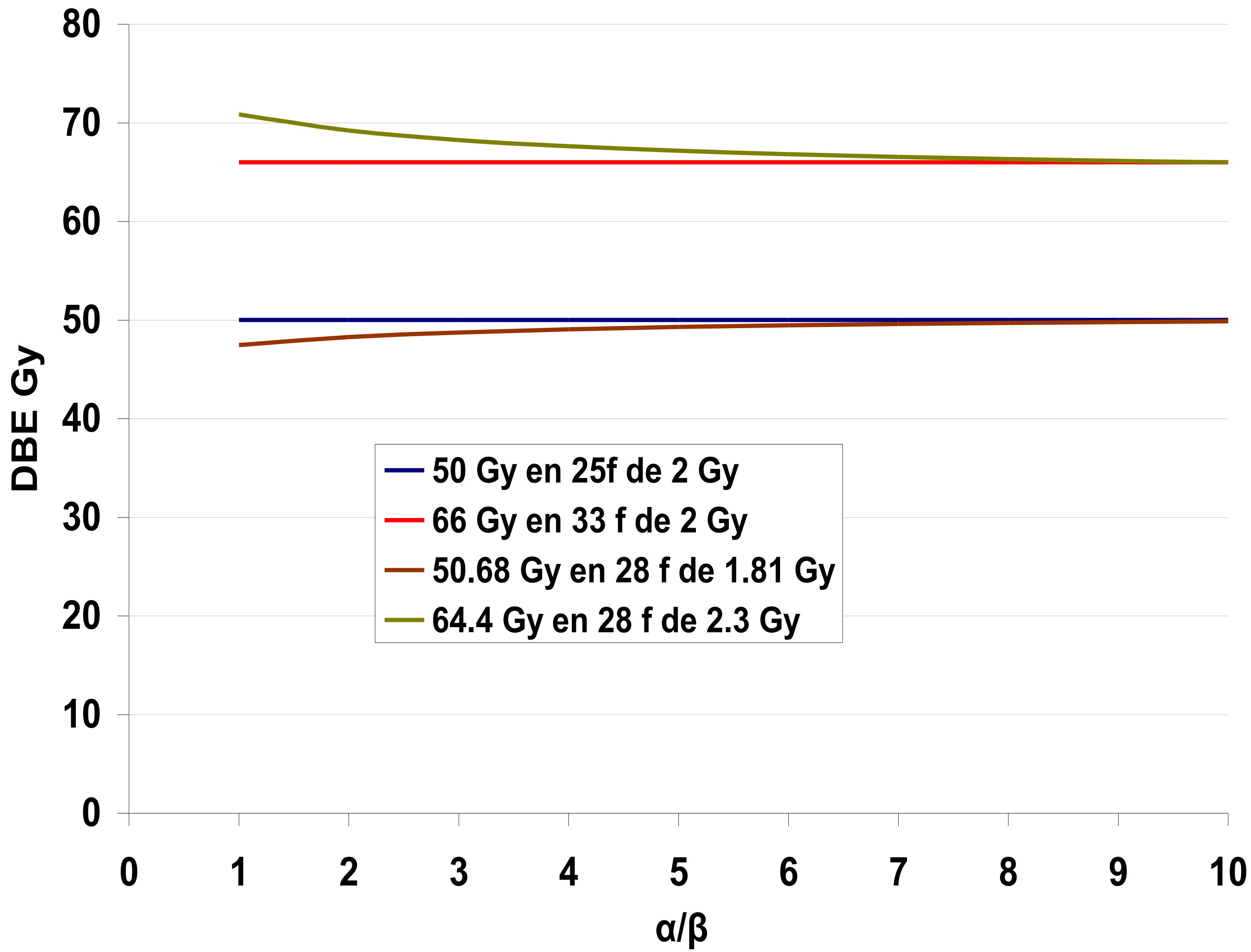
Dose equivalences



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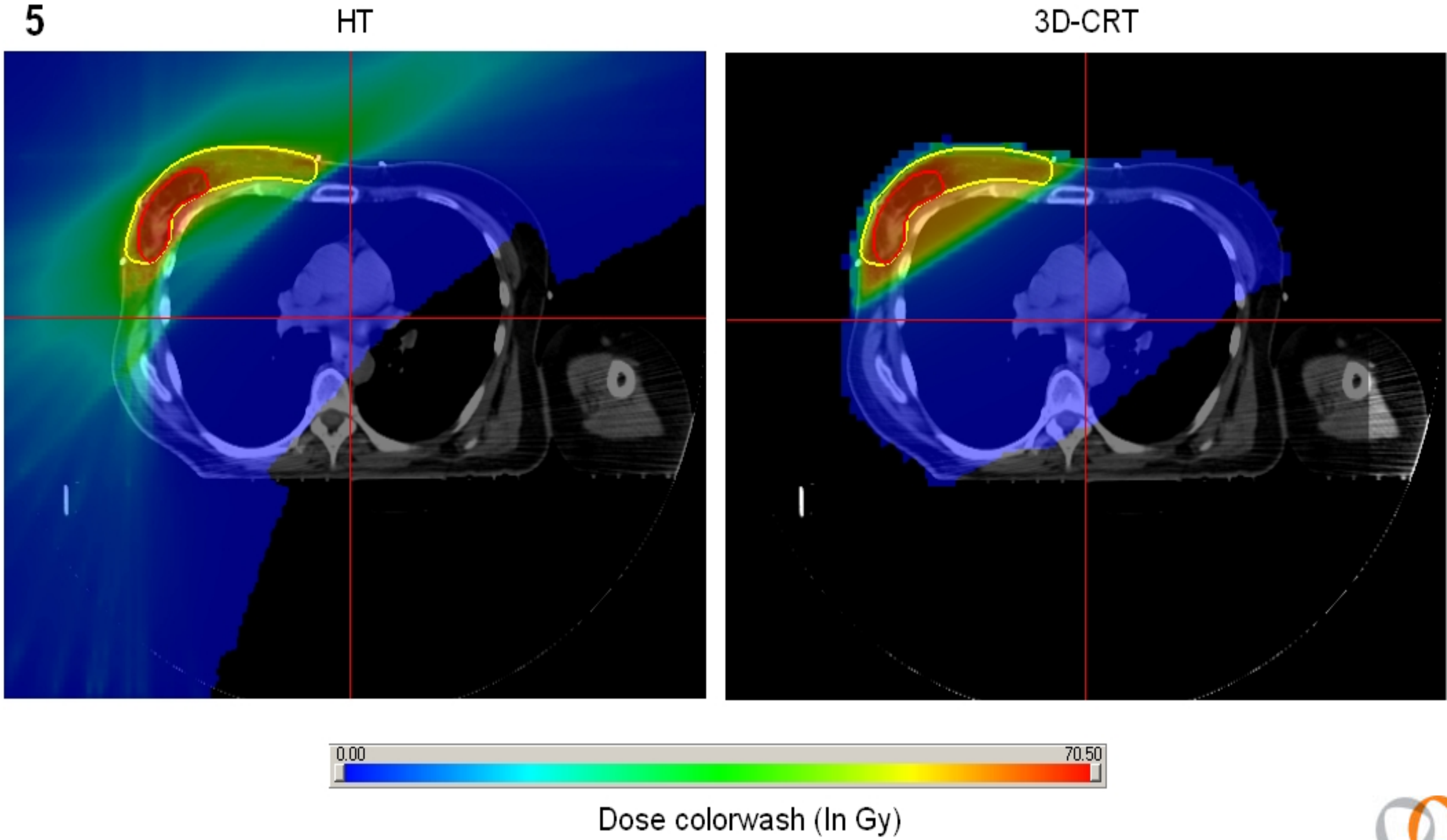
5



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Integrated Boost

	3D %	TOMO %	p
Boost (64.4 Gy)			
V107	0.26	0.70	0.03
V95	99.72	97.18	<0.001
Mean Dose (Gy)	65.47	64.97	0.08
Max. Dose (Gy)	67.95	69.47	0.08
Min. Dose (Gy)	60.60	57.76	<0.001
Breast (50.68 Gy)			
V107	30.83	12.47	<0.001
V95	96.25	96.22	0.64
Mean Dose (Gy)	53.18	51.85	<0.001
Max. Dose (Gy)	67.38	66.68	0.24
Min. Dose (Gy)	26.82	22.18	0.45

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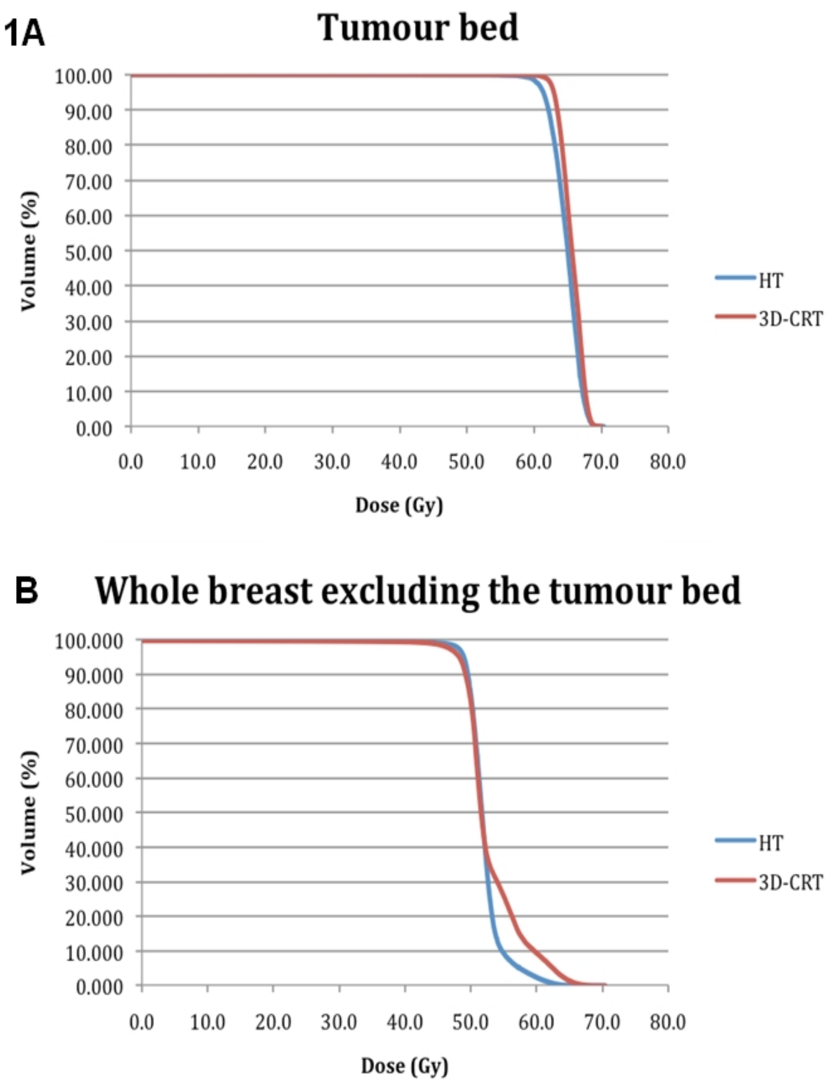
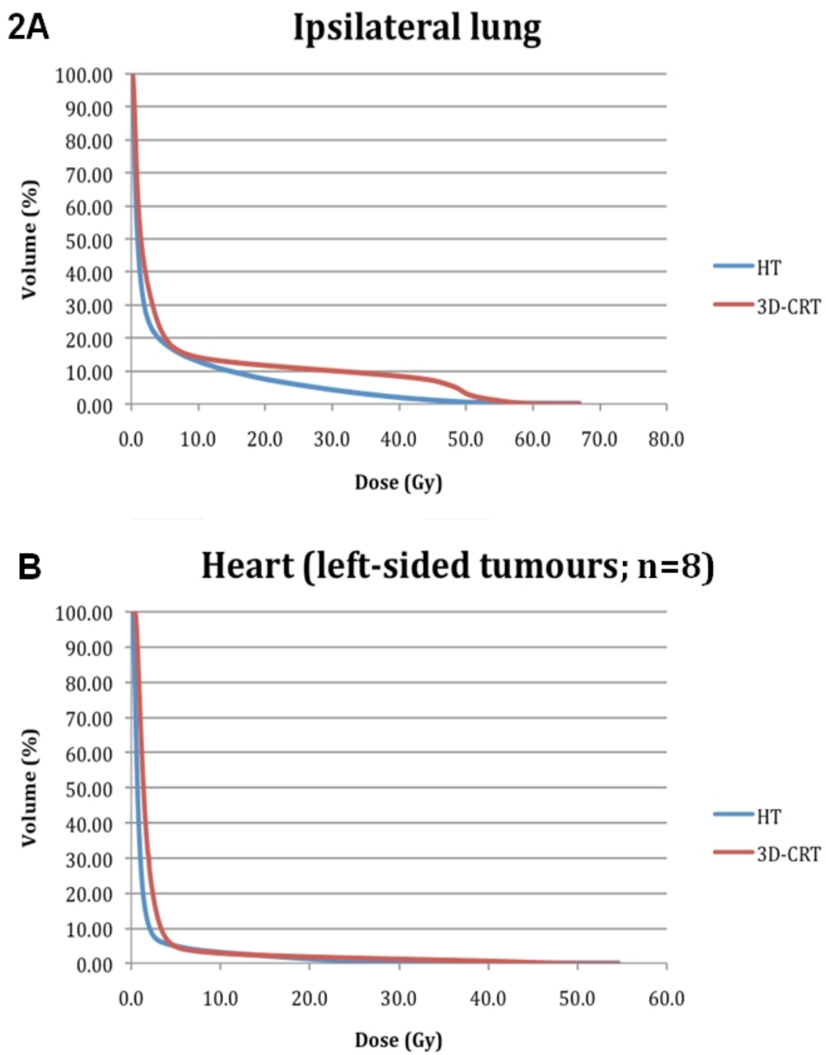
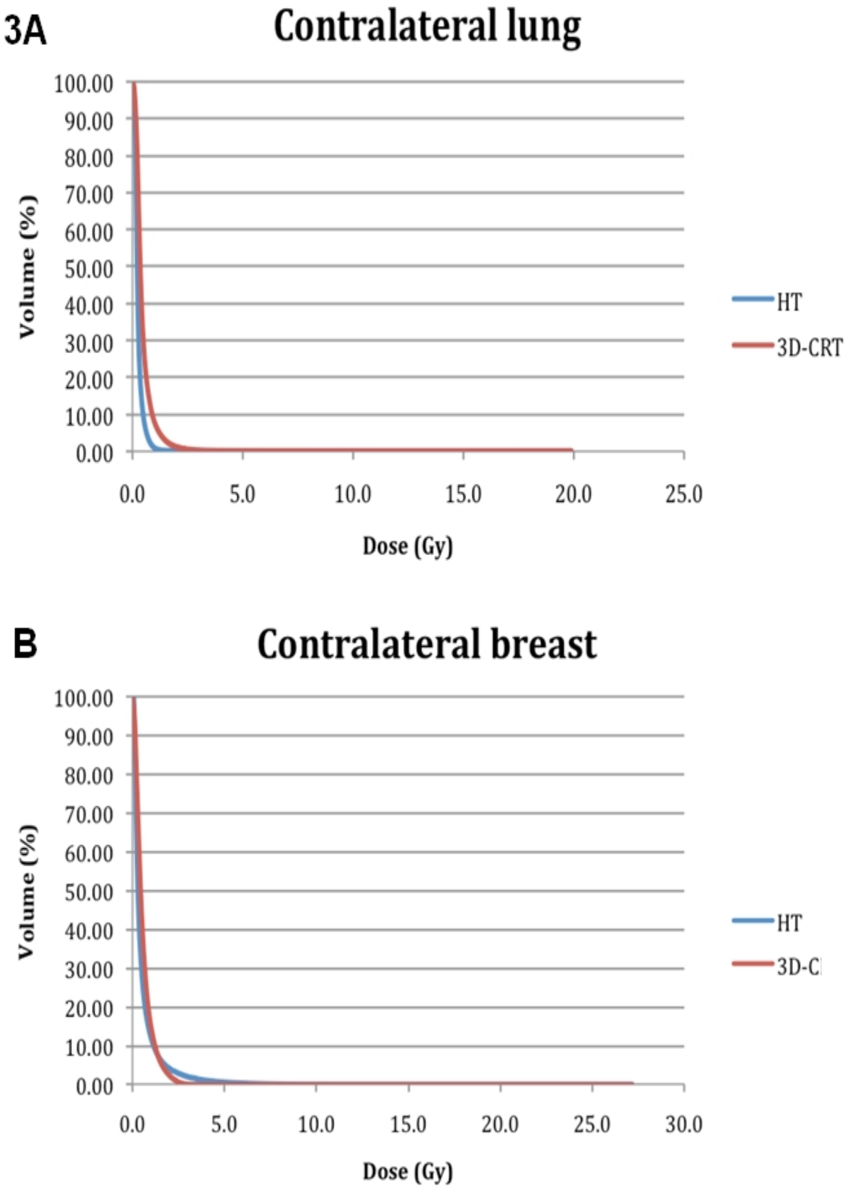
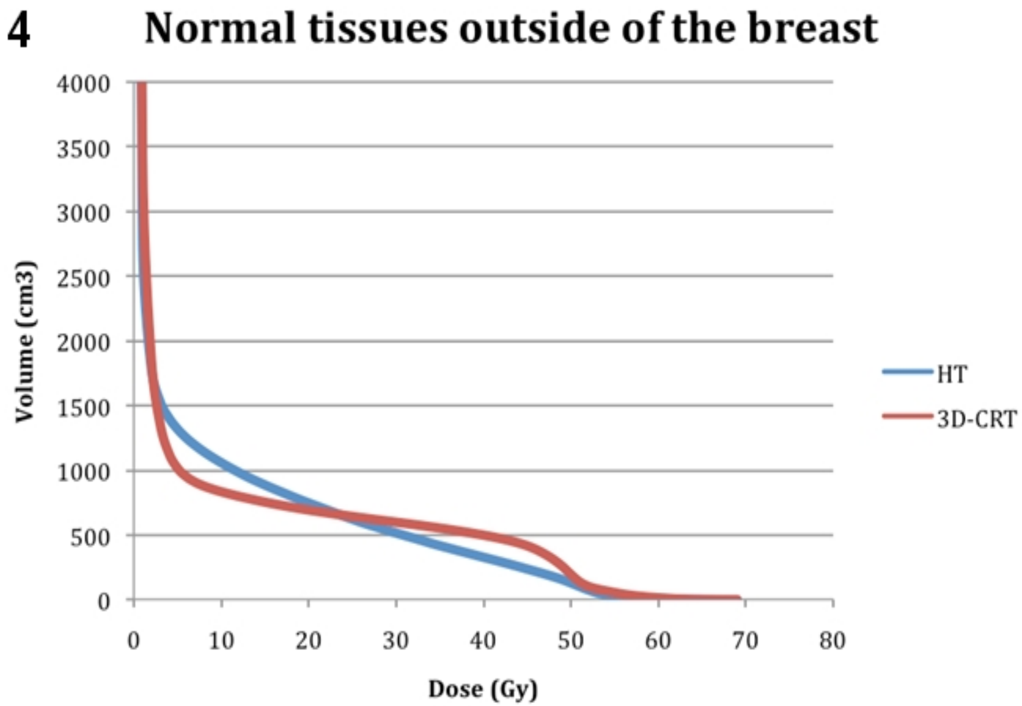

1A
Tumour bed
Volume (%)
Dose (Gy)
HT
3D-CRT
B
Whole breast excluding the tumour bed
Volume (%)
Dose (Gy)
HT
3D-CRT


2A
Ipsilateral lung
Volume (%)
Dose (Gy)
HT
3D-CRT
B
Heart (left-sided tumours; n=8)
Volume (%)
Dose (Gy)
HT
3D-CRT





Conclusion

This is the first study to compare HT and 3D-CRT in patients with breast cancer treated by radiation therapy that includes simultaneous integrated boost of the tumor bed. While both techniques provided adequate target volume coverage as well as low heart doses, HT nonetheless avoided unnecessary overdosage of the breast while improving ipsilateral lung dosimetry, compared to 3D-CRT. It is thus a feasible alternative, and prospective clinical studies comparing both techniques are warranted.

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Dosimetric optimization and new therapeutic solutions in case of breast and LN irradiation

Cancer/Radiothérapie xxx (2011) xxx–xxx

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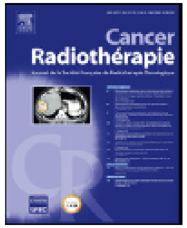

Original article

Potential benefits of using cardiac gated images to reduce the dose to the left anterior descending coronary during radiotherapy of left breast and internal mammary nodes

Bénéfice potentiel d'utilisation d'images obtenues avec gating cardiaque pour diminuer la dose d'irradiation au niveau de l'artère descendante coronaire gauche

C.E. de Almeida[a,b], N. Fournier-Bidoz[a], C. Massabeau[a], A. Mazal[a], P.C. Canary[b], I.R. Kuroki[c], F. Campana[a], A. Fourquet[a], Y.M. Kirova[a,*]

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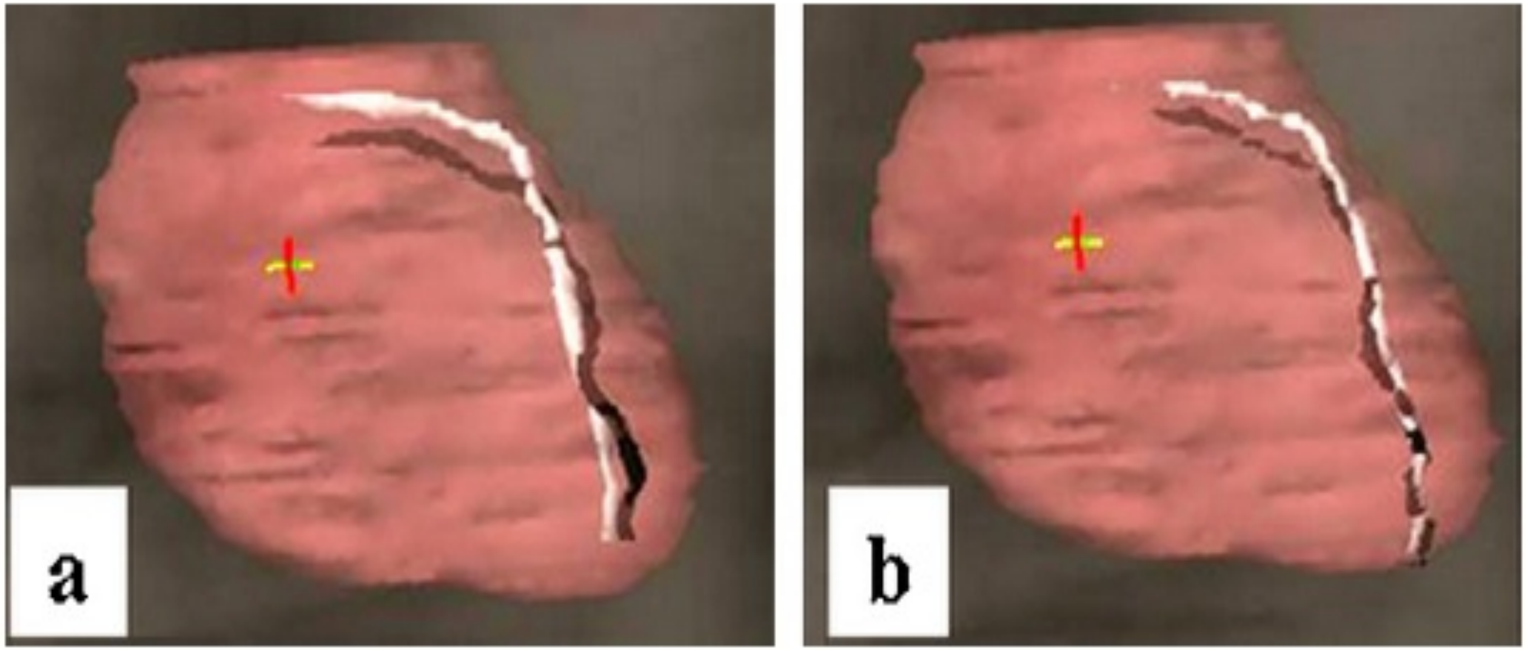
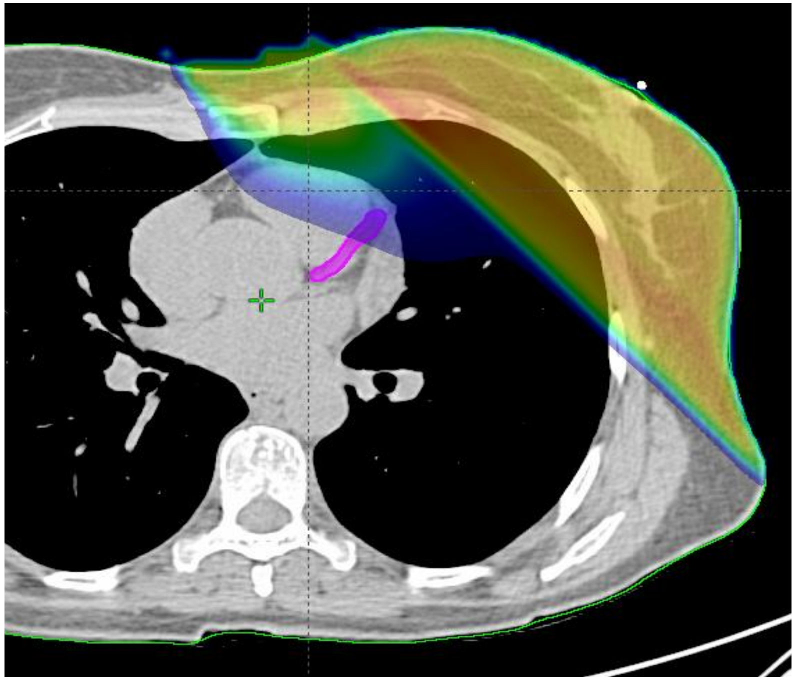


Fig. 4. a: phases 0% (white) and 50% (black); b: phases 30% (black) and 75% (white).
a : phases 0 % (blanc) and 50 % (noir) ; b : phases 30 % (noir) and 75 % (blanc).

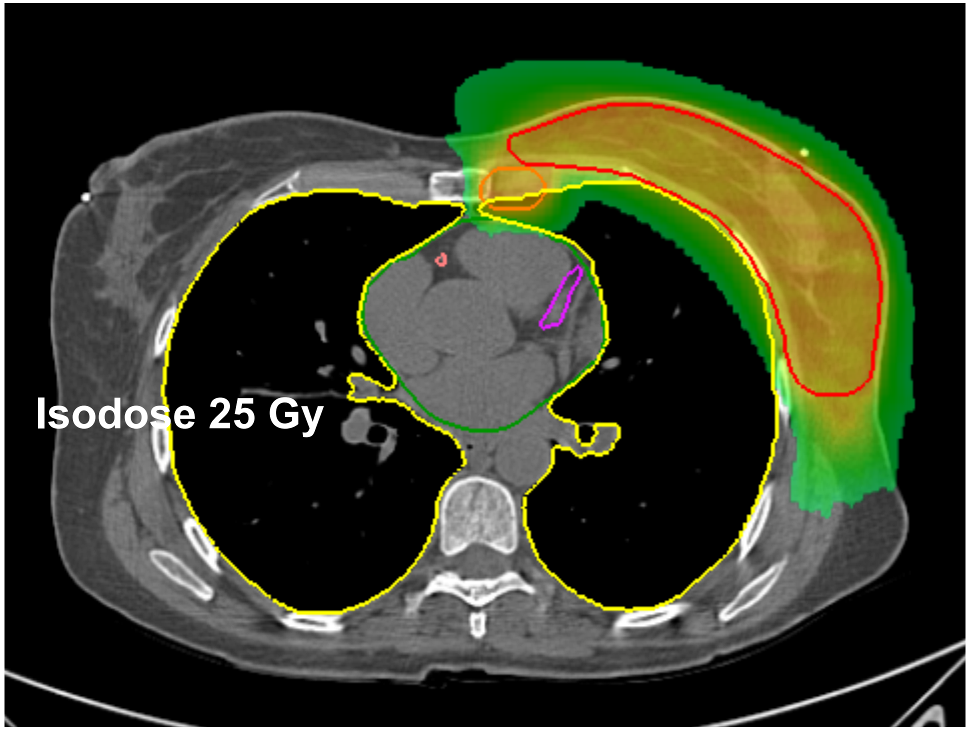
de Almeida, et al, Cancer Radiother 2012

Breast and LN irradiation



Combination of e- and photons

TOMOTHERAPY



De Almeida, Fournier-Bidoz et al, 2011

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Breast, boost, with or without LN areas: clinical experience
In press

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Cancer Radiothérapie

Article original

Résultats préliminaires d'une tomothérapie hélicoïdale adjuvante avec *boost* intégré dans le cadre d'un traitement conservateur d'un cancer du sein

Preliminary results of whole breast helical tomotherapy with simultaneous integrated boost in the adjuvant treatment of breast cancer

X. Liem[a,b], C. Chira[a], A. Fourquet[a], F. Campana[a], D. Peurien[a], N. Fournier-Bidoz[a], Y.M. Kirova[a,*]

Dose: breast 52.2 Gy, 63.8 Gy to the tumor bed 50.6 Gy to the LN areas (when indicated)

in 29 fr.

Dose par fraction:

2.2 to the boost, 1.8 to the breast

1.74 to the LN.

Dose constraints.

	SFRO [28]	Institut Curie	Autres contraintes publiées
Poumon homolatéral	V20 ≤ 15 % V30 ≤ 10 %	V20 ≤ 15 % sein seul V20 ≤ 20 % sein + aires N V5 ≤ 50 %	V30 ≤ 20 % [29] D moyenne ≤ 20 Gy [29]
Cœur	Dmax ≤ 35 Gy	Dmoy ≤ 12 Gy V25 ≤ 10 %	V35 ≤ 30 % [30] V42 ≤ 20 % [31]
Œsophage	Dmax ≤ 40 Gy (15 cm)		V20 ≤ 45 Gy [32]
Sein controlatéral		V5 ≤ 10 %	

SFRO : Société française de radiothérapie oncologique.

Breast, boost, with or without LN areas: clinical experience

Liem et al, CanRad, In press

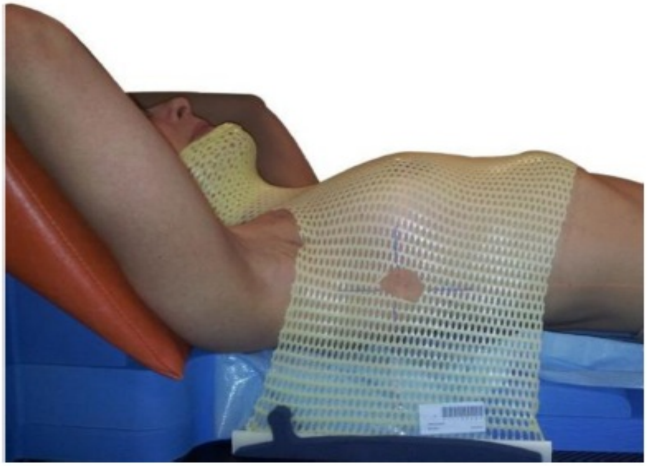
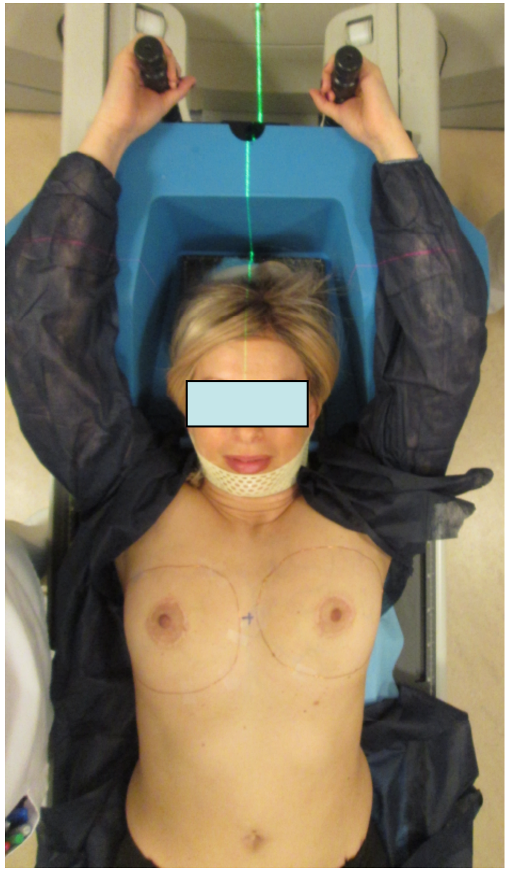


Fig. 1. Contention avec plaque thermoformée.
Contention with thermoformed plate.



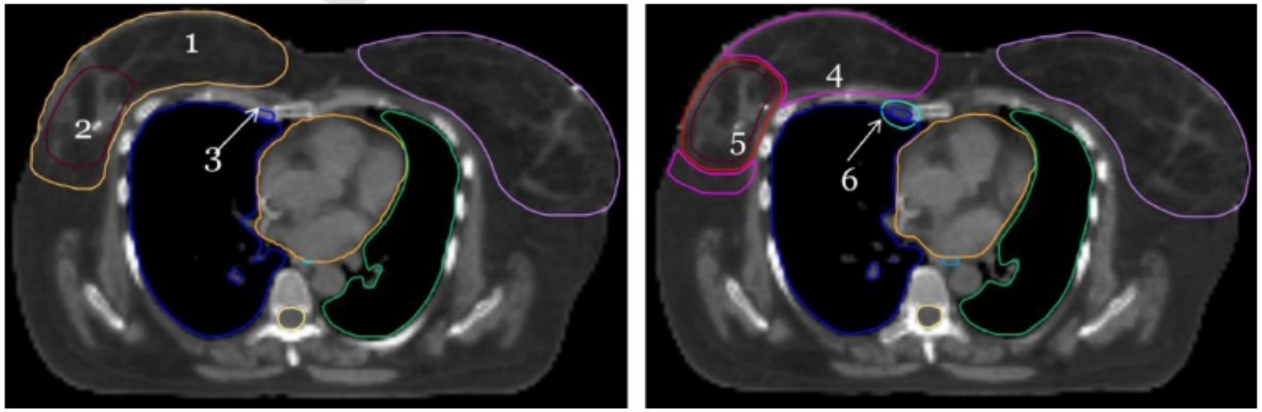


Fig. 2. Délinéation passant par la chaîne mammaire interne. 1 : volume cible anatomoclinique sein ; 2 : volume cible anatomoclinique lit opératoire ; 3 : volume cible anatomoclinique mammaire interne ; 4 : volume cible prévisionnel sein ; 5 : volume cible prévisionnel lit opératoire ; 6 : volume cible prévisionnel mammaire interne.
Delineation of clinical target volume of: 1: breast; 2: tumour bed; 3: internal mammary chain; 4: planning target volume of breast; 5: boost volume; 6: internal mammary chain.

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Patients' characteristics.

Patientes/tumeurs	20/22
Ménopause	9 (45 %)
Latéralité	
Côté droit	13 (60 %)
Côté gauche	9 (40 %)
Quadrant	
Supéro-interne	8 (32 %)
Inféro-interne	7 (32 %)
Supéro-externe	7 (32 %)
Histologie	
CCI	18 (82 %)
CLI	3 (14 %)
C muc	1 (4 %)
Stade	
Stade 1	4 (20 %)
Stade 2	13 (60 %)
Stade 3	3 (15 %)
Grade	
1	3 (14 %)
2	12 (55 %)
3	7 (31 %)
RH	
RO+ RP+	14 (64 %)
RO+ RP–	3 (14 %)
RO– RP+	0
RO– RP–	5 (22 %)
Statut HER-2	
HER-2 : +	6 (28 %)
Chimiothérapie	
–	15 (75 %)
Néo-adjuvante	8 (40 %)
Adjuvante	7 (35 %)
Trastuzumab	4 (20 %)
Statut N	
N 0	9 (41 %)
N + 1–3	11 (50 %)
N ≥ 4	2 (9 %)
Irradiation N	
Sus-claviculaire	20 (90 %)
Sous-claviculaire	15 (68 %)
Mammaire interne	20 (90 %)

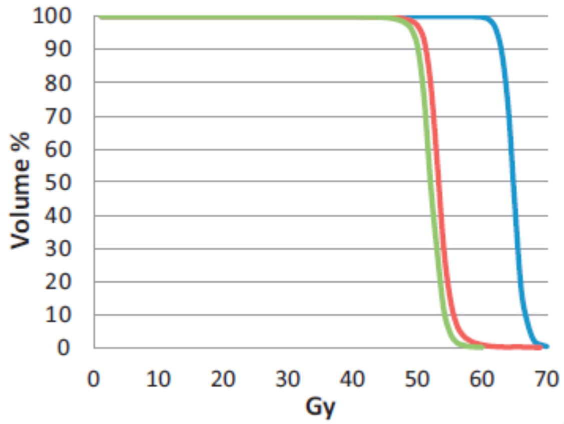


Fig. 3. Moyenne des histogrammes dose–volume. Courbe bleue : volume cible prévisionnel lit opératoire ; courbe rouge : volume cible prévisionnel sein ; courbe verte : volume cible prévisionnel aires ganglionnaires.
Mean doses received by: blue: tumour bed; red: breast; green: lymph nodes.

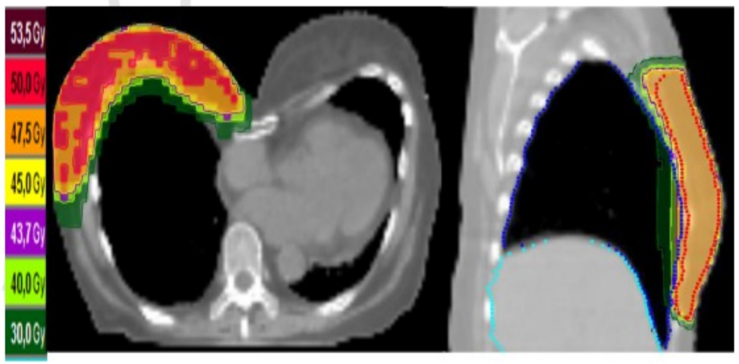


Fig. 6. Isodoses chez une patiente avec un pectum excavatum : de gauche à droite, toutes les isodoses puis isodoses supérieures à 10 Gy puis 20 Gy et 30 Gy.
Isodoses in patient with pectus exavatum: from left to right, all isodoses then isodoses superior to 10 Gy then to 20 Gy then to 30 Gy.

Breast, boost, with or without LN areas: clinical experience

Liem et al, CanRad, In press

OAR

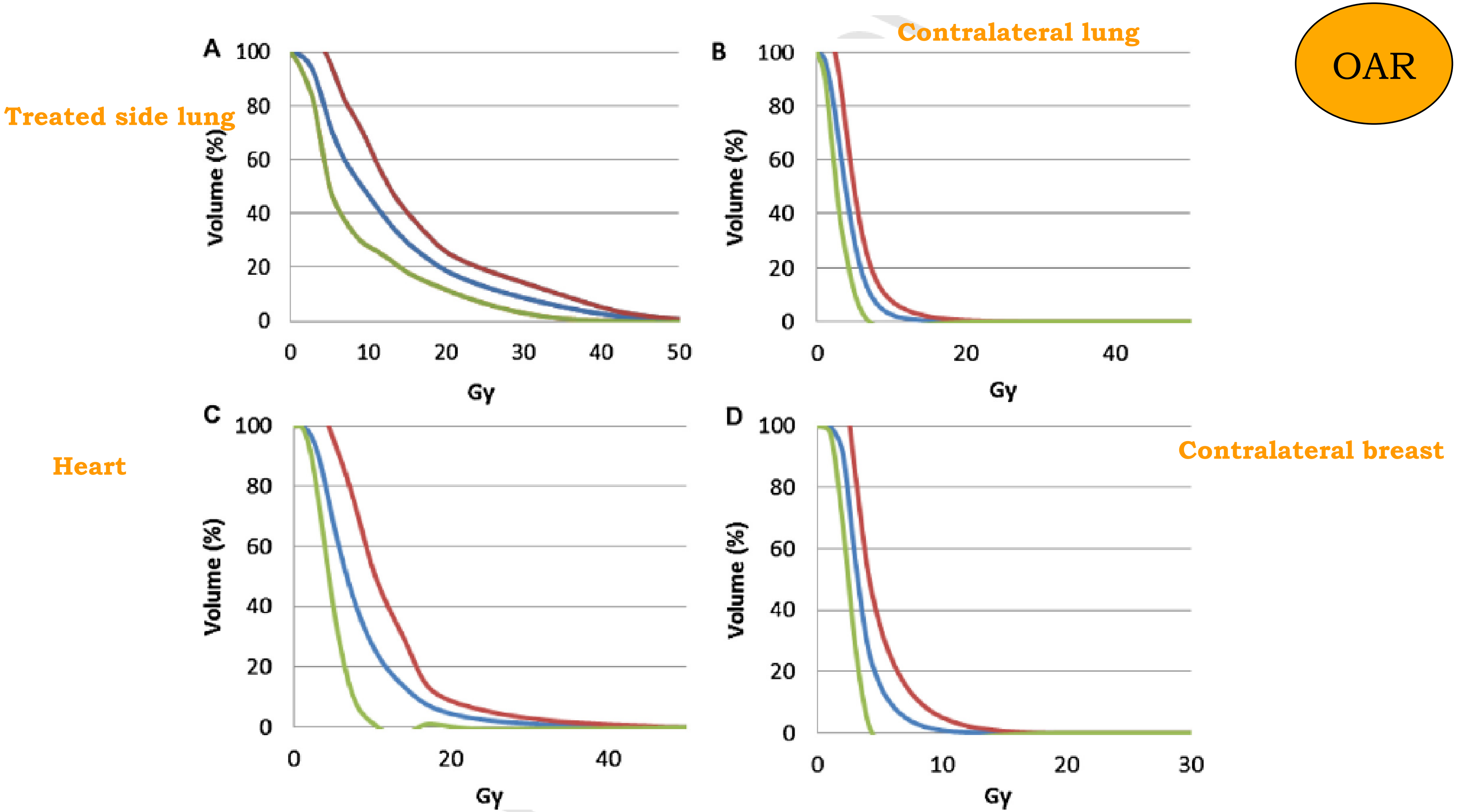


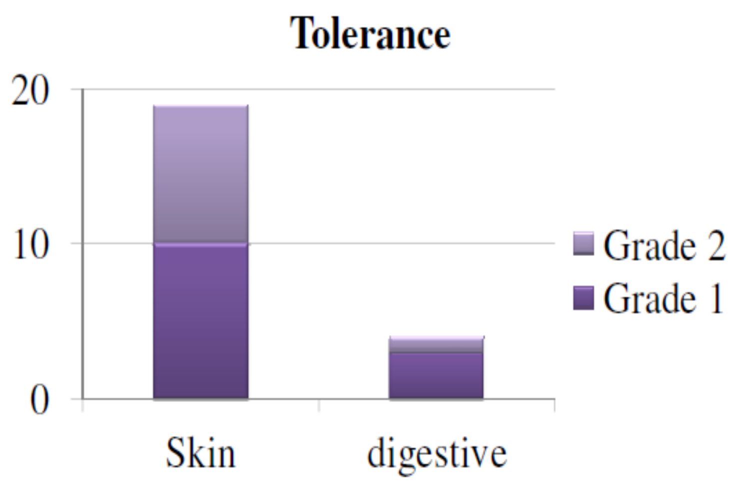
Fig. 5. Zones d'histogramme dose–volume pour les organes à risque. Courbe bleue : moyenne d'un histogramme dose–volume ; courbe verte : moyenne moins 2 fois l'écart-type ; courbe rouge : moyenne plus 2 fois l'écart-type. A. Poumon homolatéral. B. Poumon controlatéral. C. Cœur pour lésions gauches. D. Sein controlatéral.

Zones of dose–volume histograms of organs at risk. Blue curve: median value of dose–volume histograms; green curve: median value minus 2 SD; red curve: median value plus 2 SD. A. Treated side lung. B. Contralateral lung. C. Heart when left side treated. D. Contralateral breast.

Breast, boost, with or without LN areas: clinical experience
Liem et al, CanRad, In press

Indications:

pectus exavatum,
problems of field junctions or
high dose received to lung and heart,
bilateral breast cancer, etc.)



Acute toxicity.

Toxicité	n (%)	Médiane
Cutanée		
Grade 1	10 (50)	
Grade 2	9 (45)	
Délai avant toxicité cutanée		31 j/19 séances
Digestive (dysphagie)		
Grade 1	2	
Grade 2	1	
Délai avant toxicité digestive	1	32 j/22 séances
Respiratoire (toux)		
Grade 1	1	

All toxicities were described using the Common Terminology Criteria for Adverse Effects v3.0.

Conclusions. – Helical tomotherapy can achieve full target coverage while protected to the heart and ipsilateral lung. This treatment was well tolerated and reproducible. However, the low doses to normal tissue volumes need to be reduced in future studies.

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Helical TomoTherapy in the treatment of breast cancer

Early stage breast cancer: difficult cases

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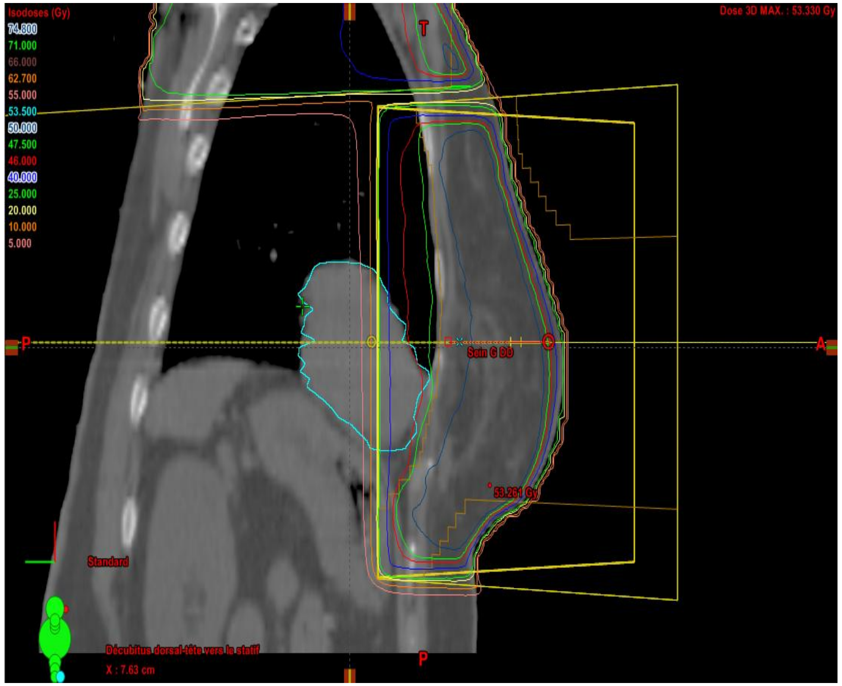
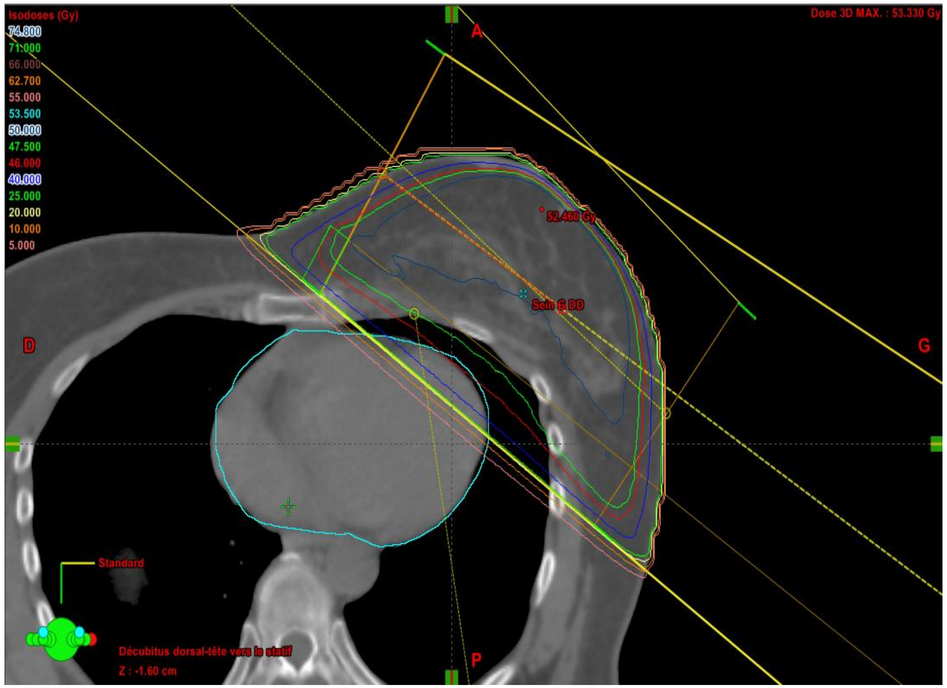
Breast cancer radiotherapy tayloring, J. Jacob et al., 2012: *Pb: doses OAR*





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Breast cancer radiotherapy tayloring,
Pb of boost volume
J. Jacob et al. 2012

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Nuclear Medicine & Radiation Therapy

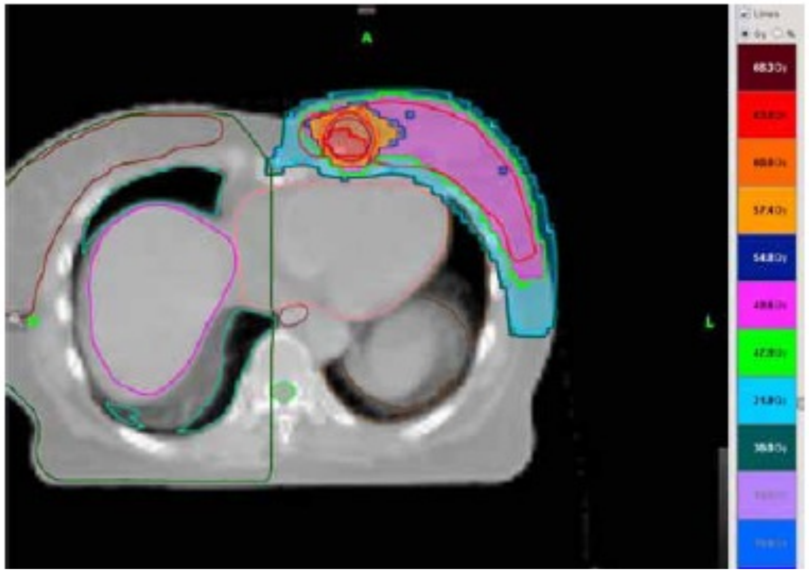
Jacob et al., J Nucl Med Radiat Ther 2012, 3:3
http://dx.doi.org/10.4172/2155-9619.1000129

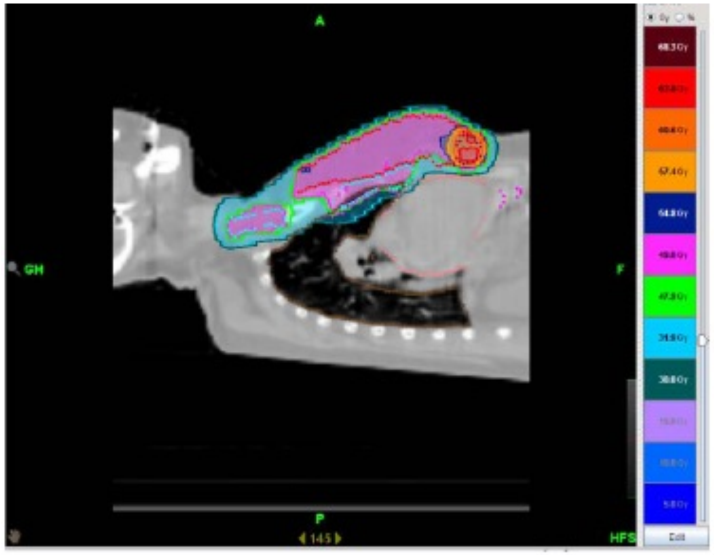
Review Article Open Access

Can Helical Tomotherapy be used as a Safe Treatment Alternative for Breast Cancer Patients?

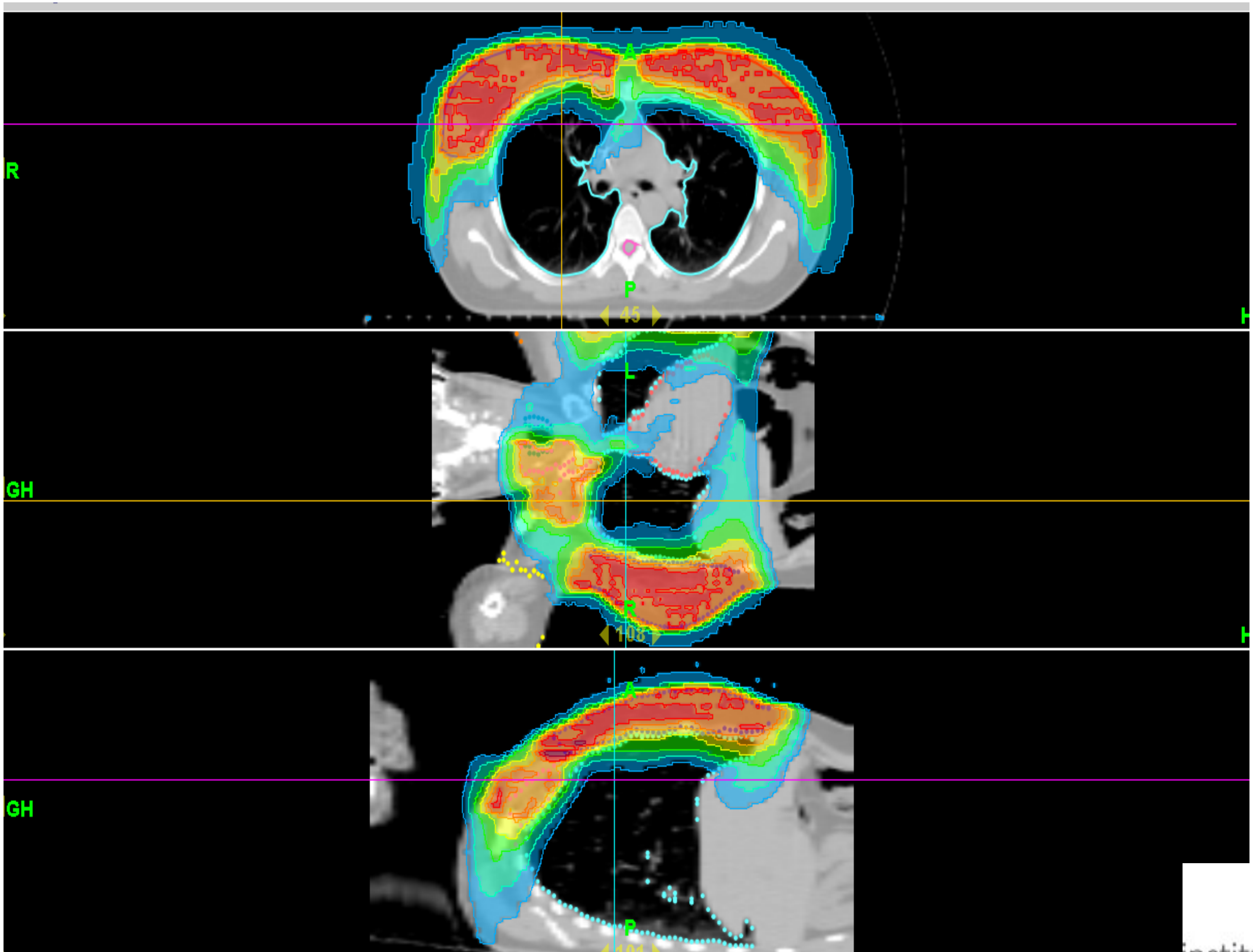
Julian Jacob, Francois Campana, Ciprian Chira, Dominique Peurien, Caroline Daveau, Nathalie Fournier-Bidoz, Alain Fourquet and Youlia M Kirova*

Department of Radiation Oncology, Institut Curie, Paris, France





Other difficult case: bilateral breast cancers with LN irradiation



Helical Tomotherapy in the treatment of breast cancer

Advanced and metastatic breast cancer

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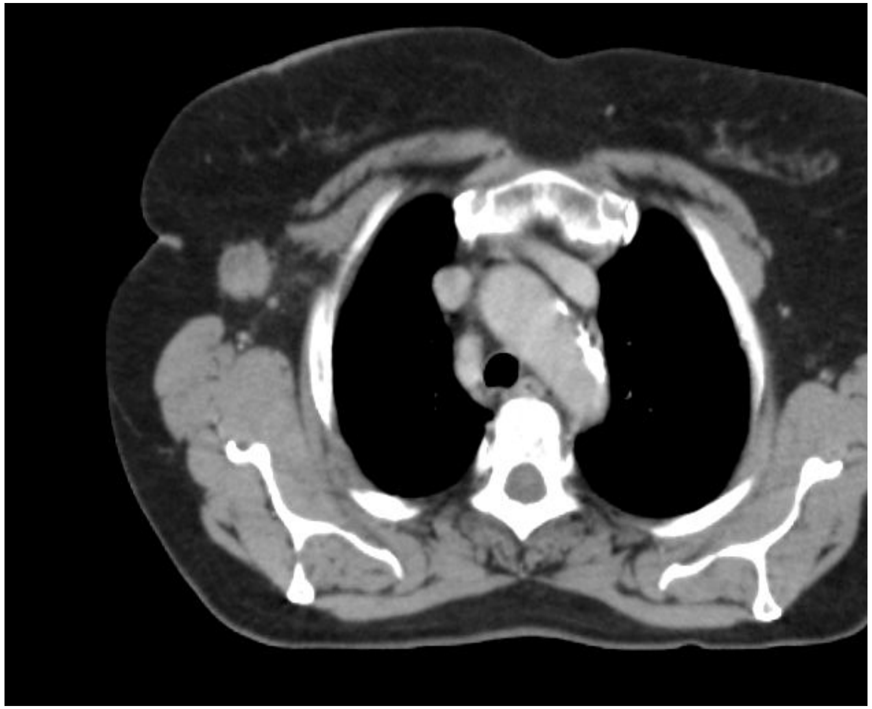
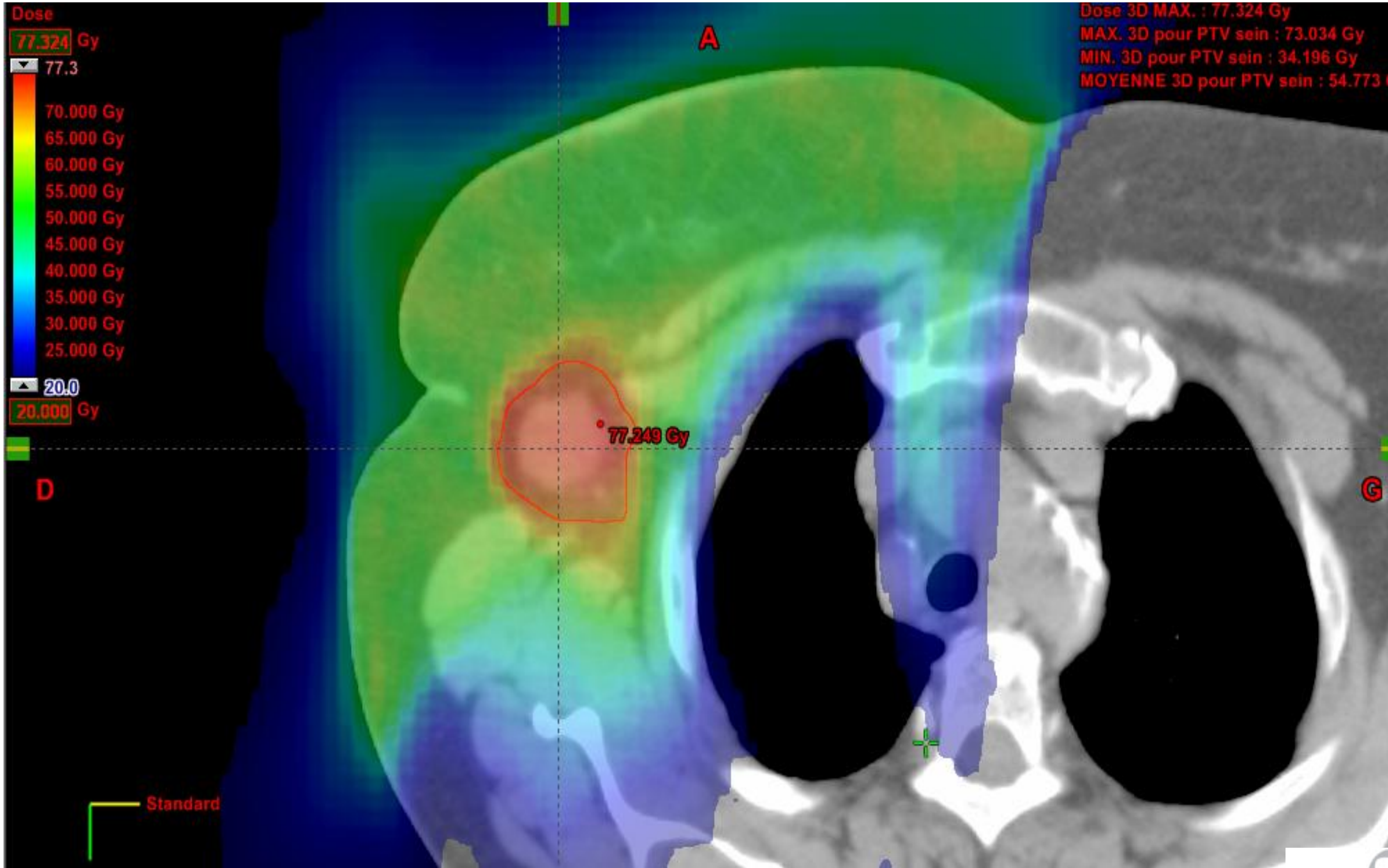
Breast cancer patient



- T4bN0M+
- IDC right breast
- Breast RT:

Breast:	51.4 Gy /31 f de 1.66 Gy
Tumor:	74.4 Gy/ 31 f de 2.4 Gy

Dose distribution



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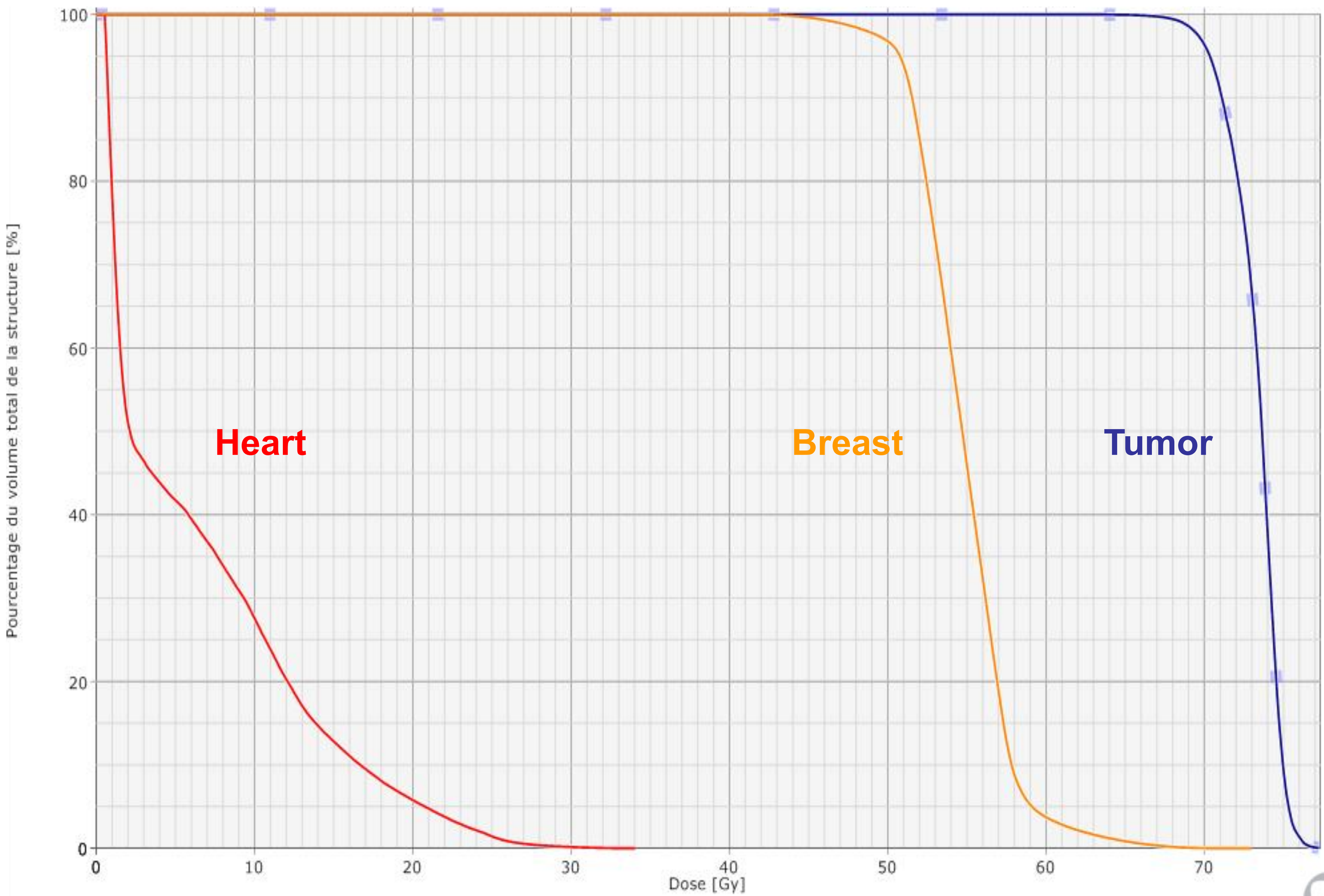
Dose-Volume Histogram



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Helical Tomotherapy in the treatment of advanced breast cancer: breast, tumour and lymph nodes

Clinical Study

Helical Tomotherapy for Inoperable Breast Cancer: A New Promising Tool

Ciprian Chira,[1] Youlia M. Kirova,[1] Xavier Liem,[1] François Campana,[1] Dominique Peurien,[2] Malika Amessis,[2] Nathalie Fournier-Bidoz,[2] Jean-Yves Pierga,[3] Rémi Dendale,[1] Pierre Bey,[1] and Alain Fourquet[1]

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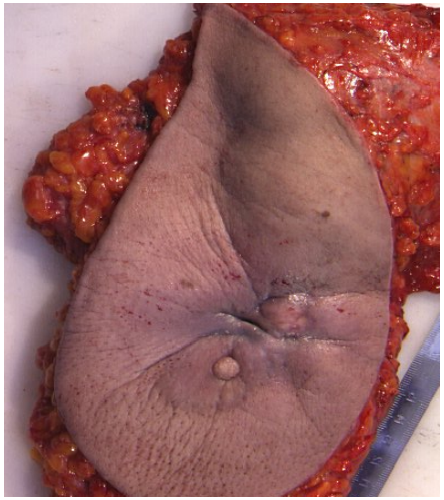
Tomotherapy with integrated boost in locally advanced disease as neoadjuvant breast, tumor and LN irradiation : patients

before



after

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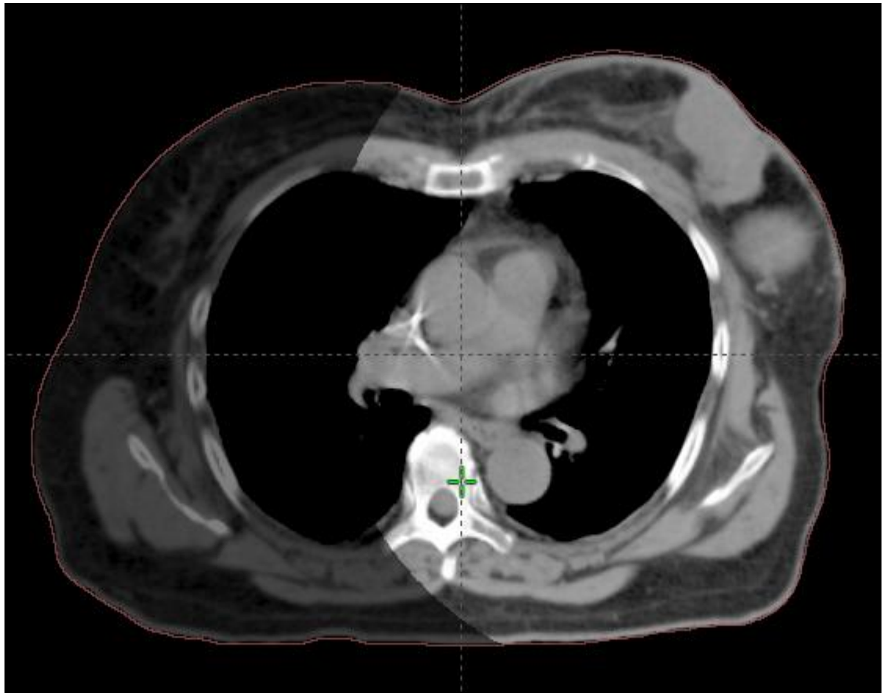
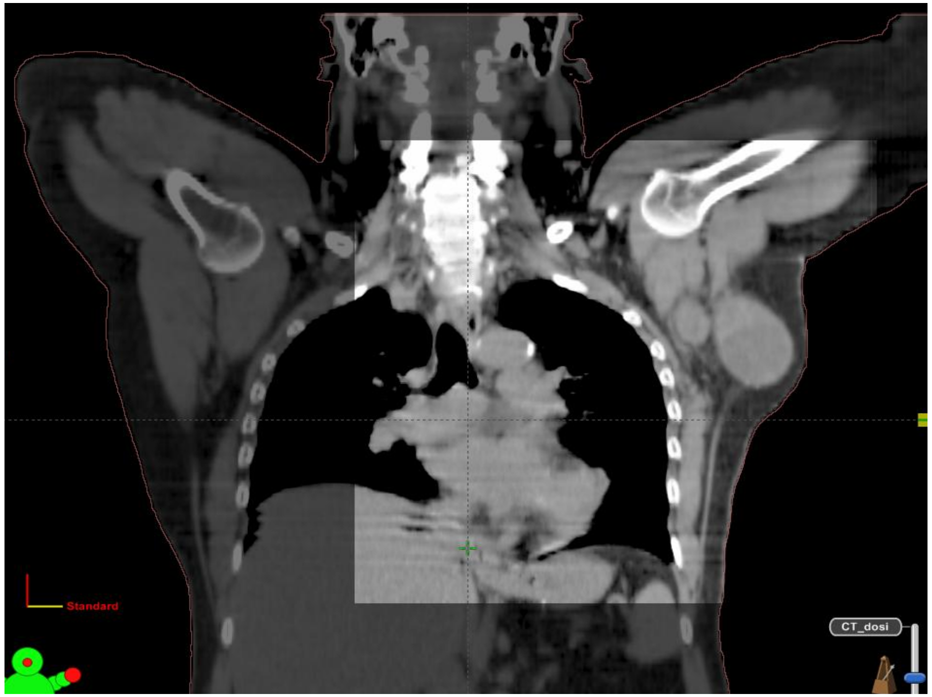
Volumes and doses

CT scan in treatment position





➢ *Delineation of the volumes after images registration*

Chira et al, 2013

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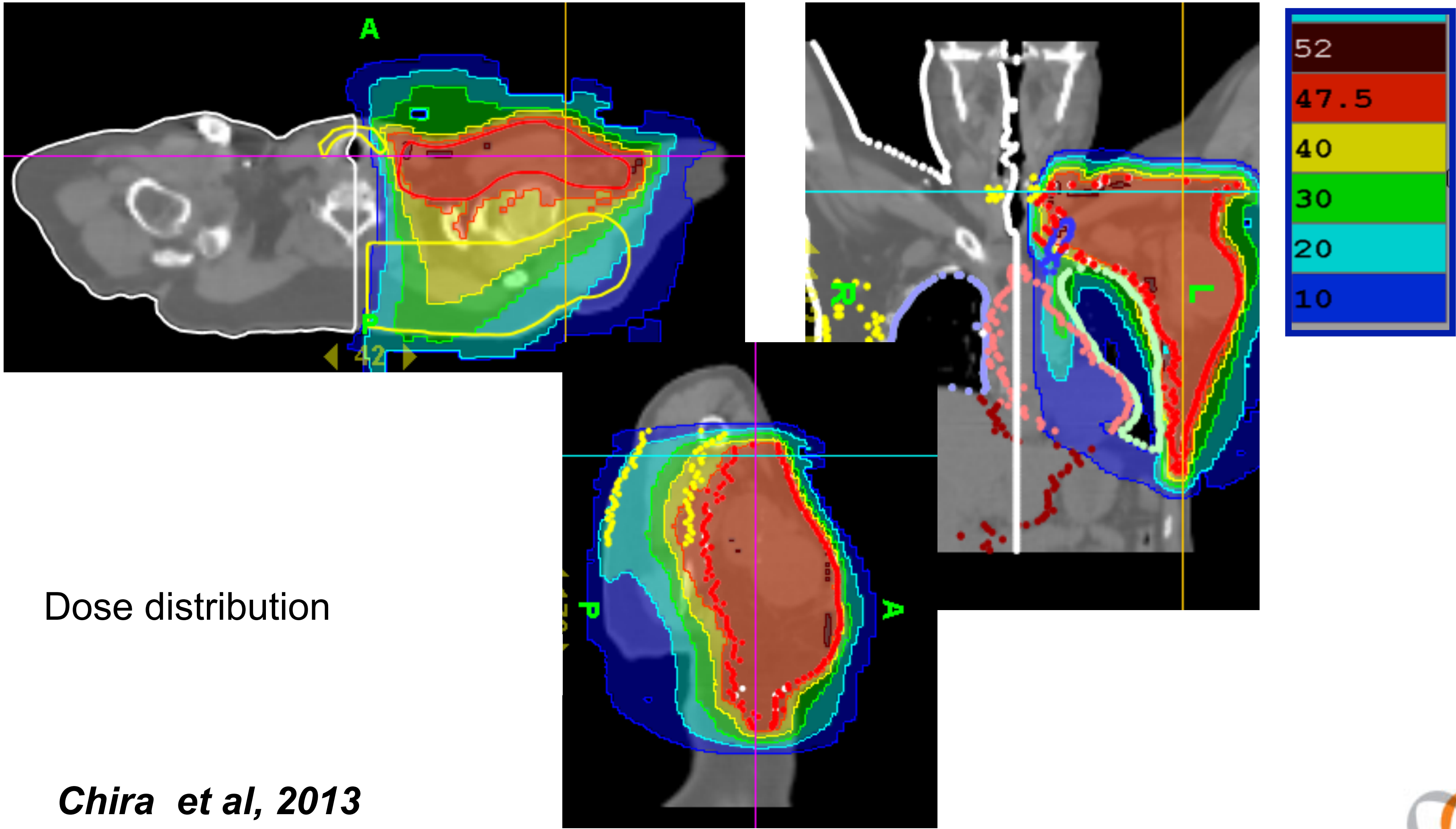
T4N+ neo adjuvant RT after failure of anthracyclines and taxans neo adjuvant chemotherapy



Dose distribution

Chira et al, 2013

Chira et al, 2013

TABLE 3: Description of treatment volumes and prescribed radiation doses with helical tomotherapy.

Patient number	Total doses (Gy)					Dose per fraction (Gy)				
	WB	Lymph nodes			TB	WB	Lymph nodes			TB
		IMN	SCV IFC	ALN			IMN	SCV IFV	ALN	
1	41.8	41.8	41.8	41.8	41.8	1.9	1.9	1.9	1.9	1.9
2	50				55	2				2.2
3	50		45	45	50	2		1.8	1.8	2
4	46	46	46	46	46	2	2	2	2	2
5	46	46	46	46	46	2	2	2	2	2

WB: whole breast, IMLN: ipsilateral internal mammary lymph nodes, SCV: ipsilateral supraclavicular fossa, IFC: ipsilateral infraclavicular fossa (level III axillary), ALN: ipsilateral level I and II axillary lymph nodes, TB: tumoral bed.

TABLE 4: Treatment characteristics and results.

Patient number	TNM stage∬	Tumor maximal diameter† (mm)	WB dose¶ (Gy)	CCT/number of cycles	Early toxicity grade (CTCAE v.4)			Surgical specimen		Pathological response§
					Skin	Digestive	Other‡	T* size (cm)	Nodal status	
1	T4bN2aM0	105	41.8	Yes/4	2	0	0	50	7+/11	PR
2	T4cN2aM0	160	50	No	1	1	0	64	0/13	PR
3	T3N0M0	75	50	Yes/4	2	0	1	22	0/15	PR
4	T4bN2aM0	85	46	Yes/4	3	1	0	4.5	2+/8	PR
5	T3N2bM0	88	46	Yes/2	3	0	3	17.6	1+/9	PR

∬ AJCC cancer staging manual, seventh edition (2010), WB: whole breast, CCT: concomitant chemotherapy, CTCAE: Common Toxicity Criteria for Adverse Events v.4, † baseline evaluation before all treatments, ¶ delivered radiation dose, ‡ cardiovascular and/or pulmonary and/or hematological toxicity, * residual invasive malignant epithelial cells, § interpretation at the Institut Curie of the concept proposed by Sataloff and colleagues (details in article), PR: partial response.

Preoperative HT with or without CCT appears to be a feasible and promising alternative to highly conformal techniques in the treatment of large inoperable breast cancers. Particular attention should be given to evaluate acute skin toxicity especially in patients receiving CCT. Larger studies are warranted to better define HT doses and to evaluate long-term toxicities.

Medical Dosimetry 37 (2012) 425-431

Medical Dosimetry

journal homepage: www.meddos.org

Implant breast reconstruction followed by radiotherapy: Can helical tomotherapy become a standard irradiation treatment?

Carole Massabeau, M.D., Nathalie Fournier-Bidoz, Ph.D., Georges Wakil, M.D., Pablo Castro Pena, M.D., Romain Viard, Ph.D., Sofia Zefkili, Ph.D., Fabien Reyal, M.D., François Campana, M.D., Alain Fourquet, M.D., and Youlia M. Kirova, M.D.

Department of Radiation Oncology, Institut Curie, Paris, France

Volume definition

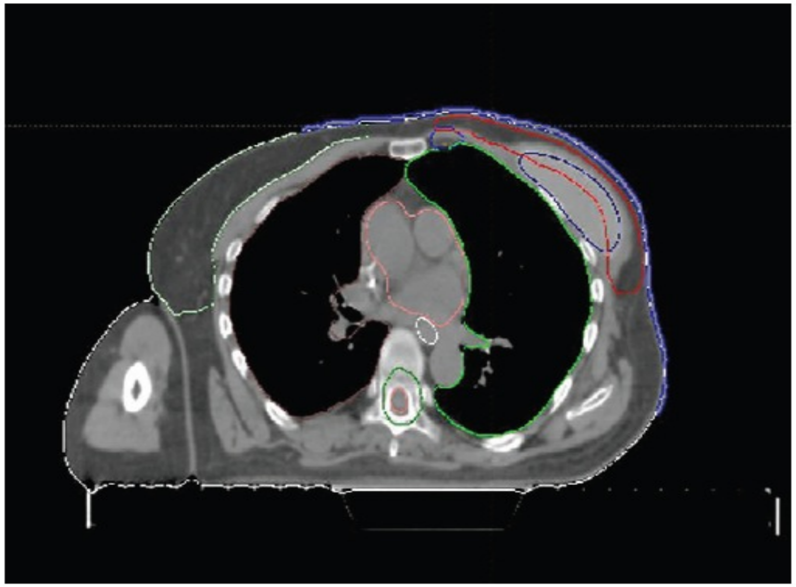


Fig. 1. Target volumes and delineation of organs at risk in a left-sided breast cancer. Red line: PTV1; dark blue line: implant; green line: left lung; brown line: right lung; pink line: great vessels and heart; light blue line: right breast; grey line: esophagus; yellow line: spinal cord; double blue line: bolus.

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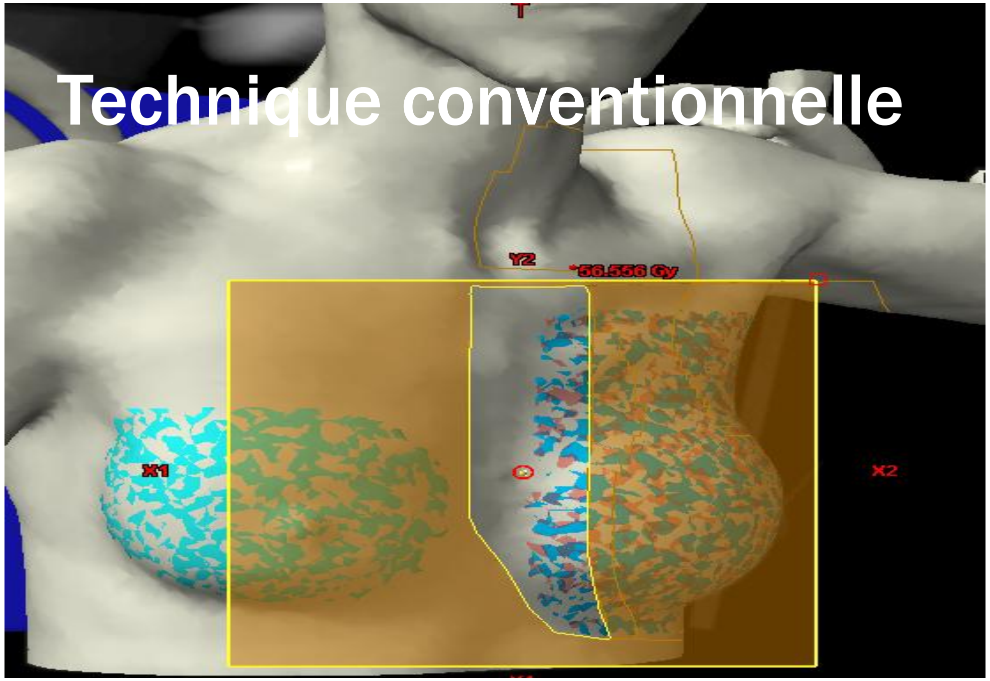
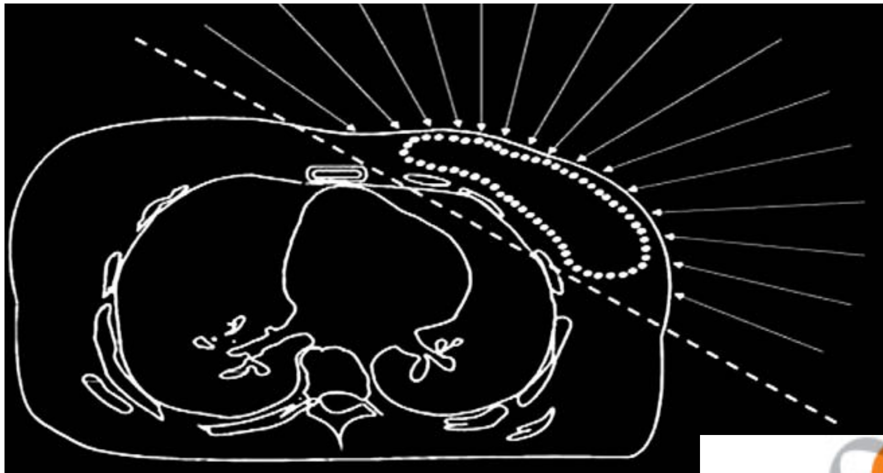
Massabeau et al, Med Dosim 2012



Tomothérapie



3D CRT vs HT
10 patients : 6 left, 4 right
uni lateral implants:
50 Gy Chest wall + supra and infra clavicular LN

Organ at risk	Priority	Blocking	Importance	Histogram Dose Volume points	Dose max
Controlateral Lung	1	directional	1000	5 %-7 Gy 30 %-3 Gy 50 %-2 Gy	10 Gy
Heart	2	directional	1000	15 %-10 Gy 5 %-15 Gy	25 Gy
Homolateral Lung	3	directional	1000	50 %-5 Gy 15 %-20 Gy 5 %-30 Gy	40 Gy
Controlateral breast	4	directional	1000	10 %-3 Gy	5 Gy
Spinal cord	5	directional	300	30 %-10 Gy	10 Gy
Liver	6	directional	300	20 %-5 Gy	20 Gy

Massabeau et al, Med Dosim 2012

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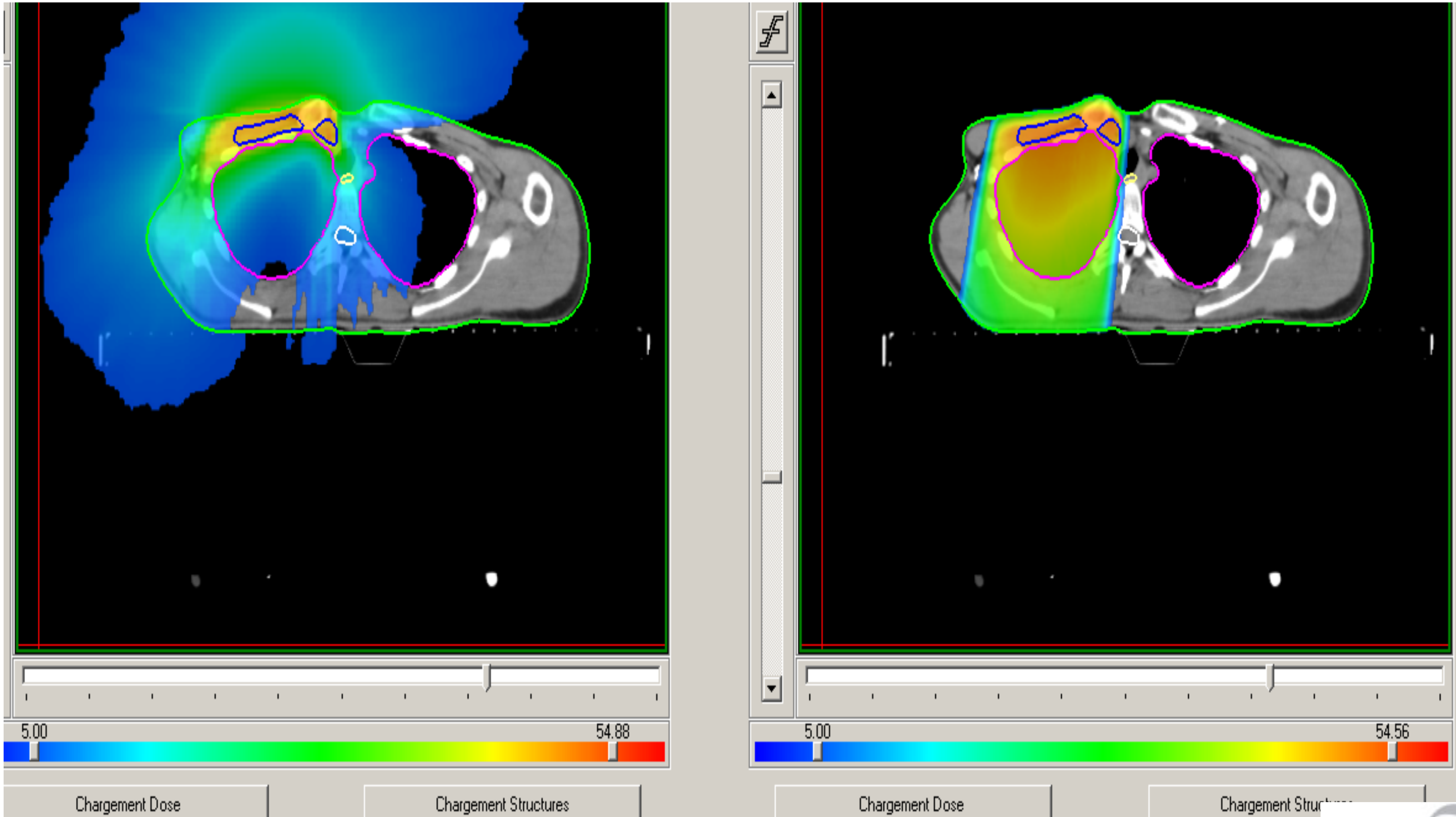
TOMO VS 3D: dose distribution LN



Massabeau et al, Med Dosim 2012

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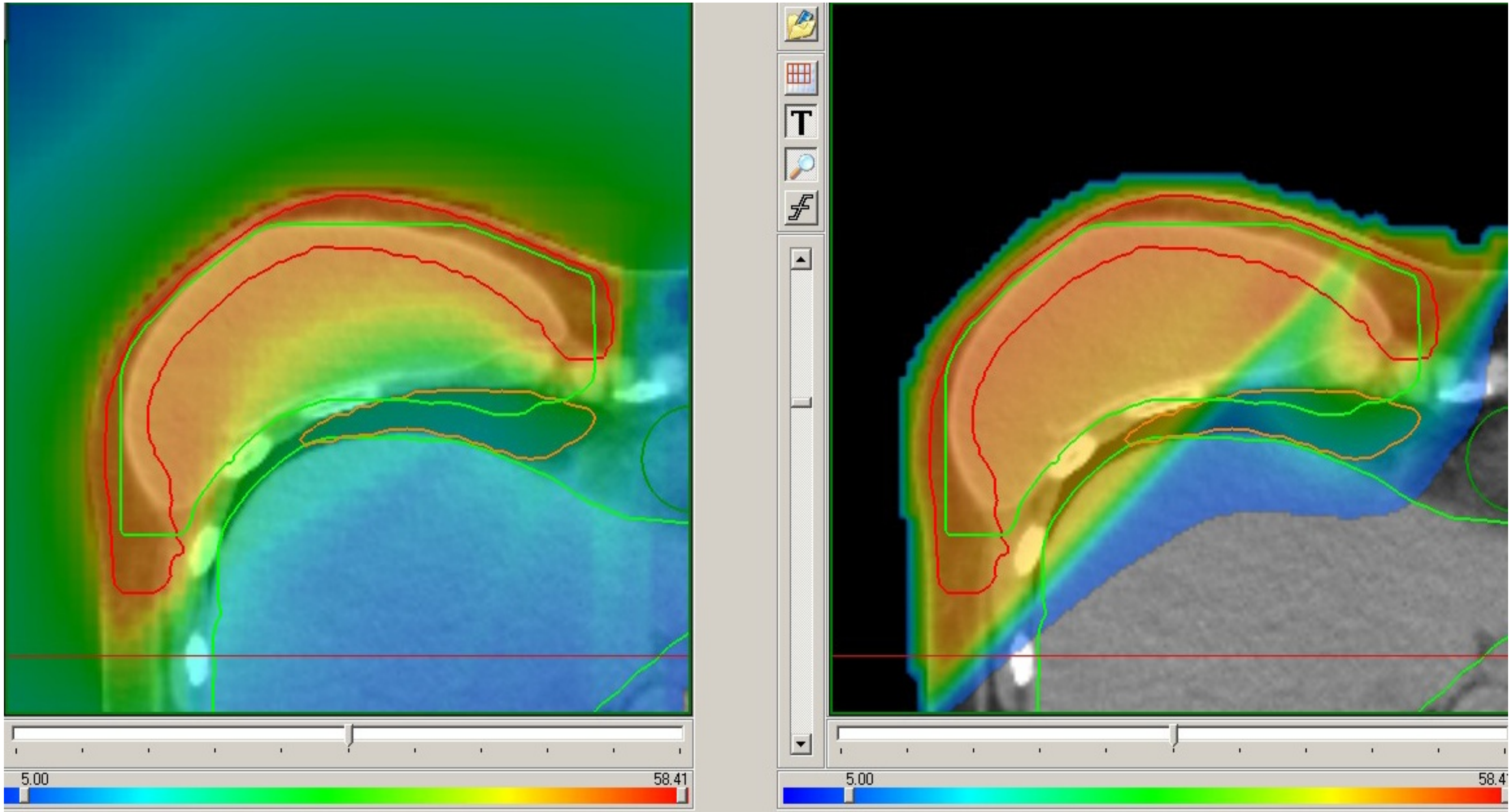
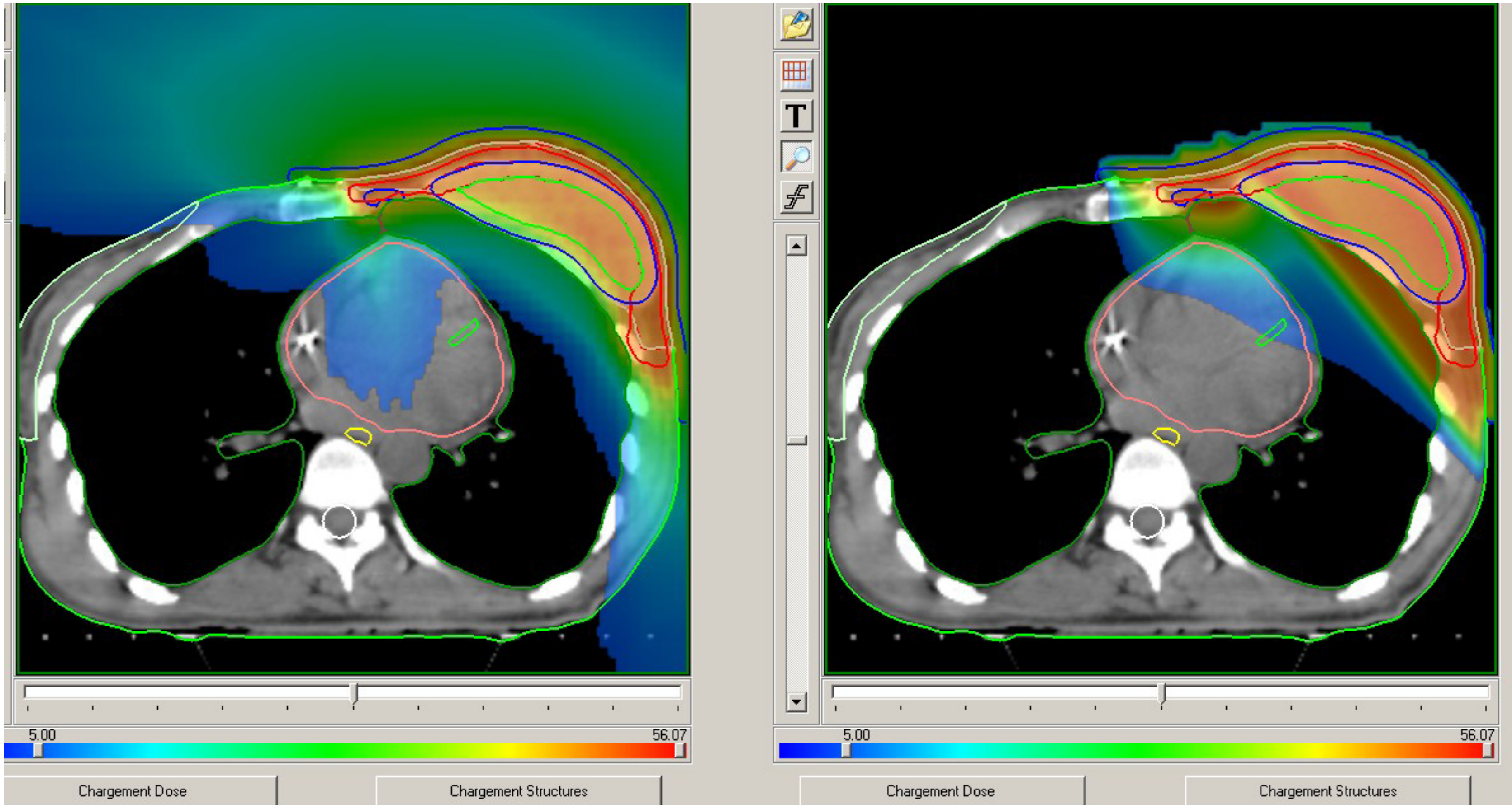
TOMO VS 3D: dose distribution chest wall



Massabeau et al, Med Dosim 2012

TOMO VS 3D: OAR



Massabeau et al, Med Dosim 2012

TOMO VS 3D for implants : Conclusions

Conclusion

This dosimetric study represents the first step toward successful optimization of comprehensive loco-regional radiation therapy after total mastectomy and implant-based reconstruction of the breast. However, planning of optimal radiation treatment for each patient must still be based on clinical judgment and on a discussion of the risks and benefits. An additional study on the HT technique needs to be performed to analyze the unknown clinical implications of some of the dosimetric differences and to address the unsolved issues of treatment delivery associated with setup uncertainty and motion caused by respiration. The long-term effects of low doses to normal tissues are still unknown and need to be studied further. Therefore, we recommend using this tomotherapy technique only for patients with aggressive breast cancers, often after chemotherapy (to reduce the heart and lung complications risk), as well as for bilateral breast cancers.

Massabeau et al, Med Dosim 2012

Conclusions

Currently the new treatment modalities as the TomoTherapy could be used to decrease the cardiac and lung toxicity.

It is also simple to deliver in complex treatment volumes with very homogenious dose distribution and perfect conformity

The aim of this breast cancer radiotherapy tailoring is to avoid the early and late side effects.

Therefore, special attention to the low doses to contralateral breast and lung is needed

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Thank you for your attention

M.D.

- **A. Fourquet**
- **F. Campana**
- **R. Dendale**
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