TOMOTERAPIA in Italia: Esperienze a confronto

BARD 20 novembre 2010

L’esperienza di Reggio Emilia – Testa collo

Alessandro Muraglia

Reasons for the use of tomotherapy:

- Complex tumor geometry and proximity of organs at risk

-Need for image guidance when immobilization was problematic or interfraction variations were to be minimized

Major Advantages highlighted

- Applicable where highly conformal dose distributions are required.

-Also considered useful for long segment and multiple target involvement or in targets in close proximity to critical organs

- Image guidance for precise treatment of difficult targets in difficult patients.

Radiotherapy and Oncology 78 (2006) 276–282
www.thegreenjournal.com

Tomotherapy

Significant improvement in normal tissue sparing and target coverage for head and neck cancer by means of helical tomotherapy

Claudio Fiorino[a,*], Italo Dell'Oca[b], Alessio Pierelli[a], Sara Broggi[a], Elena De Martin[a], Nadia Di Muzio[b], Barbara Longobardi[a], Ferruccio Fazio[b,c], Ricardo Calandrino[a]

[a]*Medical Physics*, and [b]*Department of Radiotherapy, S. Raffaele Institute, Milano, Italy*,
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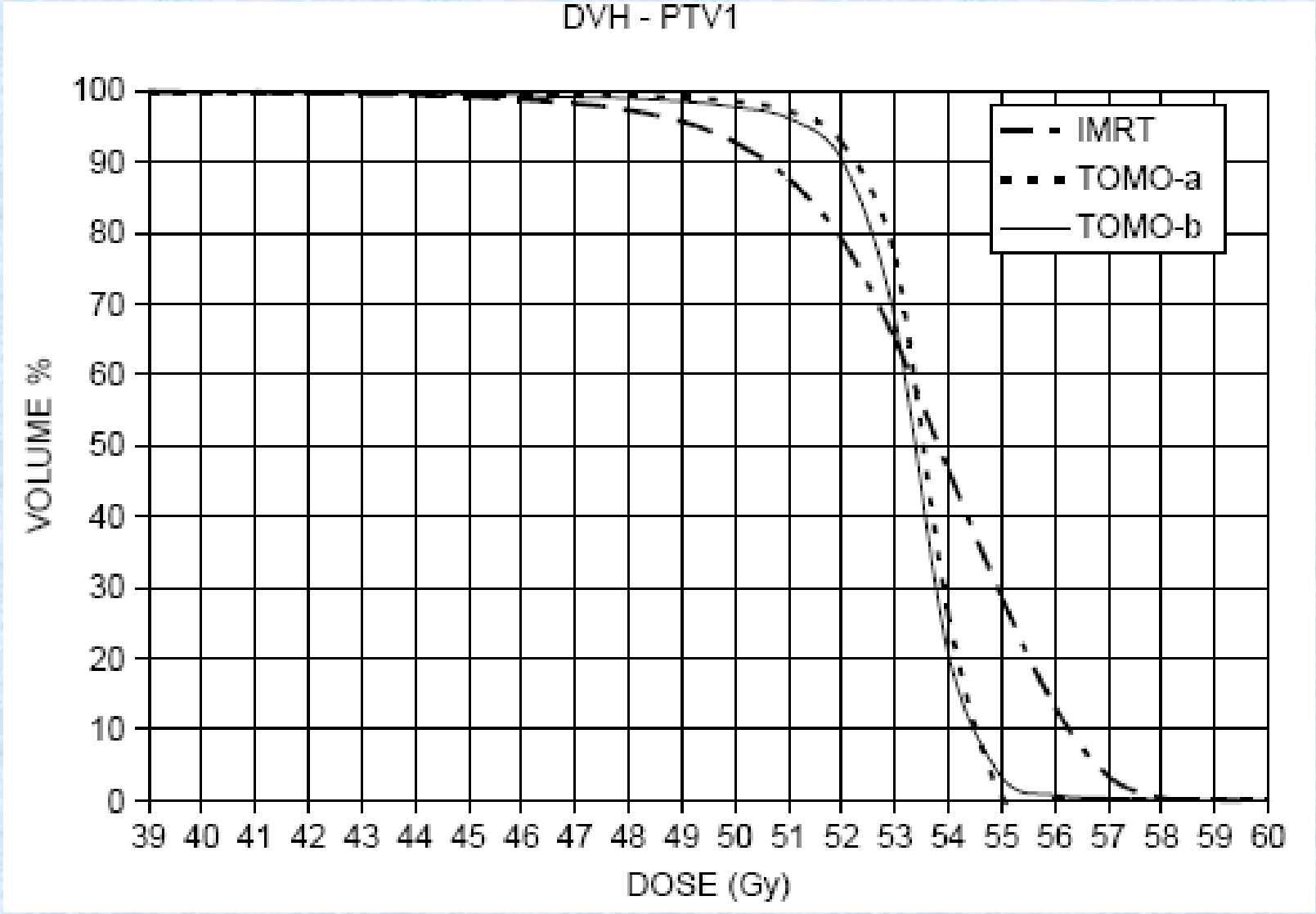
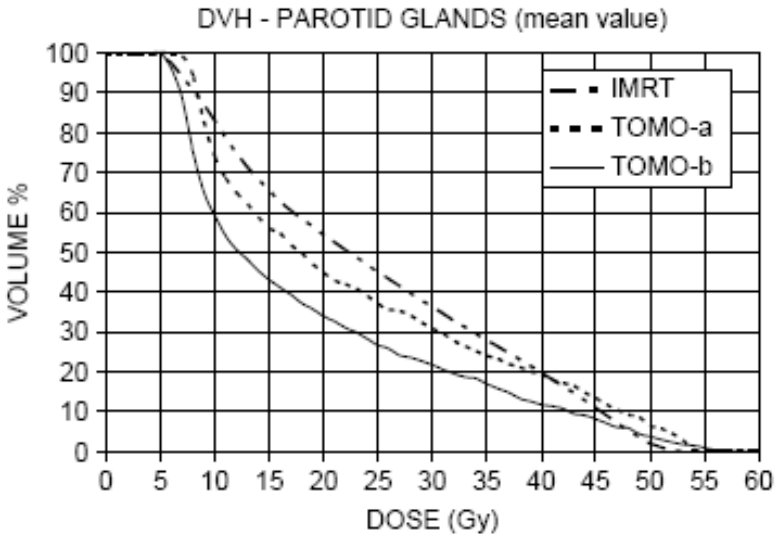
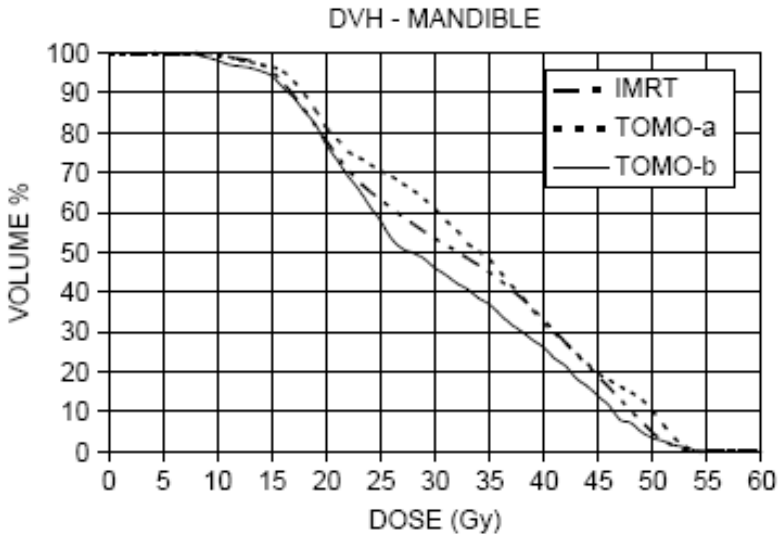
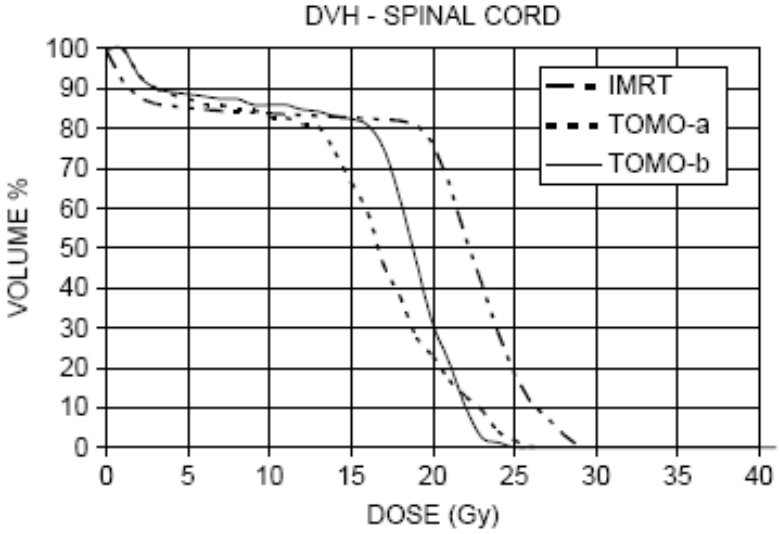
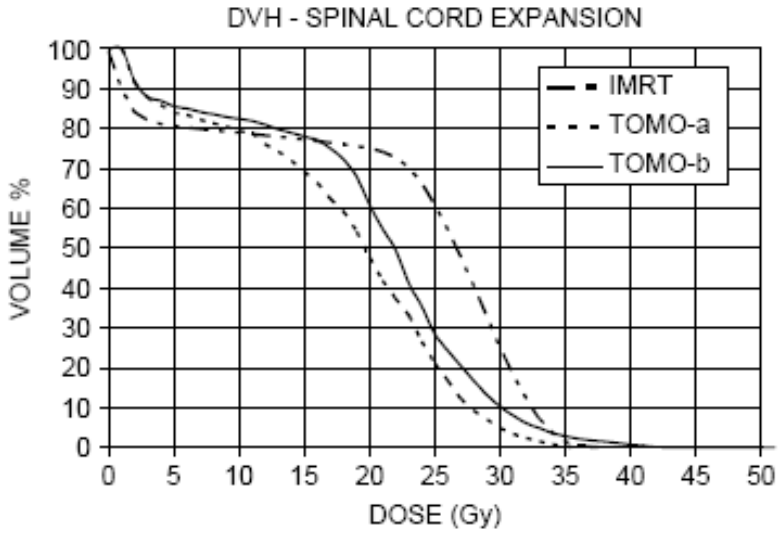
The most important result of current investigation is that Tomotherapy has the potential to significantly improve the quality of the dose distribution both in terms of better dose homogeneity within the PTV and more efficient sparing of spinal cord, parotids and mandible.


DVH - PTV1
VOLUME %
100
90
80
70
60
50
40
30
20
10
0
39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54 55 56 57 58 59 60
DOSE (Gy)
IMRT
TOMO-a
TOMO-b


DVH - PAROTID GLANDS (mean value)
VOLUME %
DOSE (Gy)
IMRT
TOMO-a
TOMO-b


DVH - MANDIBLE
VOLUME %
DOSE (Gy)
IMRT
TOMO-a
TOMO-b


DVH - SPINAL CORD
VOLUME %
DOSE (Gy)
IMRT
TOMO-a
TOMO-b


DVH - SPINAL CORD EXPANSION
VOLUME %
DOSE (Gy)
IMRT
TOMO-a
TOMO-b

INITIAL CLINICAL EXPERIENCE WITH HELICAL TOMOTHERAPY FOR HEAD AND NECK CANCER

Allen M. Chen, MD, Richard L. S. Jennelle, MD, Radhika Sreeraman, BA, Claus C. Yang, PhD, Tianxiao Liu, PhD, Srinivasan Vijayakumar, MD, James A. Purdy, PhD

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Accepted 10 February 2009
Published online 29 April 2009 in Wiley InterScience (www.interscience.wiley.com). DOI: 10.1002/hed.21123

Seventy-seven patients (55% were treated by HT with definitive intent, 45% were treated with HT postoperatively)

-Median dose of 66 Gy (range, 60 to 72 Gy)
-Megavoltage CT before each treatment

Results. The 2-year estimates:
Overall survival 82%
Localregional control 77%
Disease-free survival 71%

16 of the 18 patients who progressed in the primary site or neck failed in the high-dose planning target volume (PTV).

Head Neck 31: 1571–1578, 2009

Strahlentherapie
und Onkologie

Original Article

Pattern of Failure after Helical Tomotherapy in Head and Neck Cancer

Ashraf Farrag, Mia Voordeckers, Koen Tournel, Peter De Coninck, Guy Storme[1]

63 patients with a biopsy-proven HNC were treated with HT.
14% patients underwent surgery prior to radiotherapy.

Dose of 66–70.5 Gy in 2.2–2.35 Gy/fraction was prescribed to the primary tumor and pathologic lymph nodes (66 Gy in case of CCRT)

In the postoperative setting, a dose of 60 Gy was given when surgical section margins were negative

Strahlenther Onkol. 2010 Sep;186(9):511-6.

Results

Results. The 2-year
overall survival 66%
disease-free survival 54%
locoregional control 77%

the **volume of failure (Vf)**

“in-field failure” inwhich ≥ 95% or Vf was located within the 95% isodose (InF), (10 patients)
“marginal failure” if 20–94% of Vf was within the 95% isodose (2 patients)
“outside-field failure” if < 20% of the Vf was inside the 95% isodose (1 patient)

13 patients developed a locoregional failure
The majority of locoregional failures were in the high-dose region

Clinical Oncology xxx (2010) 1–8

Contents lists available at ScienceDirect

Clinical Oncology

journal homepage: www.elsevier.com/locate/clon

Original Article

Tumour Shrinkage and Contour Change during Radiotherapy Increase the Dose to Organs at Risk but not the Target Volumes for Head and Neck Cancer Patients Treated on the TomoTherapy HiArt™ System

H. Loo *, J. Fairfoul †, A. Chakrabarti *, J.C. Dean *, R.J. Benson *, S.J. Jefferies *, N.G. Burnet ‡

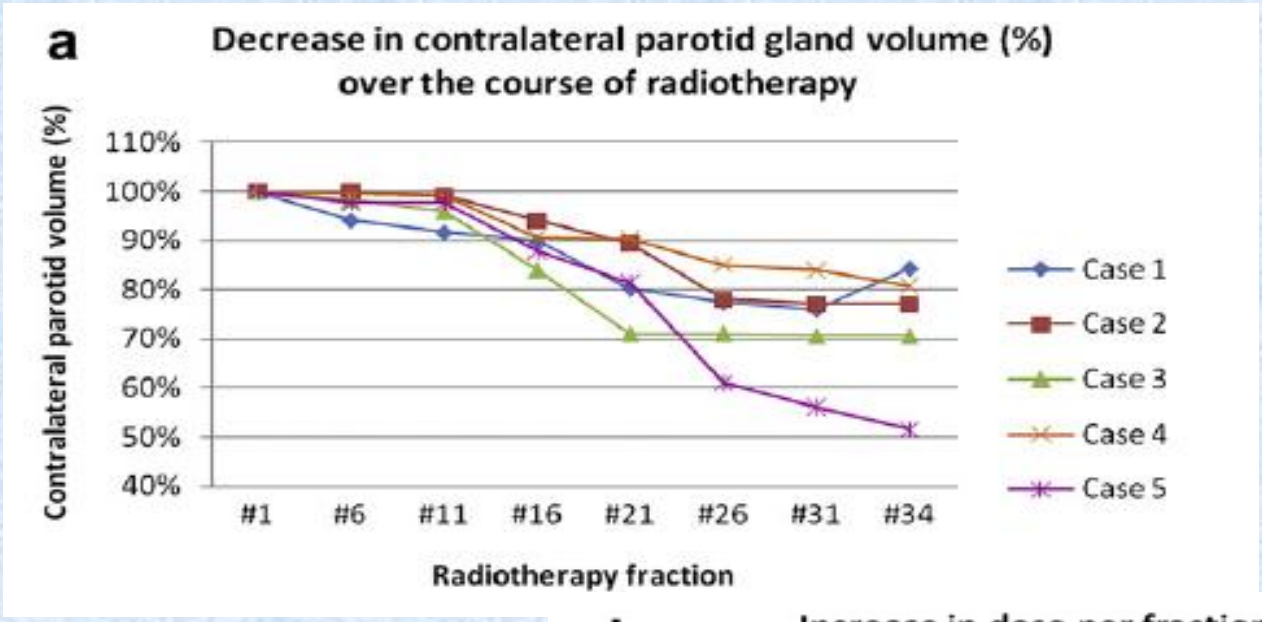
* *Oncology Centre (Box 193), Addenbrooke's Hospital, Cambridge, UK*
† *Medical Physics Department, Addenbrooke's Hospital, Cambridge, UK*
‡ *University of Cambridge Department of Oncology, Oncology Centre (Box 193-R4), Addenbrooke's Hospital, Cambridge, UK*

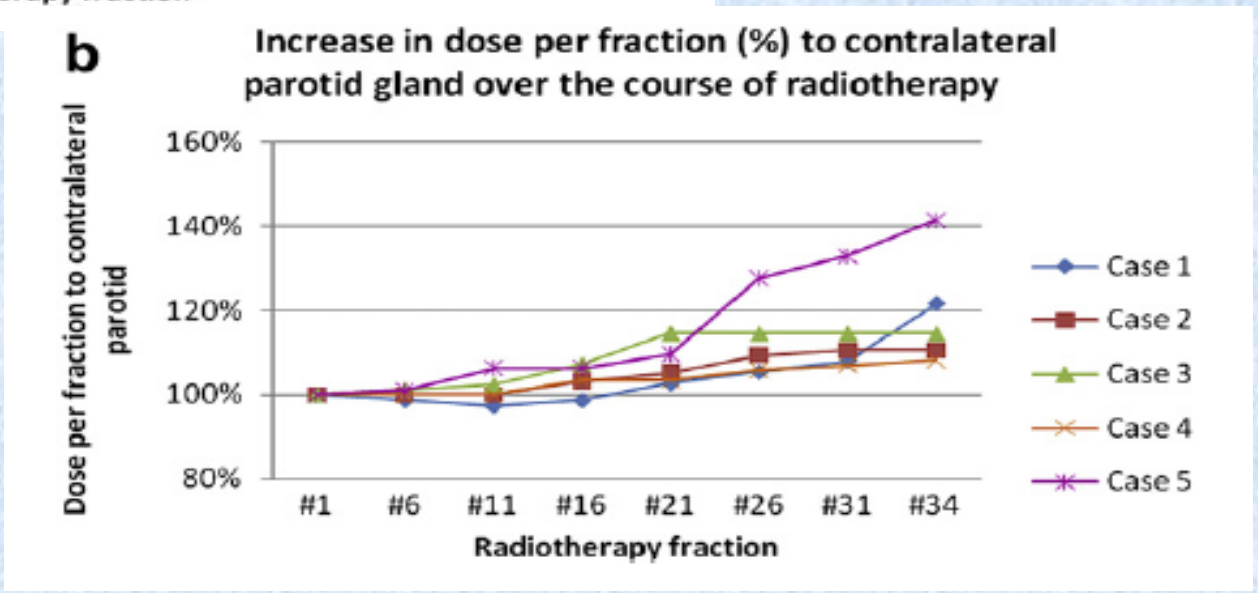
Received 2 February 2010; received in revised form 3 June 2010; accepted 29 July 2010

Five patients
MVCTs from radiotherapy fractions 1, 6, 11, 16, 22, 27, 32 and 34
The doses were then recalculated from each MVCT to show the actual delivered doses to the CTVs and OARs.

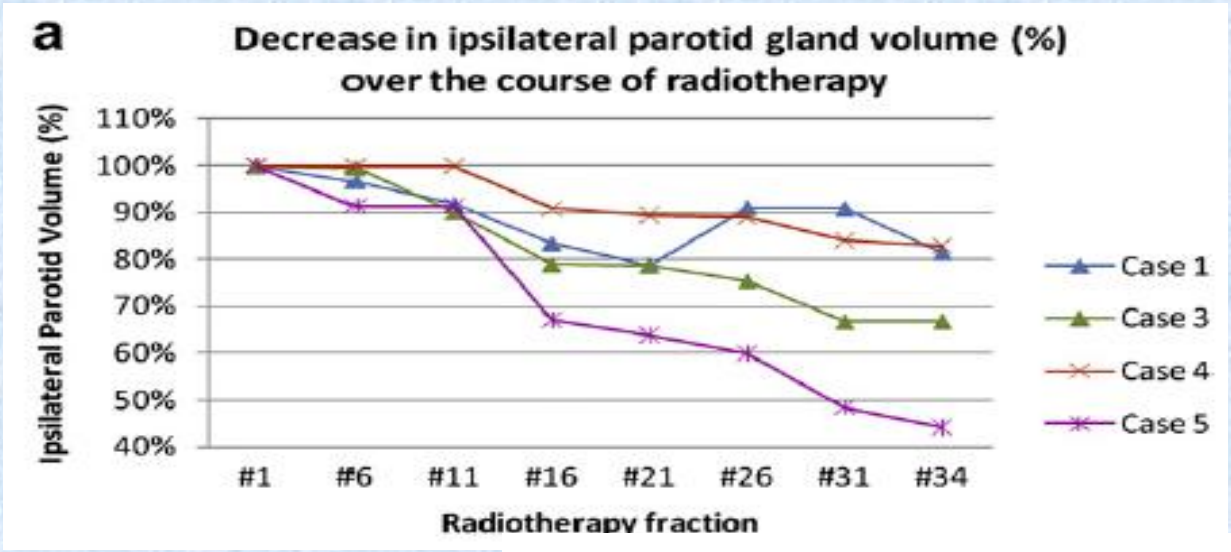
There was shrinkage in the volume of the parotid glands during treatment in all cases. **The mean volume reduction in the ipsilateral parotid gland was more marked at 30.2%**, compared with the contralateral parotid glands.
The calculated doses were higher than the planned doses in all CTV-54, CTV-60 and CTV-68, but the mean dose differences were modest, in the range 1.3-2.4%.
Adaptive radiotherapy planning **can be helpful in improving the dose to the parotid glands.**
However**, its role in the optimisation of the dosage to the clinical target volume is less likely to result in a significant clinical benefit.**

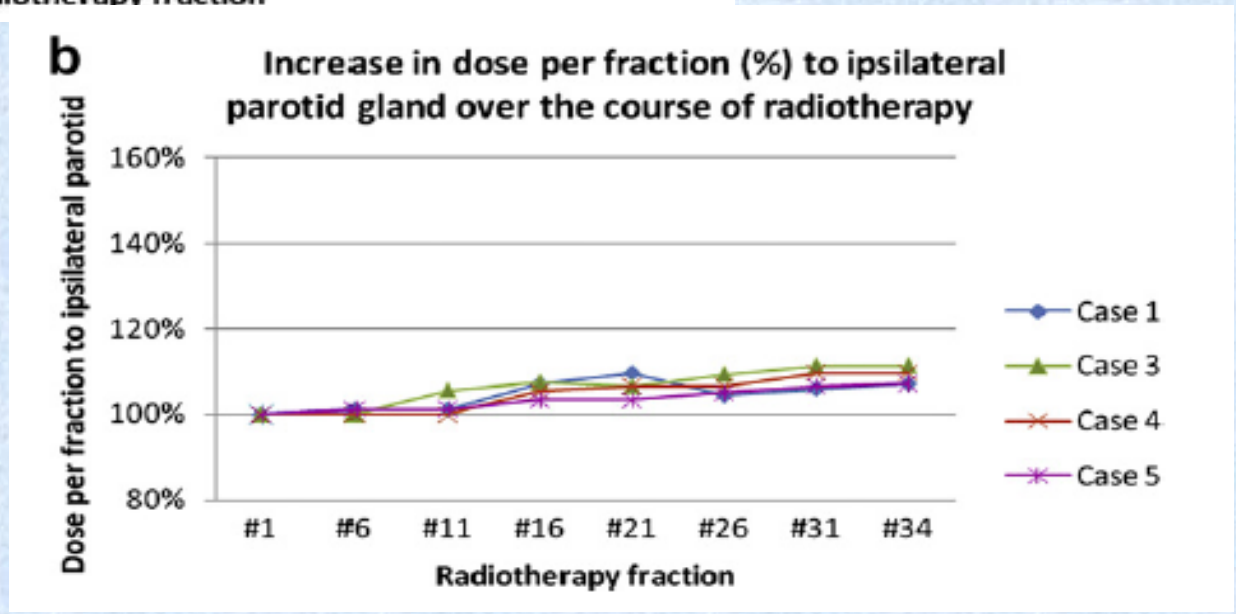
Controlateral Parotid Gland





Ipsilateral Parotid Gland





Planned and calculated doses

Table 2
Planned and calculated contralateral parotid gland doses

Case	Contralateral parotid gland mean doses		
	Planned dose (Gy)	Calculated dose (Gy)	Dose difference (Gy)
1	24.1	25.5	1.4
2	27.0	38.6	11.6
3	27.3	38.1	10.7
4	28.6	29.7	1.1
5	23.8	35.4	11.5
Overall mean dose	26.2	33.5	7.3

Table 3
Planned and calculated ipsilateral parotid gland doses

Case	Ipsilateral parotid gland mean doses		
	Planned dose (Gy)	Calculated dose (Gy)	Dose difference (Gy)
1	26.8	29.3	2.5
3	35.8	30.0	5.8
4	29.2	32.5	3.3
5	43.2	62.2	19.0
Overall mean dose	33.7	38.5	7.6

Results

There was no change to the **spinal cord** volume as expected. The mean dose difference between the planned and calculated Dmax was also small at **0.2 Gy (0.5%).**

The mean volume change in **CTV-54** throughout radiotherapy was 10.7% (5.5-18.4%), as a result of patient shrinkage. The calculated doses were higher than the planned doses in all CTV-54, but **the mean dose difference was** only **1.1 Gy (1.9%)**

The mean reduction in the **CTV-60** volume over the treatment course was 7.1% (range 0-22%). In all cases, the calculated dose to CTV-60 was slightly higher than the planned dose, with a **mean dose difference** of **1.5 Gy (2.4%)**

The mean volume change was 5.8% for the **CTV-68** volume. the calculated doses for all CTV-68 were higher than the planned doses.

However, **the mean dose difference** was rather small at **0.9 Gy (1.3%)**

The mean **volume reduction** in the **ipsilateral parotid gland** was more marked at **30.2%**, compared with the contralateral parotid glands. However, the mean percentage **dose per fraction increase** was higher in the **contralateral parotid glands at 24%,** compared with the ipsilateral parotids.

We concluded that **replanning during the course of radiation treatment to optimise the dose to the CTV is probably not necessary**. However, **there may be a significant benefit with adaptive strategy in improving the dose to the parotid glands**.

ELSEVIER

Int. J. Radiation Oncology Biol. Phys., Vol. 71, No. 5, pp. 1563–1571, 2008

0360-3016/08/$–see front matter

doi:10.1016/j.ijrobp.2008.04.013

PHYSICS CONTRIBUTION

ASSESSMENT OF PAROTID GLAND DOSE CHANGES DURING HEAD AND NECK CANCER RADIOTHERAPY USING DAILY MEGAVOLTAGE COMPUTED TOMOGRAPHY AND DEFORMABLE IMAGE REGISTRATION

CHOONIK LEE, PH.D.,* KATJA M. LANGEN, PH.D.,* WEIGUO LU, PH.D.,† JASON HAIMERL, M.S.,† ERIC SCHNARR, PH.D.,† KENNETH J. RUCHALA, PH.D.,† GUSTAVO H. OLIVERA, PH.D.,† SANFORD L. MEEKS, PH.D.,* PATRICK A. KUPELIAN, M.D.,* THOMAS D. SHELLENBERGER, M.D., D.M.D.,†§ AND RAFAEL R. MAÑON, M.D.*

Departments of *Radiation Oncology and †Head and Neck Surgery, M. D. Anderson Cancer Center Orlando, Orlando, FL; †TomoTherapy, Inc., Madison, WI; and §Department of Head and Neck Surgery, The University of Texas M. D. Anderson Cancer Center, Houston, TX

10 head-and-neck cancer patients

330 daily MVCT images were acquired

deformable image registration algorithm

Results

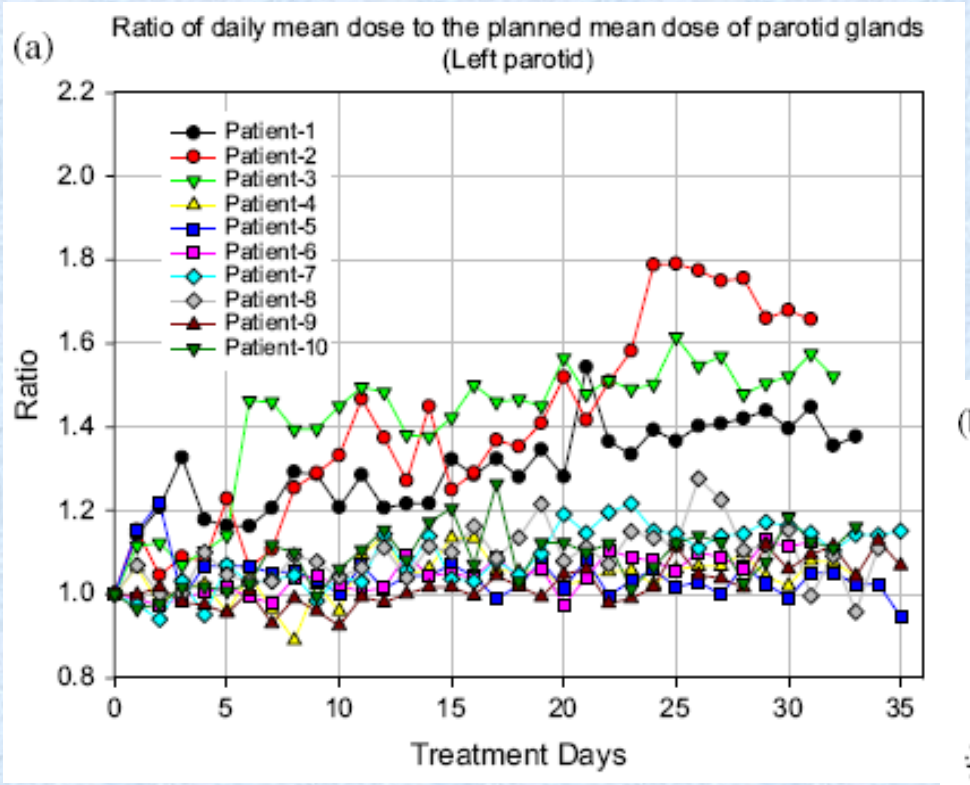
The parotid glands in the study cohort **tended to shift toward midline** as treatment progressed the parotid glands may migrate into high-dose target volumes.

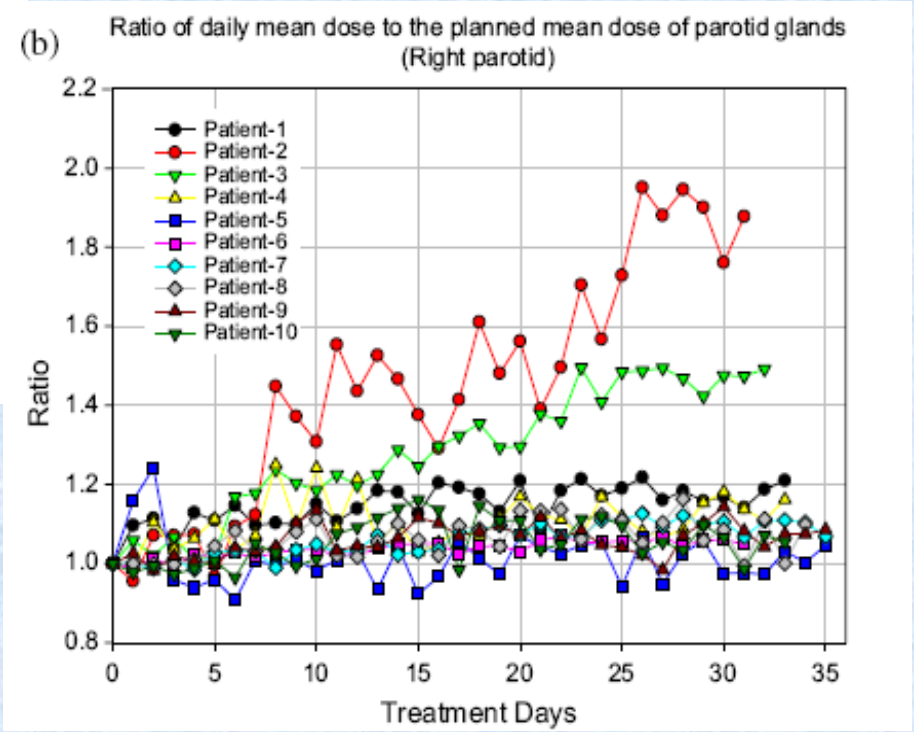
The reasons for such **changes are multifactorial** and may be related to the **decrease of tumor and nodal volumes**, **weight loss, alteration in muscle mass and fat distribution**, and **fluid shift in the body**

All patients lost weight throughout their treatment course.
There was a correlation between percent weight loss and higher parotid mean doses.

Ideally the correlation data would be used to derive a replanning threshold.
The calculation of delivered cumulative doses may also allow us to calculate more accurate dose–volume constraints regarding these radiosensitive structures, which have so far been estimated only by using the initial planning information and corresponding clinical outcome

Ratio of daily mean dose to the planned mean dose of parotid glands





Radiotherapy and Oncology 94 (2010) 206–212

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Radiotherapy and Oncology

journal homepage: www.thegreenjournal.com

Parotid radiotherapy

A two-variable linear model of parotid shrinkage during IMRT for head and neck cancer

Sara Broggi [a,*], Claudio Fiorino [a], Italo Dell'Oca [b], Nicola Dinapoli [c], Marta Paiusco [d], Alessandro Muraglia [e], Eleonora Maggiulli [a,f], Francesco Ricchetti [g], Vincenzo Valentini [c], Giuseppe Sanguineti [g], Giovanni Mauro Cattaneo [a], Nadia Di Muzio [b], Riccardo Calandrino [a]

[a] *Medical Physics Department; and* [b] *Radiotherapy Department, San Raffaele Scientific Institute, Milano, Italy;* [c] *Radiation Oncology, Università Cattolica S. Cuore, Roma, Italy;* [d] *Medical Physics Department; and* [e] *Radiotherapy Department, Arcispedale S. Maria Nuova, Reggio Emilia, Italy;* [f] *Medical Physics School, Università degli Studi di Milano, Milano, Italy;* [g] *Radiation Oncology, The John Hopkins University, Baltimore, MD, USA*

Intent of assessing predictors of significant shrinkage and possibly developing a predictive model for this effect

Table 1
Patient, tumor and treatment characteristics.

No. of patients (87)	HSR: 32; UCSC: 22; JHU: 25; RE: 8
No. of parotid glands (172)	HSR: 64; UCSC: 44; JHU: 50; RE: 16
Gender	Male: 68
	Female: 19
Age (year)	58 [31–86]
Tumor location	Oropharynx: 51; nasopharynx: 19
	larynx: 11; hypopharynx: 2; others: 4
Surgery	10
Chemotherapy	75 pts
	Neoadjuvant: 20 pts
	Concomitant: 70 pts

Two different delivery modalities were considered: in two Institutes

(HSR, RE), patients (n = 40) were treated with the Helical Tomotherapy (HT) unit;

in the other two departments (UCA, JHU) (n = 47), the conventional MLC-based modulation was used in dynamic or step-and-shoot mode.

Results

For the enrolled patients, **parotid volume variations**:

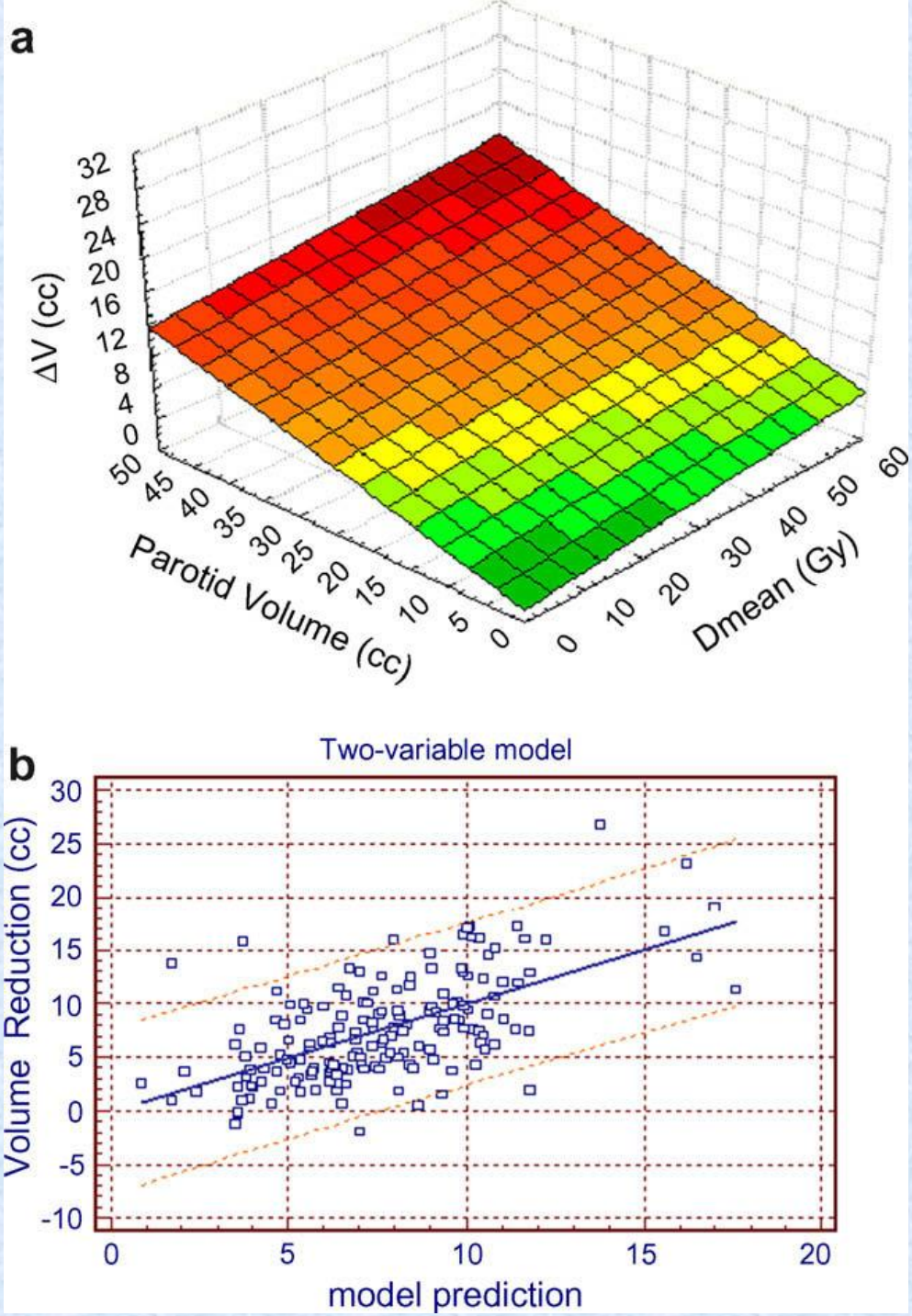
Median absolute (DVcc) : **6.95 cc**
Percentage (DV%): **26%**

median **weight loss** (DW) equal to **8%** [range: 21.23% to +6.1%]
body **thickness variation**, measured at C2 vertebral body level,
equal to 0.6 cm **(8%)** between the start and end of the treatment.

IVP (initial parotid volume) and parotid **Dmean** were the best pre-treatment independent predictors for DVcc;

Age and **V40** resulted the best independent predictors for DV%.

Fig. 2. (a) Graphic description of the bi-linear model for absolute parotid volume shrinkage (z-axis) in terms of Dmean (x-axis) and IVP (y-axis); (b) Goodness of the predictivity of the model: correlation between DVcc effectively measured and DVcc predicted by the model.



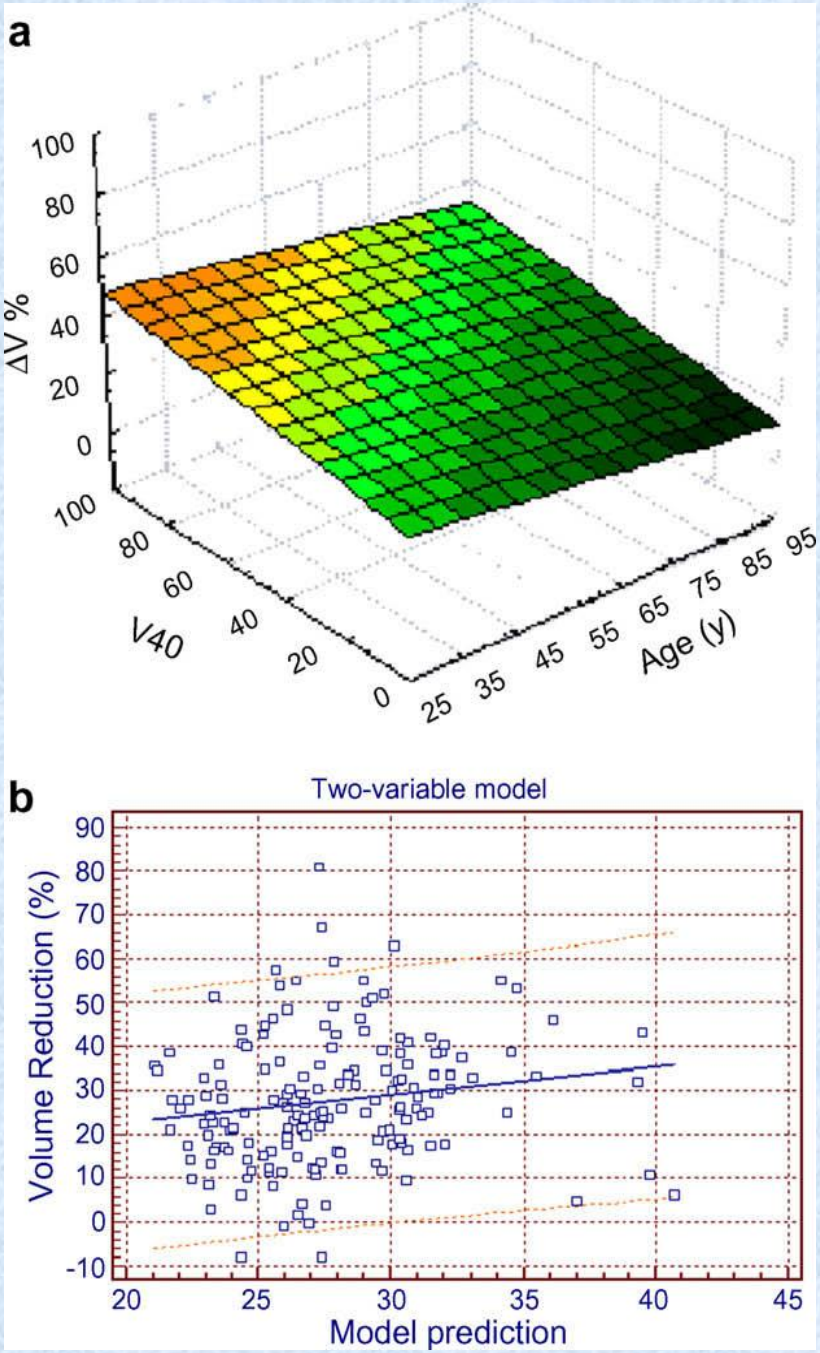


Fig. 3. (a) Graphic description of the bi-linear model for percentage parotid volume shrinkage (z-axis) in terms of patient age (x-axis) and V40 (y-axis); (b) Goodness of the predictivity of the model: correlation between DV% effectively measured and DV% predicted by the model

All these published results suggest that for a treatment duration of around 30–35 fractions/45 days (median treatment time for patients enrolled in this study) a parotid volume shrinkage of 30–35% could be expected between the start and end of treatment, slightly larger than the value found in our study (around 26%), probably due to the more stressful plan optimization constraints in most of these patients, especially when using Helical Tomotherapy

Acta Oncologica, 2010; 49: 991–996

informa
healthcare

ORIGINAL ARTICLE

Feasibility and sensitivity study of helical tomotherapy for dose painting plans

MICHAEL A. DEVEAU[1], STEPHEN R. BOWEN[1], DAVID C. WESTERLY[2] & ROBERT JERAJ[1,3,4]

[1]*University of Wisconsin School of Medicine and Public Health, Department of Medical Physics, Madison, Wisconsin, USA,* [2]*University of Colorado, Denver, Aurora, Colorado, USA,* [3]*University of Wisconsin School of Medicine and Public Health, Department of Human Oncology, Clinical Sciences Center, Madison, Wisconsin, USA and* [4]*Jozef Stefan Institute, Jamova 39, 1000 Ljubljana, Slovenia*

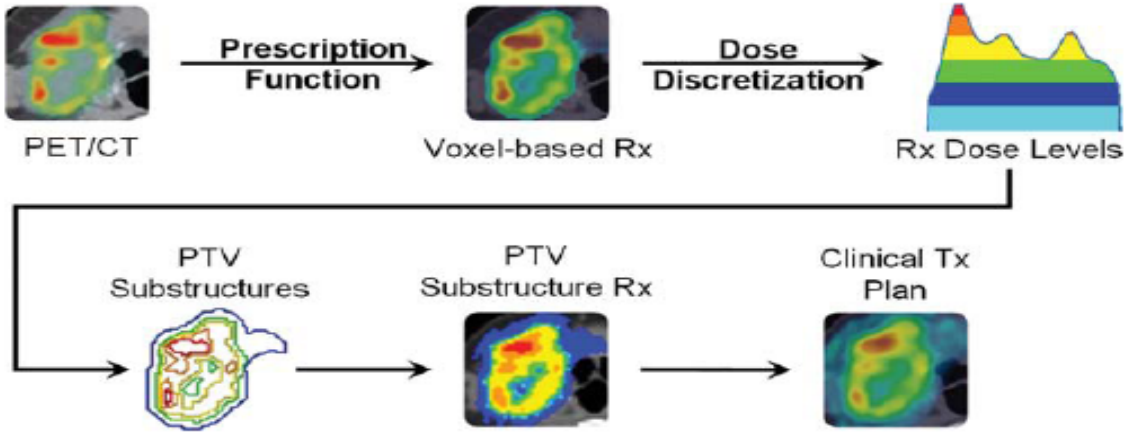


Figure 1. Schematic of workflow for dose painting with clinical treatment planning systems. From a fused PET/CT image, PET uptake within the target volume is transformed to a voxel-based prescription via a linear redistribution of dose (prescription function). The prescription is discretized into equi-spaced dose levels (e.g. 5 levels), which form the basis for target substructures (dose discretization). Each substructure is prescribed the mean dose representative of the underlying voxel doses, with a DVH objective given by the fractional volume receiving this mean dose or higher. A clinically deliverable treatment plan is generated from IMRT optimization to substructure objectives, yielding a planned dose that can be compared back to the prescribed dose at every voxel.

Reggio Emilia

August 2008

440 patients
50 head&neck cancer patients (37 definitive intent, 7 postoperatively, 6 reirradiations)

Multidisciplinary Team Involvement

ORL
Radioterapist
Oncologist

Pianification

Five points fixation *masks* Tc simulation (contrast enhanced ct always)
TC PET (always in definitive treatments)
RM (rinopharynx)

VOLUMES

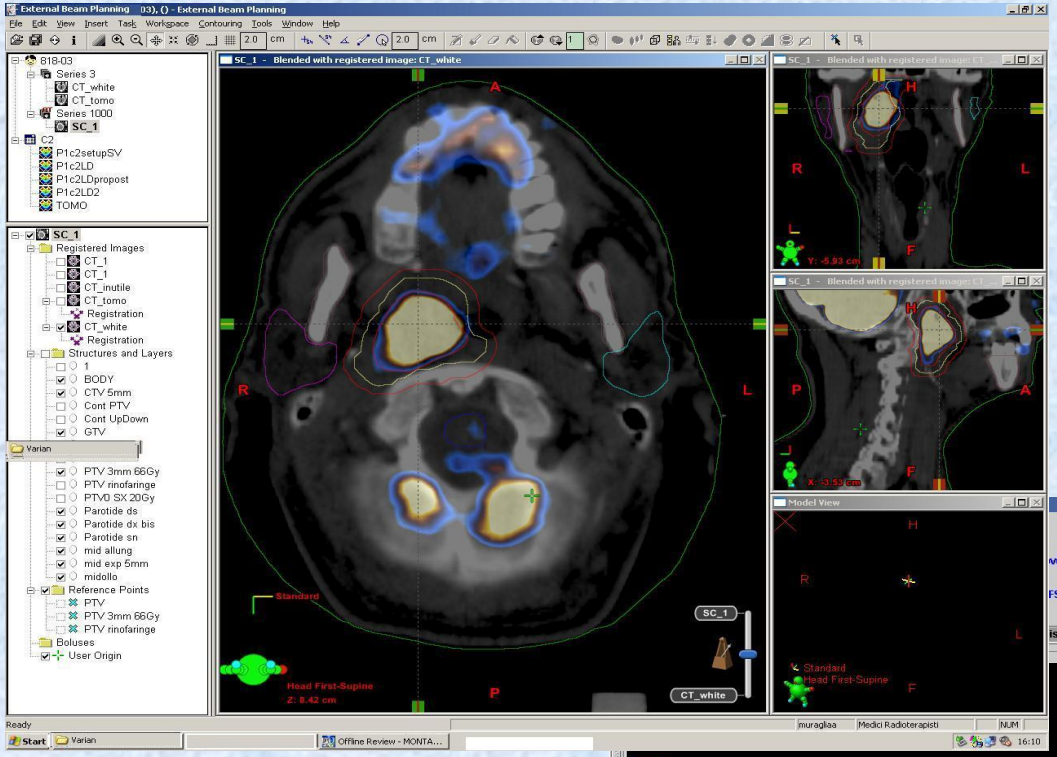
GTV= Imaging (TC+PET+RM)+Clinical examination

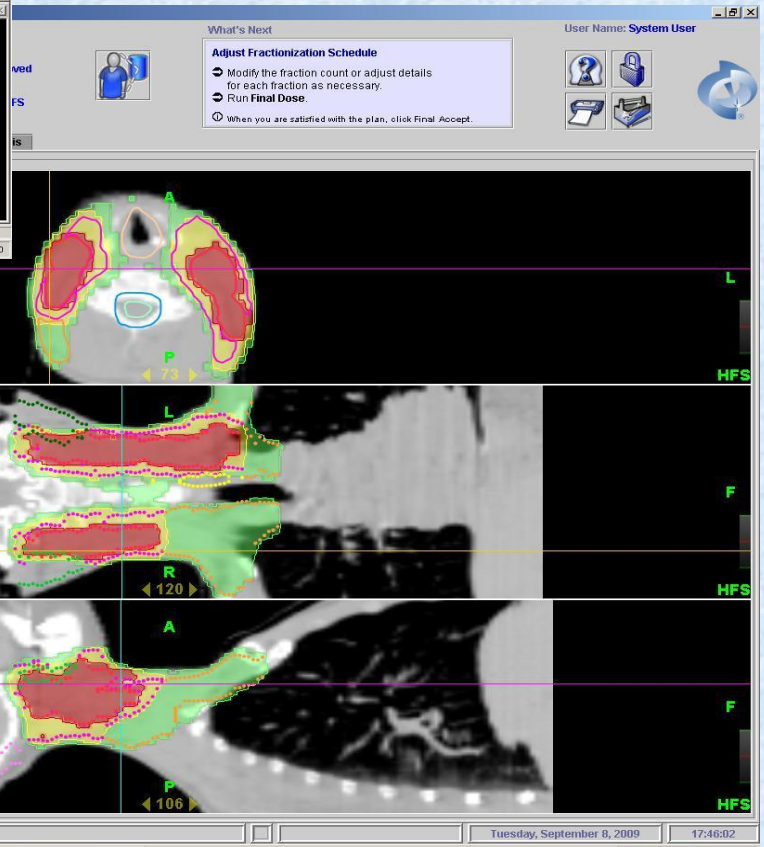
CTV1= GTV*+5mm (bones, muscles, air)
CTV2= CTV1+ 5mm, high risck node levels (N+)
CTV3= low risck node levels

30 fractions SMART

2.2/2.3 Gy/fr (66/69 Gy)
2 Gy/fr (60 Gy)
1.8 Gy/fr (54 Gy)

Eclipse

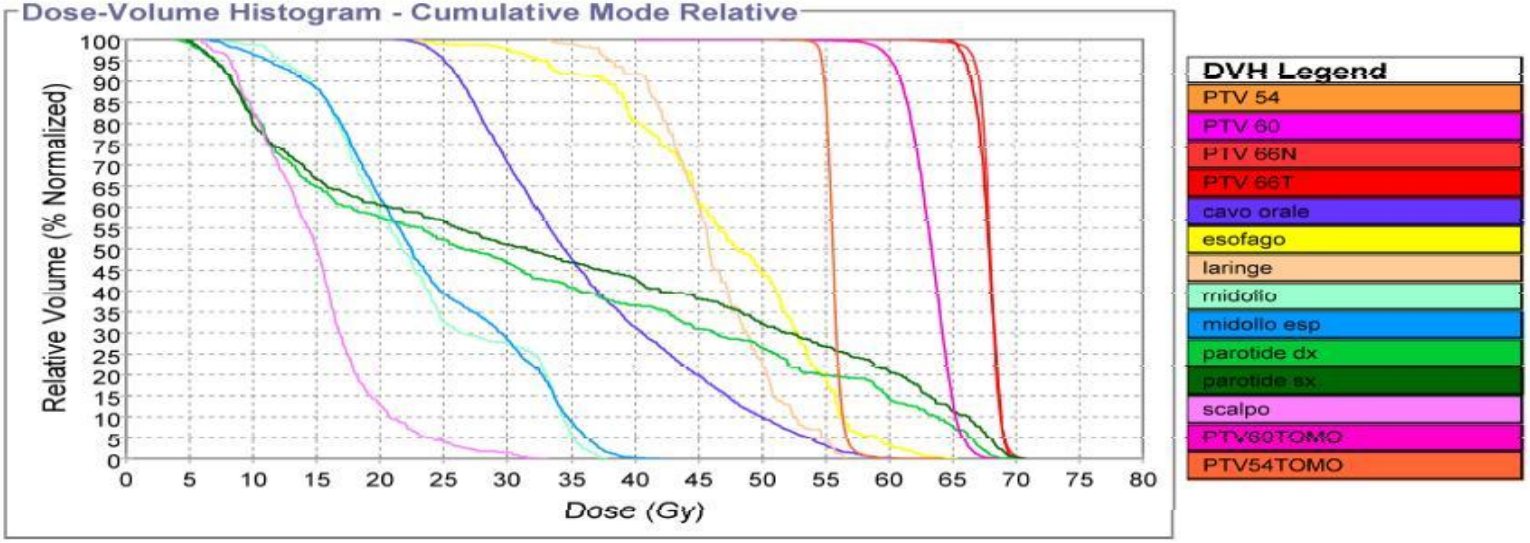




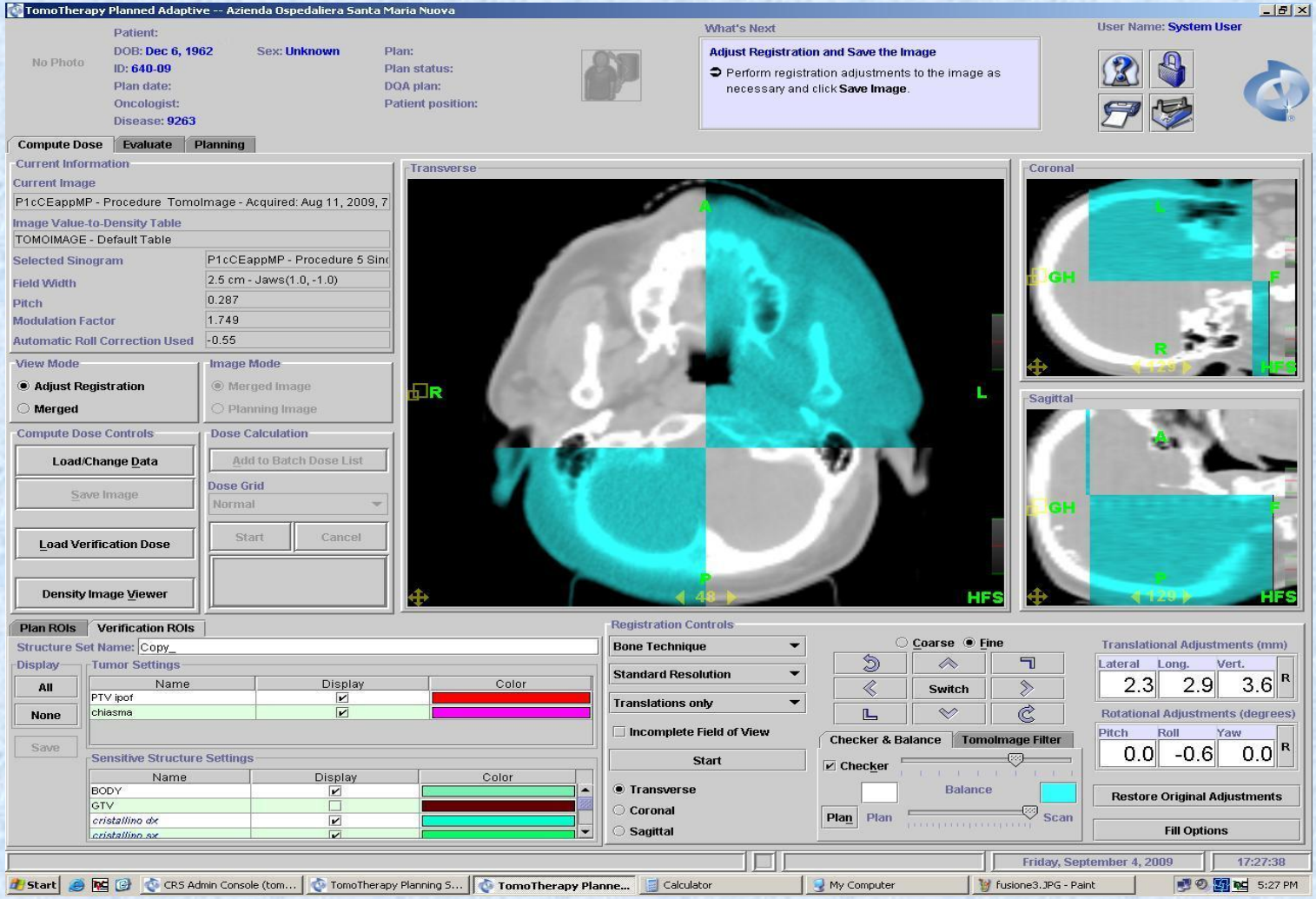
Tomo

Prescription: 97.80% of the PTV 66T volume receives at least 66.00 Gy for the current plan.
The plan has 30 fractions defined for a planned delivery of 66.00 Gy

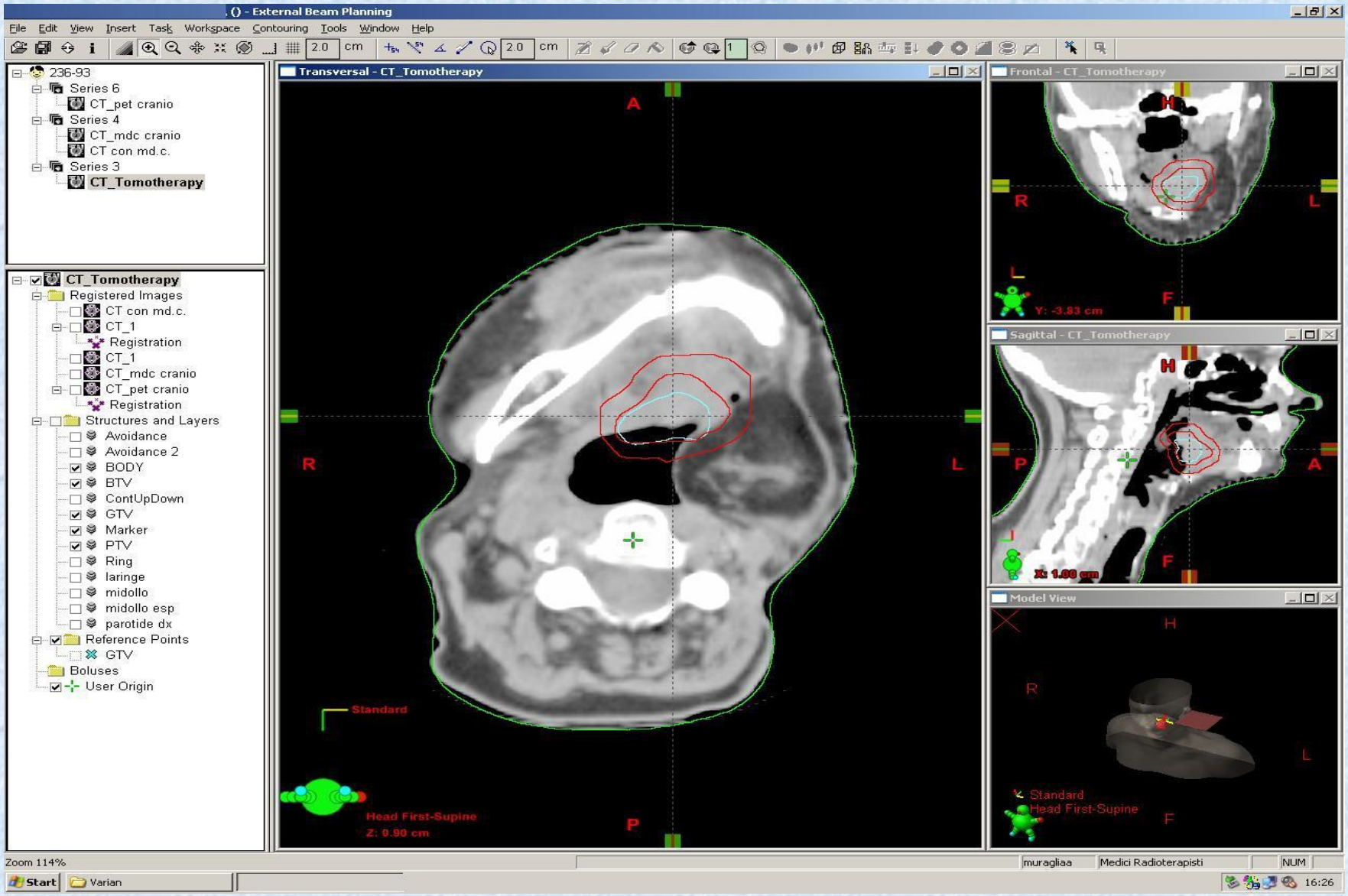
Sex:	UNKNOWN
Date of Birth:	Mar 9, 1963
Disease Name:	10449
Plan State:	APPROVED
Machine Name:	0210200
Field Width:	2.5 cm
Pitch:	0.287
Sinogram Segments:	9.5
Planning Modulation Factor (Actual):	2.500 (1.596)
Relative Movable Laser Positions:	X = 0.1 cm, Y = 5.7 cm, Z = 0.0 cm
Delivered Dose:	100.00% (66.00 Gy of 66.00 Gy)
Plan Calculation Grid:	NORMAL (0.390 x 0.390 cm)
Approved By:	System User



Megavoltage CT before each treatment

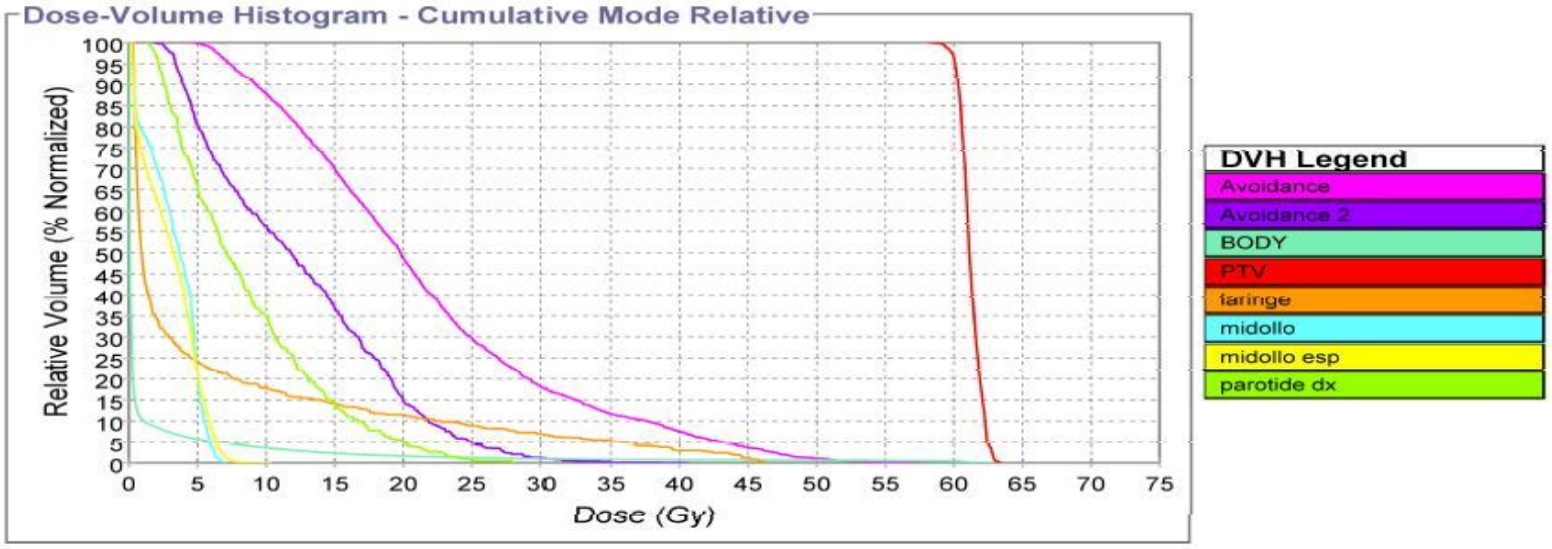


Reirradiation

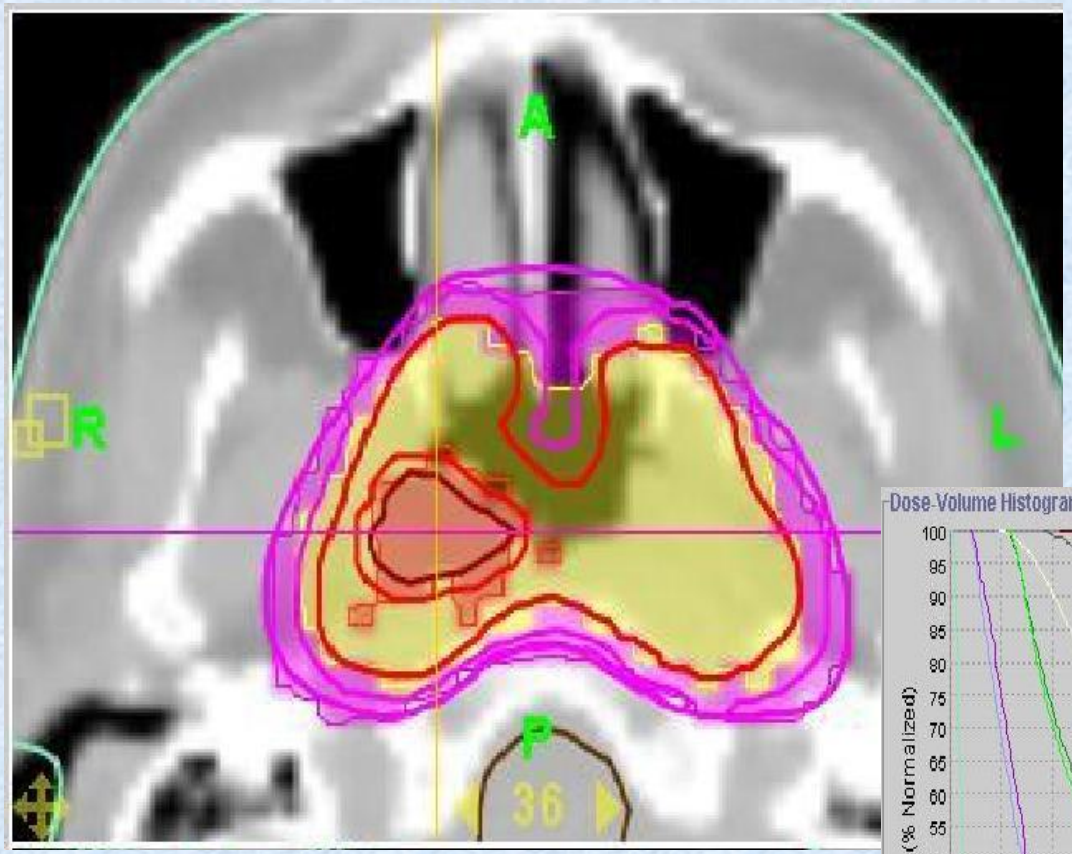


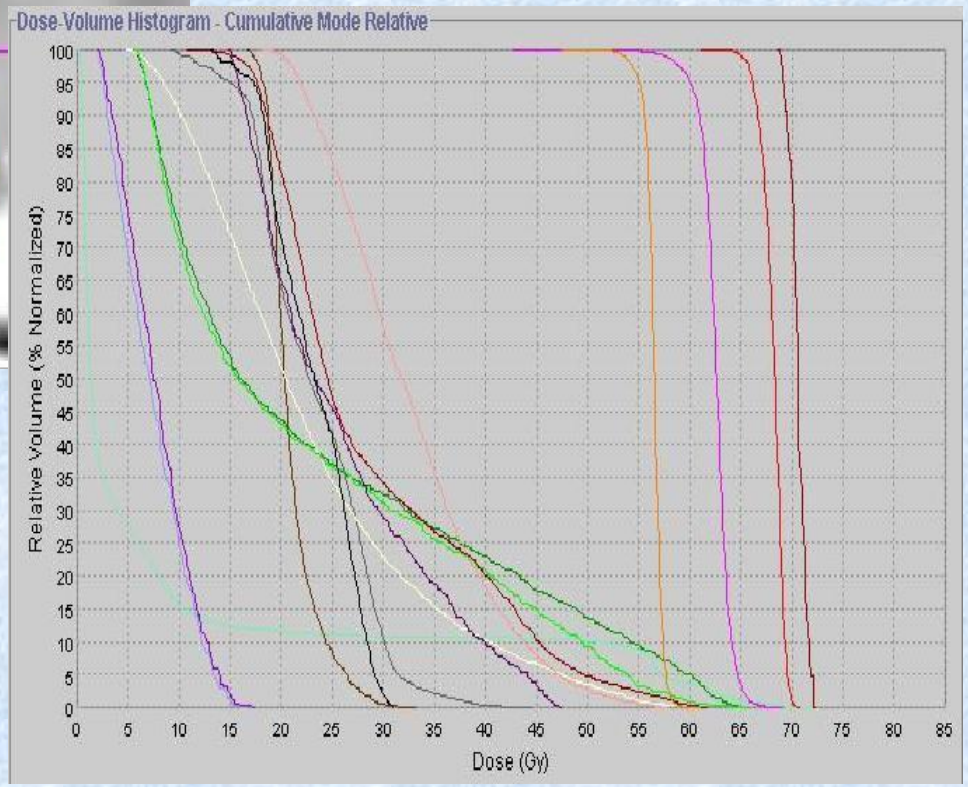
Prescription: 99.70% of the PTV volume receives at least 60.00 Gy for the current plan.
The plan has 40 fractions defined for a planned delivery of 60.00 Gy

Sex:	UNKNOWN
Date of Birth:	Jul 1, 1941
Disease Name:	10253
Plan State:	APPROVED
Machine Name:	0210200
Field Width:	2.5 cm
Pitch:	0.300
Sinogram Segments:	2.7
Planning Modulation Factor (Actual):	3.500 (2.081)
Relative Movable Laser Positions:	X = 2.7 cm, Y = 2.6 cm, Z = -0.1 cm
Delivered Dose:	97.50% (58.50 Gy of 60.00 Gy)
Plan Calculation Grid:	NORMAL (0.390 x 0.390 cm)
Approved By:	System User

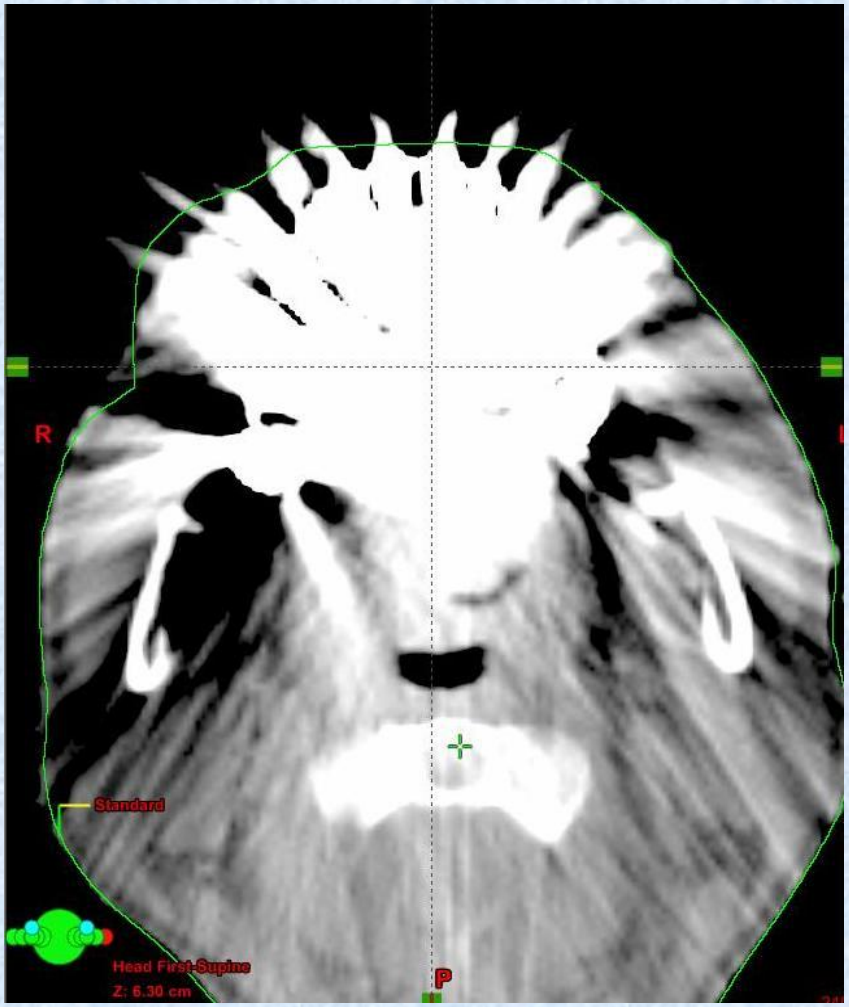


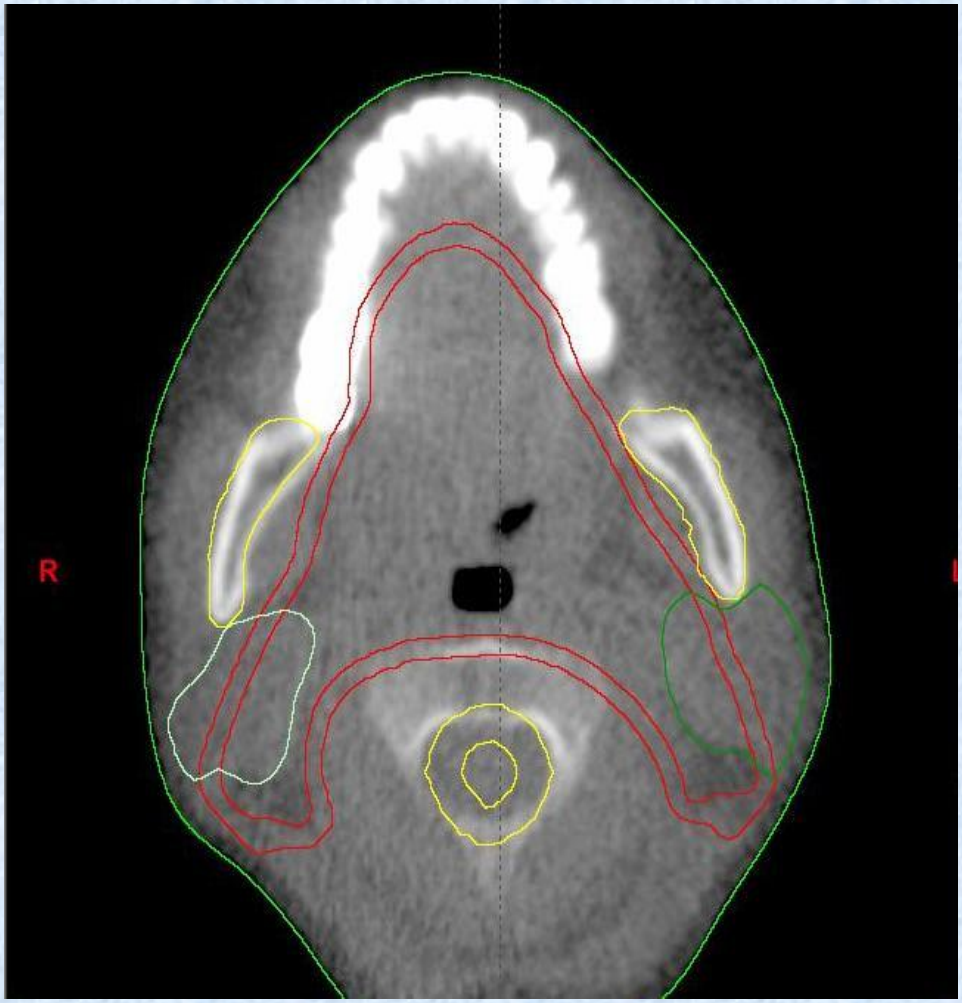
Dose escalation (BTV)





Metallic implants





Conclusions

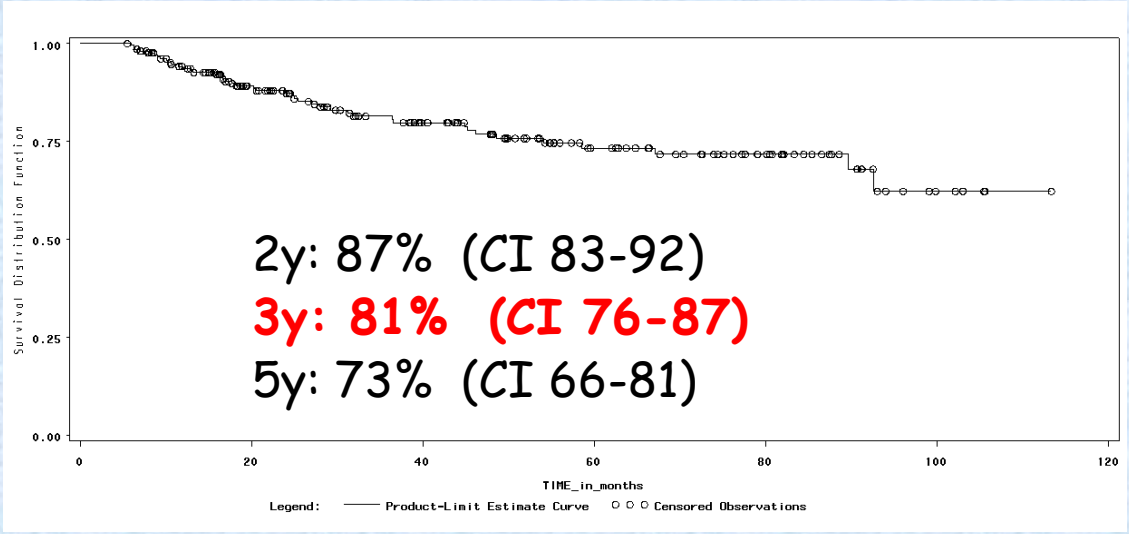
Image-guided radiotherapy (IGRT) and intensity-modulated radiotherapy (IMRT) represent two important technical developments that will probably improve the outcome for appropriately selected patients receiving radiotherapy.

Helical tomotherapy provides an elegant integrated solution for the combination of IGRT and IMRT.

IMRT enables significant reductions in the dose to the parotid glands with a reduction in long-term xerostomia when compared with conventional radiation techniques.

There may be a significant benefit with adaptive strategy in improving the dose to the parotid glands.

Iotti AIRO 2010



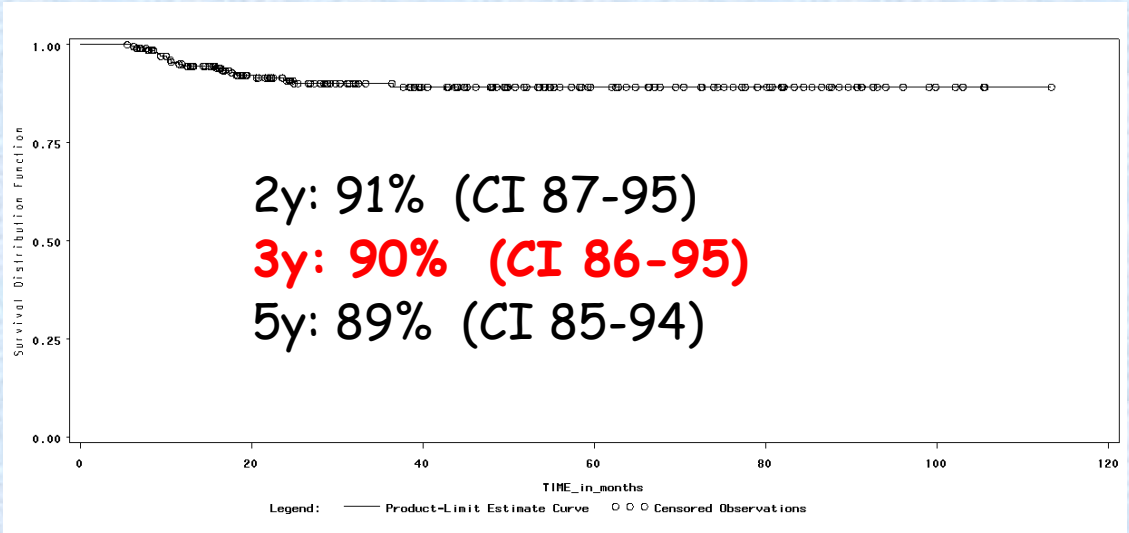
2y: 87% (CI 83-92)

3y: 81% (CI 76-87)

5y: 73% (CI 66-81)

Overall Survival

Combined AJCC stage, any site



2y: 91% (CI 87-95)

3y: 90% (CI 86-95)

5y: 89% (CI 85-94)

Cause Specific Survival

Combined AJCC stage, any site

2y LRC: 78%

3y LRC: 76%

5y LRC: 74%

ultimate 2y LRC: 88

ultimate 3y LRC: 86

ultimate 5y LRC: 86

Late toxicity (CTCAE v3.0)

	grade 0	grade 1	grade 2	grade 3
Xerostomia *	70 (43.2%)	67 (41.4%)	25 (15.4%)	0 (0%)

** 162 evaluable patients*

Other grade > 2 late toxicity

- grade 3 laryingeal stenosis……1
- grade 4 laryingeal necrosis……1
- grade 3 disphagya ……1

Cumulative incidence: 1,4%

Conclusion

- The results are extremely satisfying, in terms of disease control and toxicity and provide data supporting the safety and feasibility of IMRT in the treatment of advanced head and neck cancer.

- There is still room for improvements (i.e. sparing of other organs/tissues and dose escalation)

- IMRT needs a more thorough knowledge of the tumor target and pattern of spread
- IGRT should be used more frequently in these patients to assess both anatomic and positional variability
- All cases should be scrutinized prior to planning