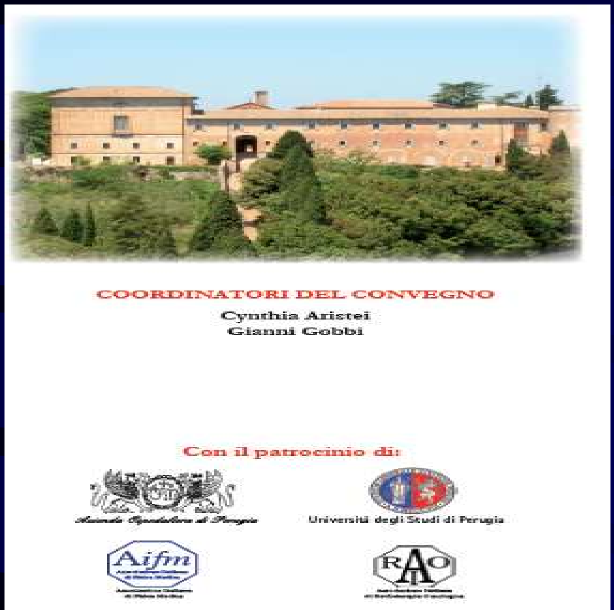
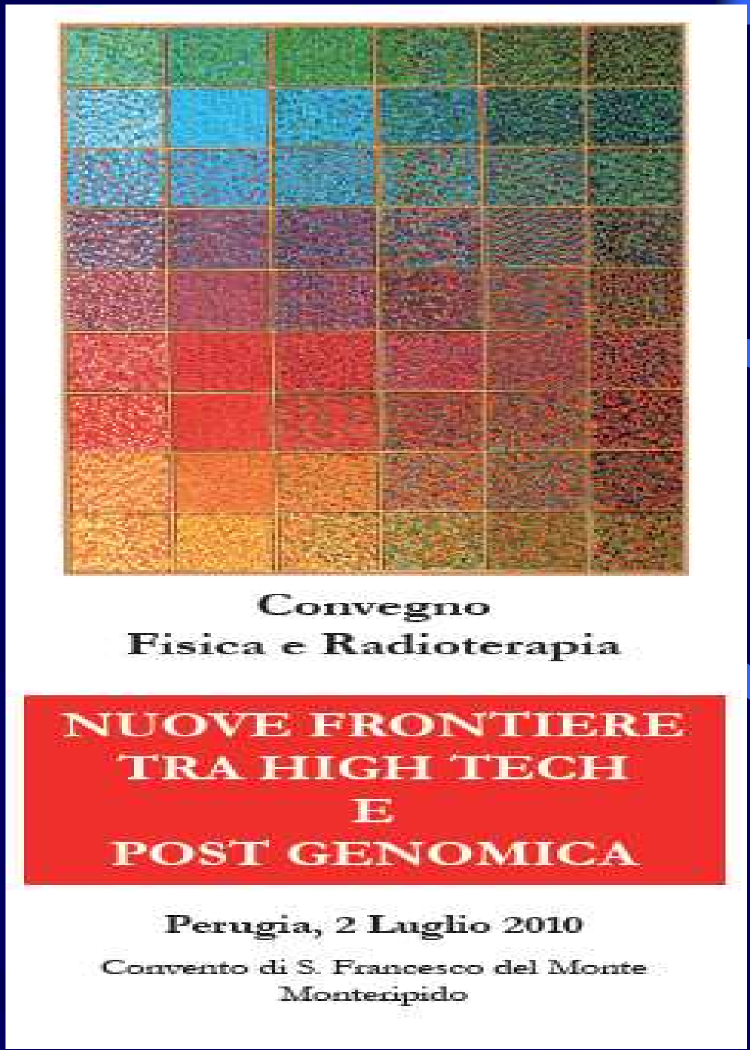
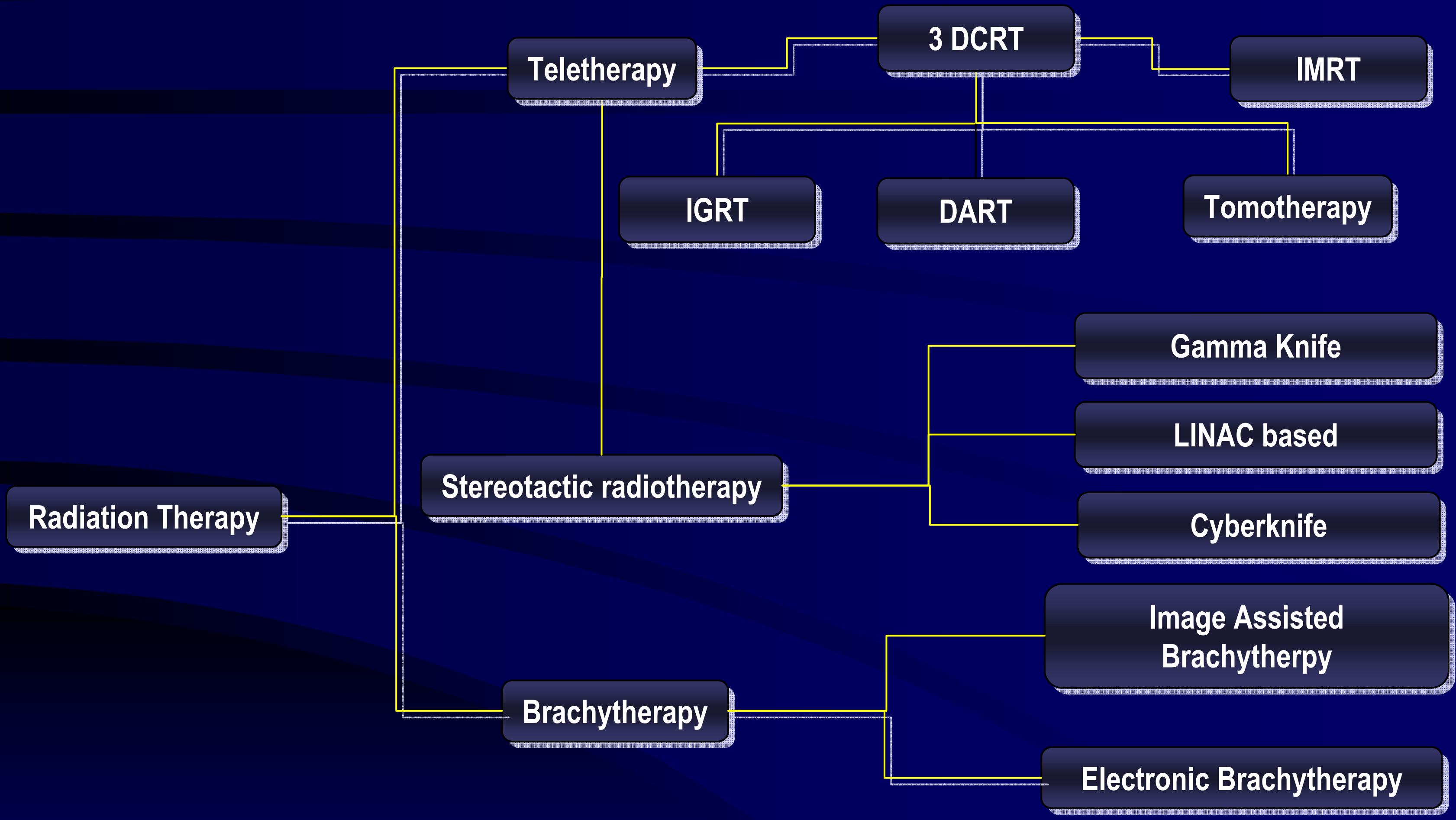
Imaging MR per il planning in RT



M. Lupattelli
S.C. Radioterapia Oncologica
Perugia



NUOVE TECNOLOGIE IN RADIOTERAPIA



INTRODUZIONE

- Correlazione dose RT-risposta clinico-strumentale neoplasia
- Somministrazione dose RT accurata e riproducibile
- Riduzione tossicità

INTRODUZIONE

Incertezze “treatment planning and delivery” correlate a:

- Definizione volumi (GTV-CTV e OAR)
- Movimento organo
- Posizione paziente

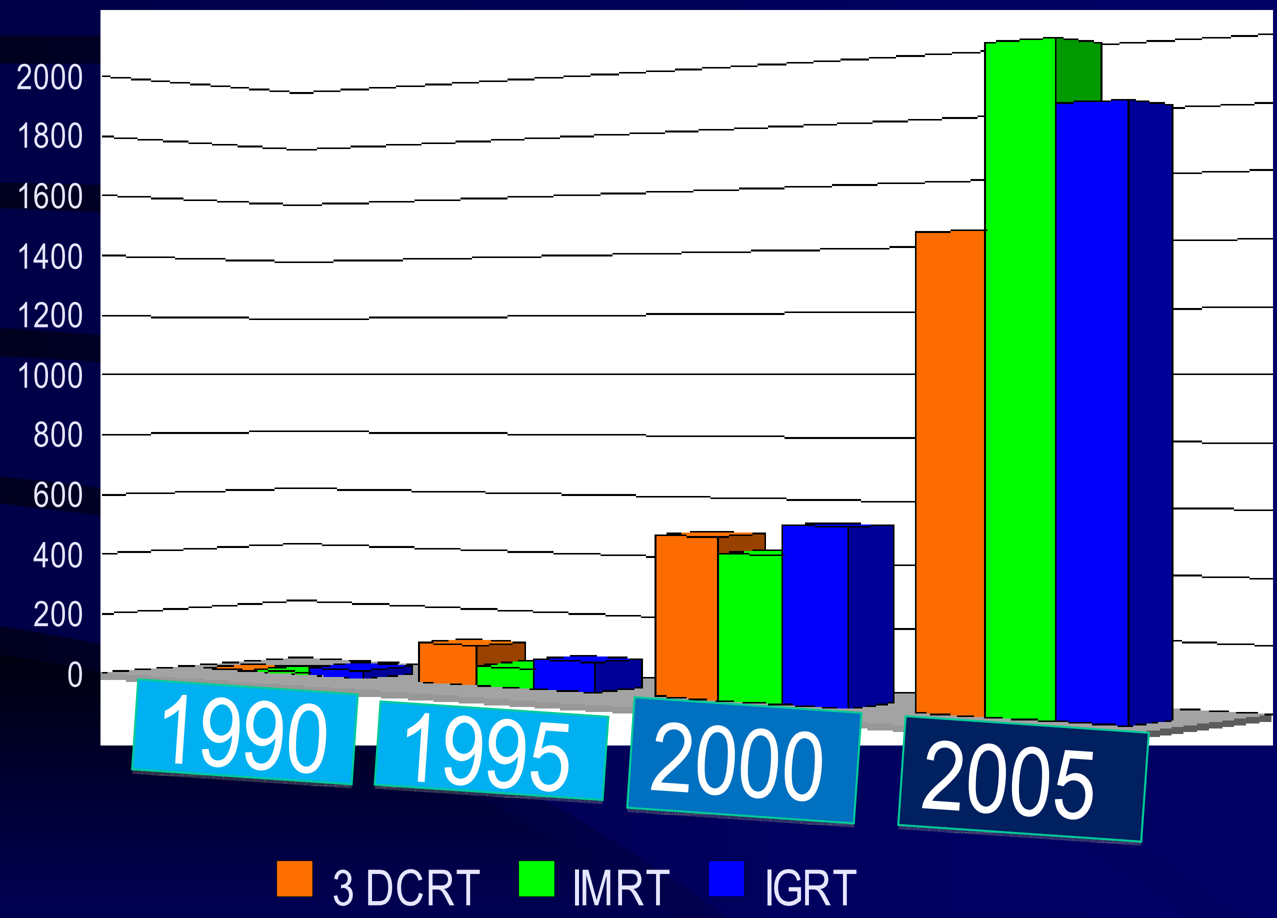
INTRODUZIONE

TC indagine di riferimento per "planning" RT:

- Risorsa disponibile
- Informazioni sede e dimensioni neoplasia
- Geometria paziente
- Densità elettronica………... ma

Definizione "target RT" subottimale

“IMAGING” IN RADIOTERAPIA



Pubblicazioni su tecniche di irradiazione *(scholar.google.com)*

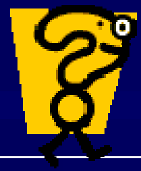
DIAGNOSI E STADIAZIONE: ruolo RM

“ Gold Standard”

↓

- Neoplasie del SNC e spinali
- Tumori pelvici
- Tumori sfera ORL
- Sarcomi dei tessuti molli

IMAGING IN RADIOTERAPIA: RM



- TC: standard per il piano di trattamento radioterapico
- RM: migliore caratterizzazione dei tessuti molli, multiplanarità

PRO……

- Migliore definizione degli OAR
- Riduce la variabilità interosservazionale ed intraosservazionale
- Evita gli artefatti dovuti a strutture ossee e metalliche
- Utile sia in prima diagnosi che nel ritrattamento con RT: differenza recidiva dalla fibrosi

CONTRO……

- mancanza di informazioni sulla densità elettronica dei tessuti
- distorsione delle immagini

⇓

CO-REGISTRAZIONE delle IMMAGINI TC-RM

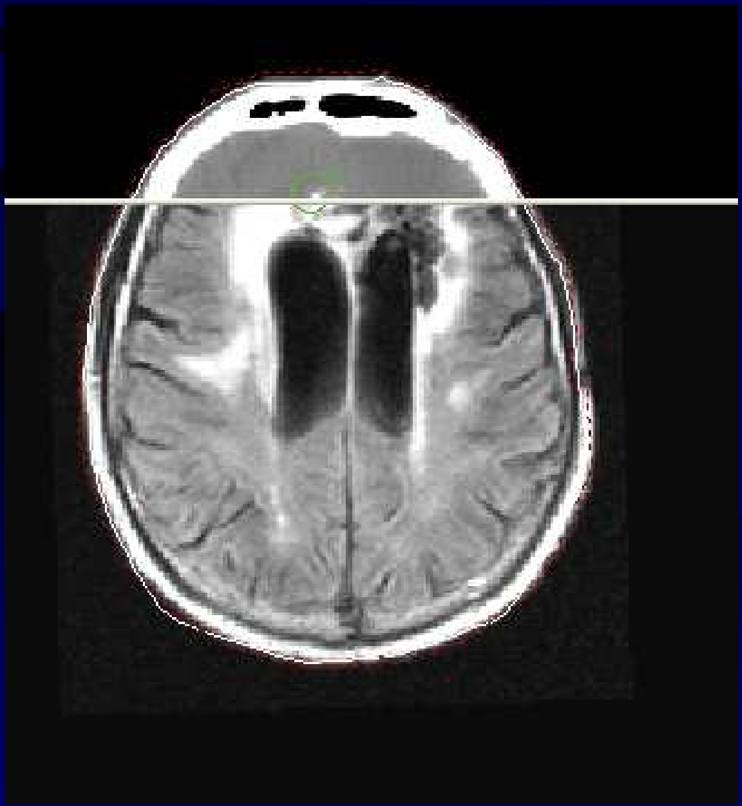
Table 1. Advantages and disadvantages of MRI for radiotherapy planning (RTP)

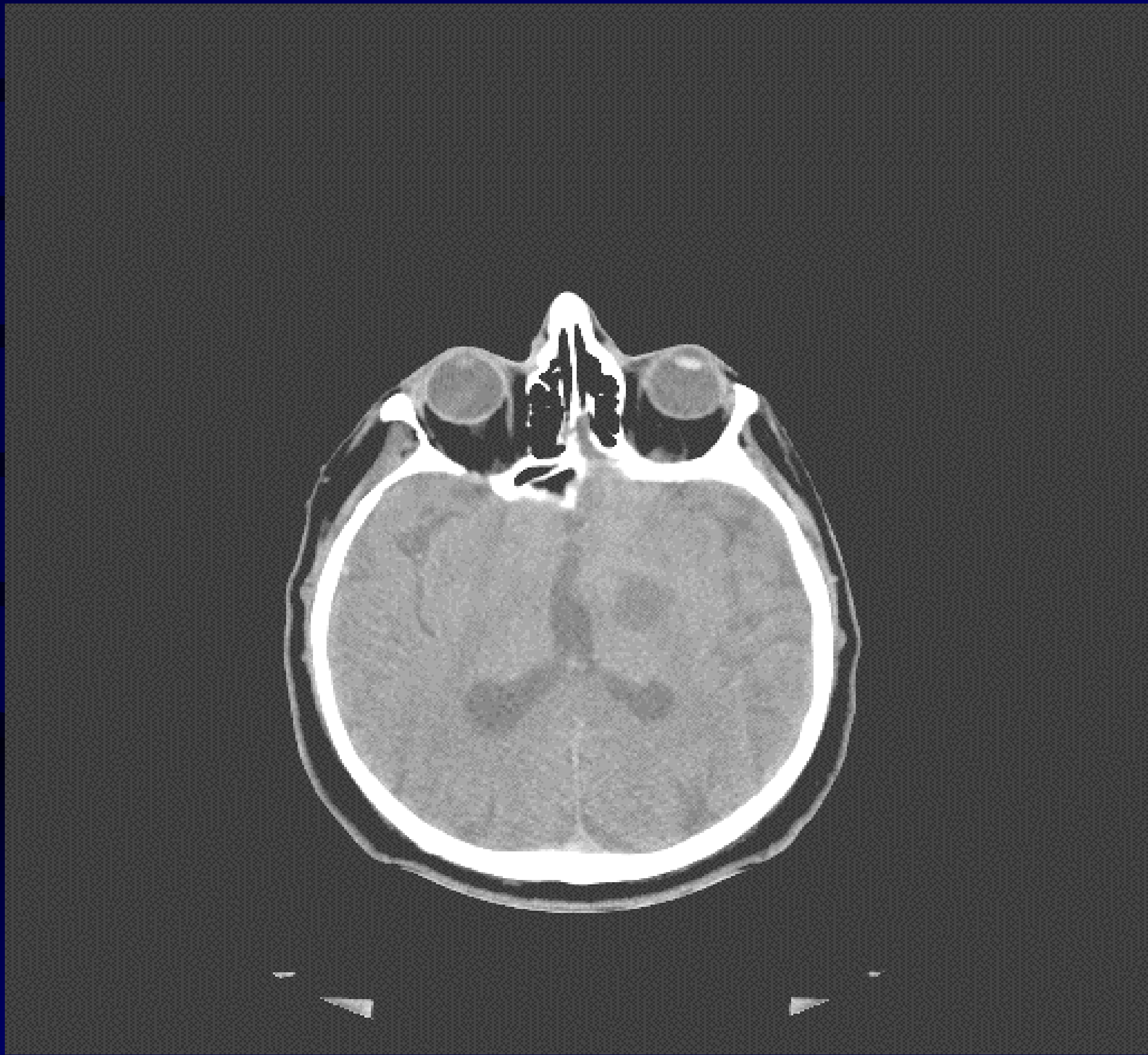
Features	Advantages	Disadvantages
Patient	Non or minimally invasive procedure Few patient risks No radiation associated with imaging This may be advantageous to paediatric patients and pregnant women This may be a useful for follow-up scanning	Claustrophobia due to the smaller patient bore Contraindicated in patients with loose metal foreign bodies within the body, particularly the orbits or pacemakers
Imaging	Increased number of imaging parameters for more imaging flexibility Superior soft tissue imaging with excellent spatial resolution to provide better visualization for the following: determining the tumour/GTV extent and degree of tumour infiltration Understanding the surgical bed or altered anatomy secondary to surgery Distinguishing between post-treatment fibrosis or tumour recurrence Improved definition of normal soft tissue structures and tissue planes avoidance of image artefact from metal prosthesis and large bony regions True multiplanar capability to image in any oblique plane and reduction of the "partial volume" imaging effect increased accuracy, reliability and consistency of target definition to reduce both interobserver and intraobserver variability Providing functional and biological information for functional avoidance or biological targeting Ultra-fast volumetric and cine mode acquisitions to assess temporal-spatial variations in target positioning or deformation Can be registered with CT information for use in RTP systems	MR image distortion Systems Object induced distortions Lack of electron density information for dosimetry and needs additional steps to permit dose calculations Lack of cortical bone information to create digitally reconstructed radiographs (DRR) in radiotherapy May have longer scan times than CT with more potential for motion artefacts Need for specific training to comprehend and understand MR images for RTP use RTP systems can only import transverse MR images and cannot take full advantage of sagittal and coronal in-plane MR images Immobilization devices used in radiotherapy may not be MR compatible
Contrast agents	New contrast agents (*i.e.* USPIO) to define nodal status Less incidence of allergic reactions to gadolinium than iodine-based contrast agents	
Machine	New bore flange openings to reduce patient claustrophobia Open MR systems for easier patient access, tolerance and positioning for radiotherapy	Not as readily available and accessible as CT Smaller bore than CT (52 cm *vs* 82–85 cm) Curved table top

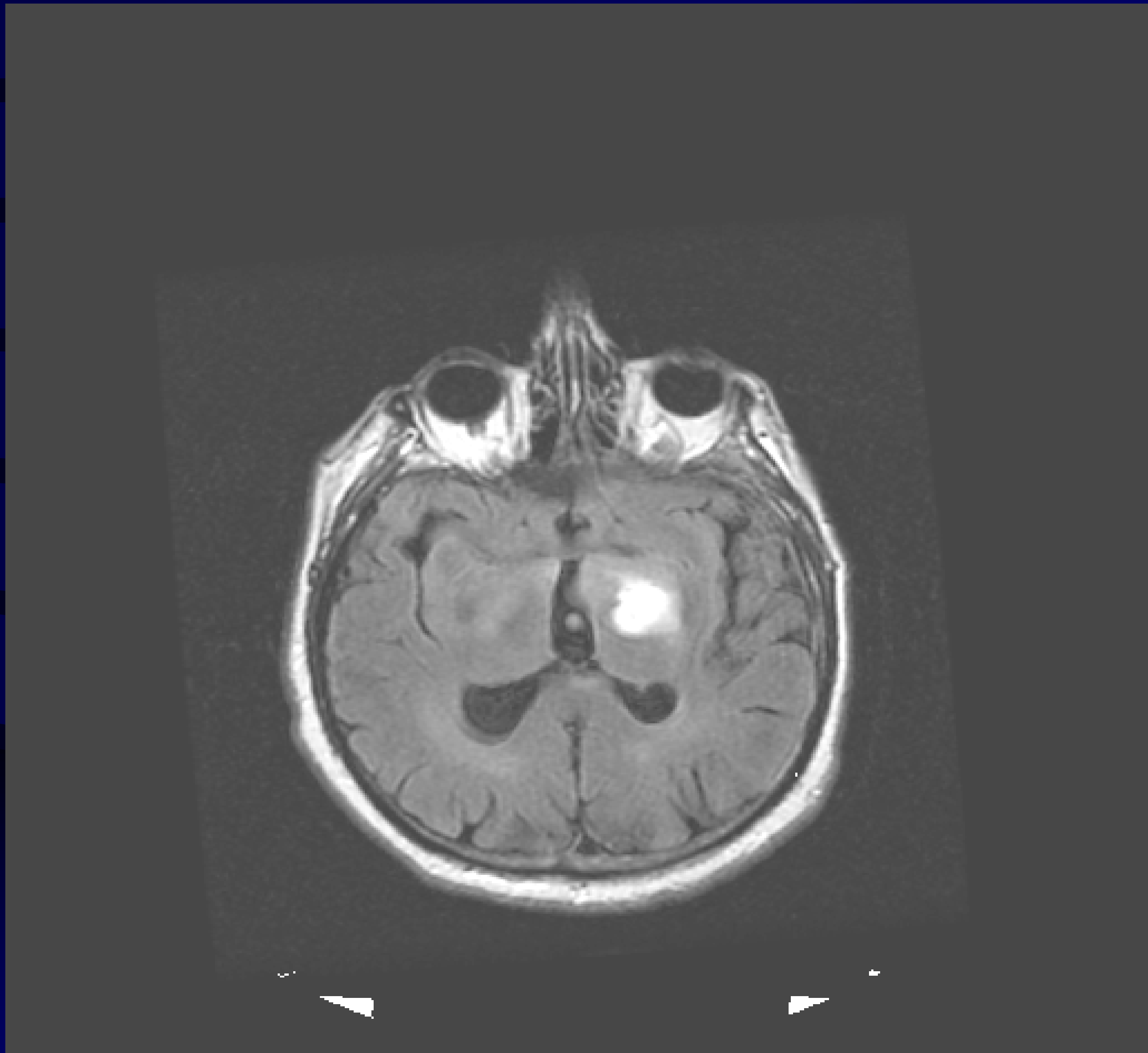
GTV, gross tumour volume; USPIO, ultrasmall paramagnetic iron oxide.

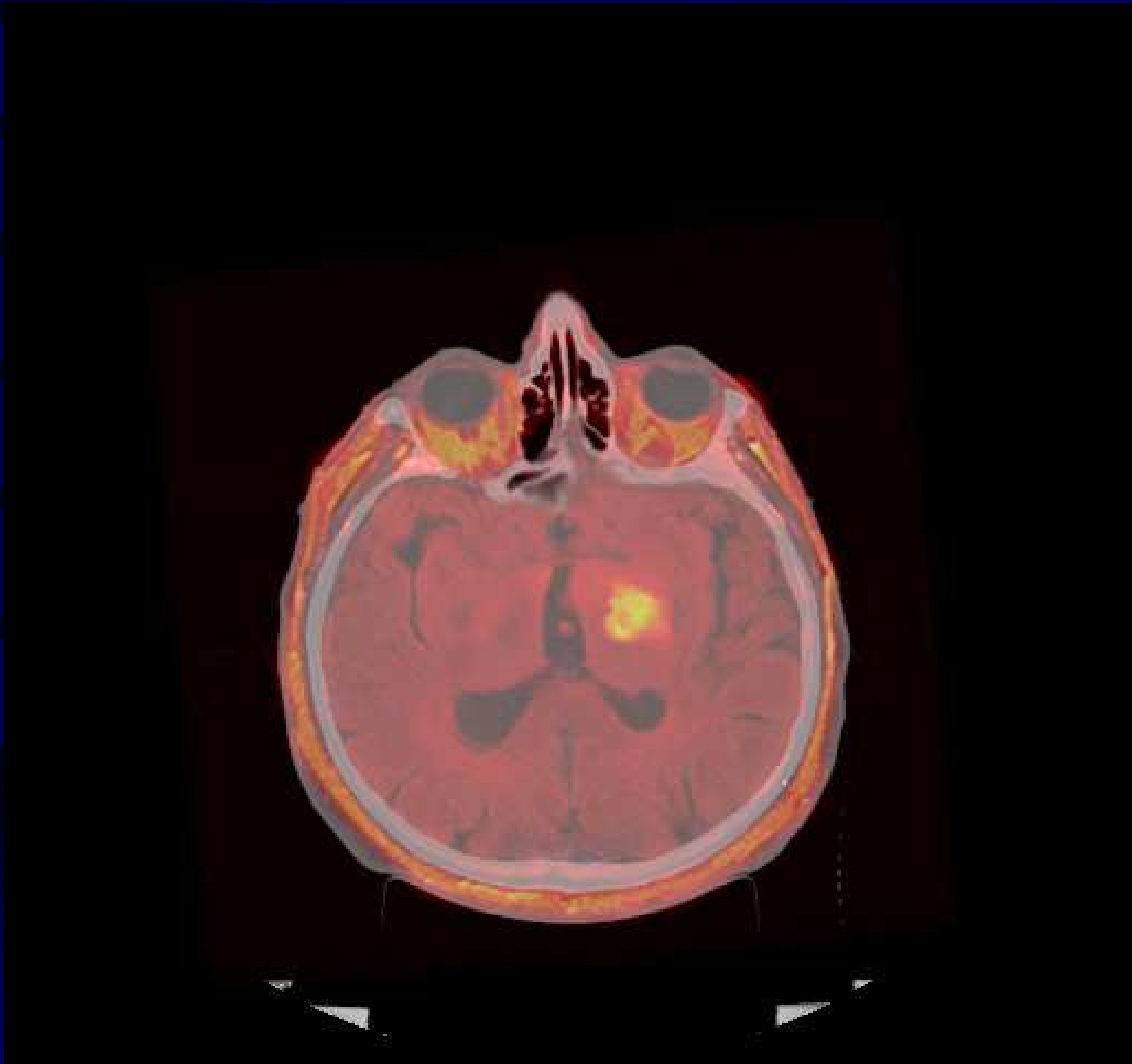
Tumori del SNC: RM e Radioterapia

- Tumori SNC: errori set-up 2-3mm, non “organ-motion”
- Def. volumi RT → elemento determinante









Tumori del SNC: RM e Radioterapia

- Migliore definizione del target fino all' 80 % dei casi con riduzione variabilità interosservazionale

  Ten Haken R.O. 1992, Thornton IJROBP 1992, Heester Strahlenter Onkol 1993, Aoyama IJROBP 2001, Sultanem IJROBP 2004

- Volumi definiti con TC-RM più grandi rispetto solo TC

  Ten Haken R.O. 1992, Khoo IJROBP 2000, Weltens R.O. 2001

- In alcuni casi i volumi TC ed RM: molto diversi (es.meningiomi base cranica con erosione ossea)

  Khoo IJROBP 2000

Review article

Target volumes in radiotherapy for high-grade malignant glioma of the brain

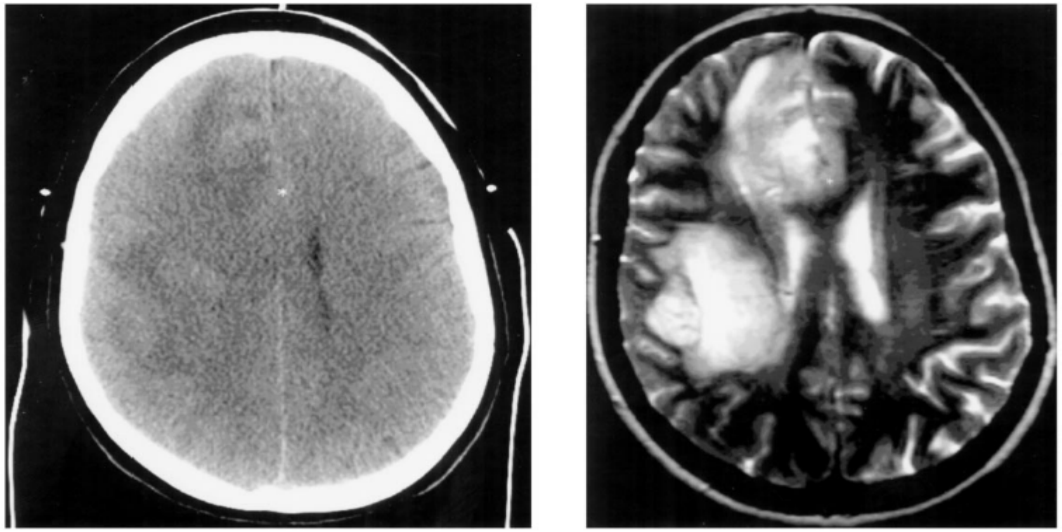
Radiother Oncol 2000

Edwin P.M. Jansen, Luc G.H. Dewit*, Marcel van Herk, Harry Bartelink

Abstract

Delineation of the clinical target volume (CTV) in radiation treatment planning of high-grade glioma is a controversial issue. The use of computerized tomography (CT) and magnetic resonance imaging (MRI) has greatly improved the accuracy of tumor localization in three-dimensional planning. This review aims at critically analyzing available literature data in which tumor extent of high-grade glioma has been assessed using CT and/or MRI and relating this to postmortem observations. Attention is given to the pattern of tumor spread at initial presentation and to tumor recurrence pattern after external beam irradiation. Special emphasis is given to the site of tumor regrowth after radiation treatment in relation to the boundaries of the CTV. Guidelines for delineating CTV will be inferred from this information, taking data on radiation effects on the normal brain into account.

CTV:
confronto TC-RM (T2)



Interobserver variations in gross tumor volume delineation of brain tumors on computed tomography and impact of magnetic resonance imaging

Caroline Weltens[a,*], Johan Menten[a], Michel Feron[b], Erwin Bellon[b], Philippe Demaerel[c], Frederik Maes[b], Walter Van den Bogaert[a], Emmanuel van der Schueren[a]

Abstract

Purpose: (1) To assess the interobserver variability of brain tumor delineation on computed tomography (CT). (2) To assess the impact of the addition of magnetic resonance imaging (MRI) information.

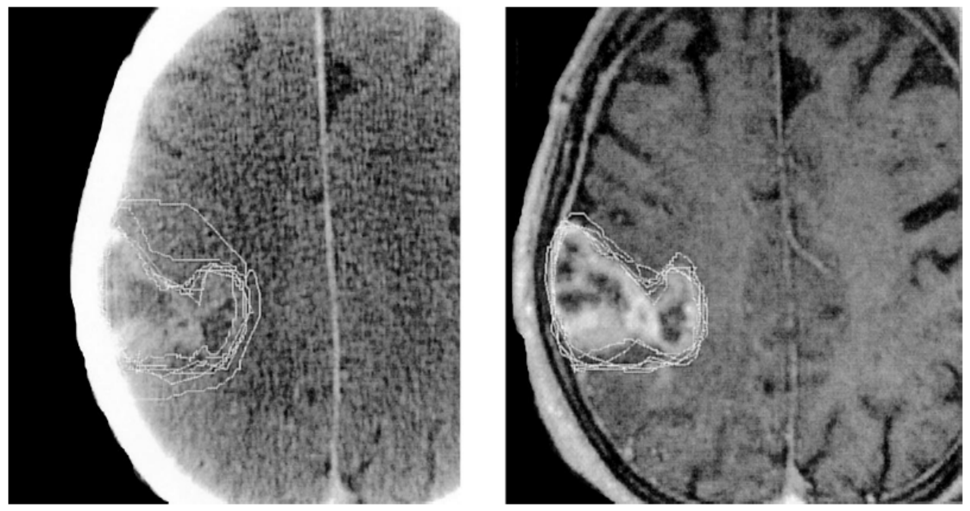
Methods: Nine physicians were asked to delineate the gross tumor volume (GTV) of five patients with supratentorial inoperable brain tumors on CT scans and 2 weeks (or more) later on MRIs. The delineations were performed on a computer screen. During delineation on MRI, the registered CT images (without delineation) were displayed on the screen (MRI + CT).

Results: A high interobserver variability in GTV delineation on CT is found: the ratio of the largest to the smallest defined volumes varies for the five patients by factors of resp. 2.8, 1.8, 1.8, 1.9 and 1.7. The interobserver variability is as large on MRI + CT as on CT alone (ratio largest/smallest volume: 2.4, 1.7, 1.9, 2.7 and 1.5). Volumes delineated on MRI + CT (mean: 69.6 cm^3) are larger than on CT alone (mean: 59.5 cm^3). Residual volumes (volume delineated on one image modality but not on the other) are >0 for CT alone and for MRI + CT.

Conclusions: A large interobserver variability in GTV delineation of brain tumors is demonstrated. The addition of MRI to CT does not reduce interobserver variability. GTVs delineated on MRI + CT are larger than on CT alone, but some volumes are delineated on CT and not on MRI. Therefore, a combination of the two image modalities is recommended for brain tumor delineation for treatment planning.

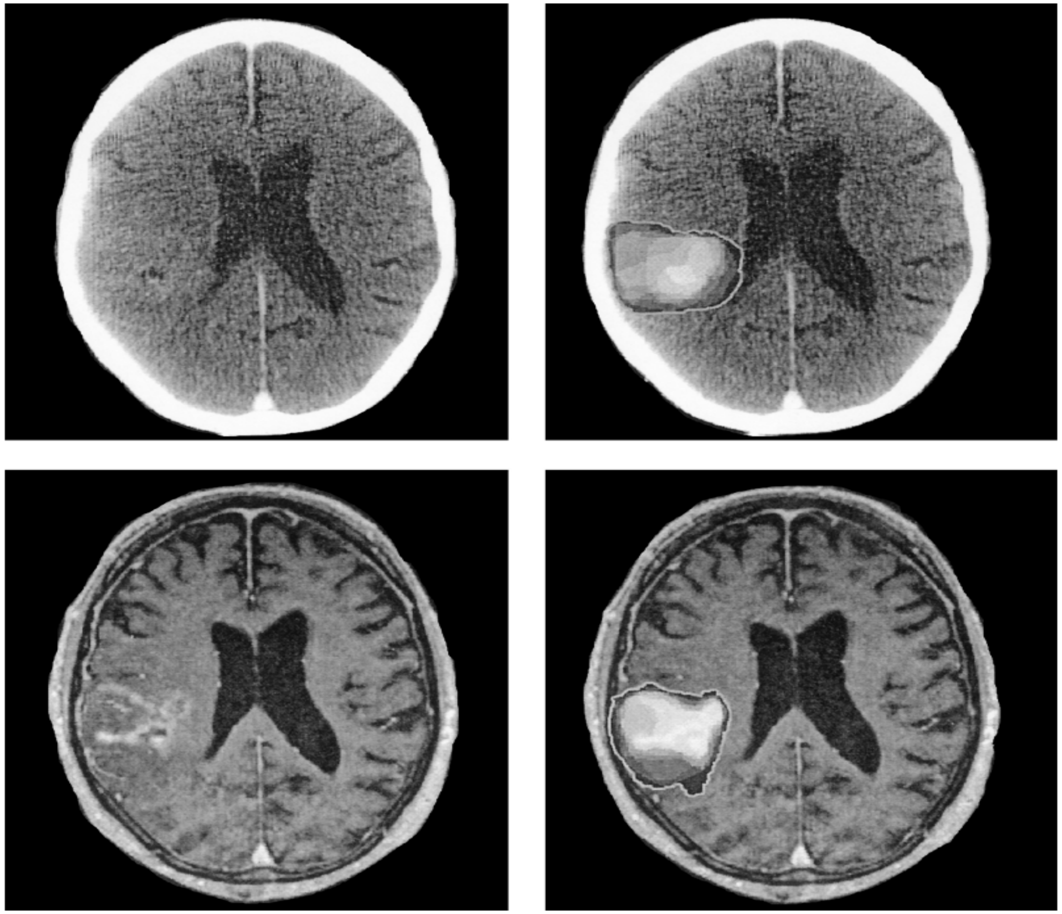
Variazione interosservazionale GTV:
- Criteri definizione GTV (enhancement – edema?)
- Tipo Software
- Tipo finestra
- Incapacità specialista definire lesione alla TC

Radiother Oncol 2001



Variabilità Interosservazionale GTV (TC-RM)

"agreement" definizione GTV tra specialisti



Target delineation in post-operative radiotherapy of brain gliomas: Interobserver variability and impact of image registration of MR(pre-operative) images on treatment planning CT scans

Giovanni Mauro Cattaneo[a,*], Michele Reni[b], Giovanna Rizzo[c], Pietro Castellone[d], Giovanni Luca Ceresoli[b], Cesare Cozzarini[b], Andrés José Maria Ferreri[b], Paolo Passoni[b], Riccardo Calandrino[a]

[a]*Medical Physics, Scientific Institute, H.S. Raffaele, Milano, Italy,* [b]*Radiochemotherapy, Scientific Institute, H.S. Raffaele, Milano, Italy,* [c]*IBFM-CNR, Nuclear Medicine, Scientific Institute, H.S. Raffaele, Milano, Italy,* [d]*Physics Department, University of Napoli Federico II°, Napoli, Italy*

Abstract

Background and purpose: To investigate the interobserver variability of intracranial tumour delineation on computed tomography (CT) scans using pre-operative MR hardcopies (CT+MR(conv)) or CT-MR (pre-operative) registered images (CT+MR(matched)).

Patients and methods: Five physicians outlined the 'initial' clinical tumour volume (CTV0) of seven patients affected by HGG and candidates for radiotherapy (RT) after radical resection. The observers performed on screen-tumour delineation using post-operative CT images of the patients in the treatment position and pre-operative MR radiographs (CT+MR(conv)); they also outlined CTV0 with both CT and corresponding MR axial image on screen (CT+MR(matched)). The accuracy of the image fusion was quantitatively assessed. An analysis was conducted to assess the variability among the five observers in CT+MR(conv) and CT+MR(matched) modality.

Results: The registration accuracy in 3D space is always less than 3.7 mm. The concordance index was significantly better in CT+MR(matched) (47.4±12.4%) than in CT+MR(conv) (14.1±12.7%) modality ($P<0.02$). The intersecting volumes represent 67±15 and 24±18% of the patient mean volume for CT+MR(matched) and CT+MR(conv), respectively ($P<0.02$).

Conclusions: The use of CT and MR registered imaging reduces interobserver variability in target volume delineation for post-operative irradiation of HGG; smaller margins around target volume could be adopted in defining irradiation technique.

 Radiotherapy and Oncology 75 (2005) 217-223.

Uso della MRI per la segmentazione del tumore

CT di centratura — MRI - T1 pesata — MRI - T2 pesata — MRI - T1 pesata con gadolinio

- Sequenze standard per la definizione del volume tumorale:
  - ✓ T1-pesata fornisce un alto contrasto ma con debole descrizione del tessuto (simile alla CT).
  - ✓ T2-pesata fornisce molte informazioni sulla composizione del tessuto (grado di idratazione) ed è la più sensibile alla conformazione della patologia.
  - ✓ T1-pesata con gadolinio fornisce un alta definizione del volume tumorale che cattura il contrasto

RESEARCH

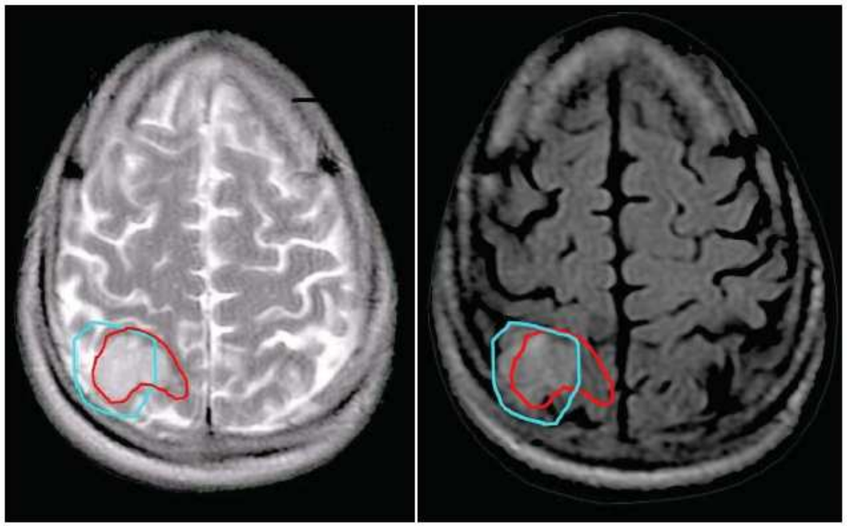
RADIATION ONCOLOGY

2010

Open Access

Comparison of T2 and FLAIR imaging for target delineation in high grade gliomas

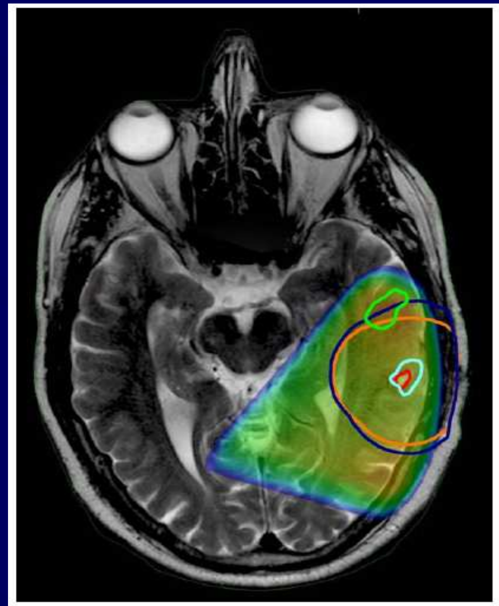
Bronwyn Stall, Leor Zach, Holly Ning, John Ondos, Barbara Arora, Uma Shankavaram, Robert W Miller, Deborah Citrin, Kevin Camphausen*



T2 weighted MRI | FLAIR MRI

DIAGNOSI

RECIDIVA



Conclusions: Although both T2 and FLAIR MRI sequences are used to define high grade glial neoplasm and surrounding edema, our results show that the volumes generated using these techniques are different and not interchangeable. These differences have bearing on the use of intensity modulated radiation therapy (IMRT) and highly conformal treatment as well as on future clinical trials where the bias of using one technique over the other may influence the study outcome.

RESULTS OF A MULTI-INSTITUTIONAL BENCHMARK TEST FOR CRANIAL CT/MR IMAGE REGISTRATION

IJROBP 2010

Kenneth Ulin, Ph.D.,* Marcia M. Urie, Ph.D.,* and Joel M. Cherlow, M.D., Ph.D.†

*Quality Assurance Review Center, Providence, RI, and †Long Beach Memorial Medical Center, Long Beach, CA

Purpose: Variability in computed tomography/magnetic resonance imaging (CT/MR) cranial image registration was assessed using a benchmark case developed by the Quality Assurance Review Center to credential institutions for participation in Children's Oncology Group Protocol ACNS0221 for treatment of pediatric low-grade glioma.
Methods and Materials: Two DICOM image sets, an MR and a CT of the same patient, were provided to each institution. A small target in the posterior occipital lobe was readily visible on two slices of the MR scan and not visible on the CT scan. Each institution registered the two scans using whatever software system and method it ordinarily uses for such a case. The target volume was then contoured on the two MR slices, and the coordinates of the center of the corresponding target in the CT coordinate system were reported. The average of all submissions was used to determine the true center of the target.
Results: Results are reported from 51 submissions representing 45 institutions and 11 software systems. The average error in the position of the center of the target was 1.8 mm (1 standard deviation = 2.2 mm). The least variation in position was in the lateral direction. Manual registration gave significantly better results than did automatic registration ($p = 0.02$).
Conclusion: When MR and CT scans of the head are registered with currently available software, there is inherent uncertainty of approximately 2 mm (1 standard deviation), which should be considered when defining planning target volumes and PRVs for organs at risk on registered image sets.

Neoplasie SNC: RM e RT

Co-registrazione TC-RM

↓

Standard

← Condivisione linee-guida def. CTV

CLINICAL INVESTIGATION IJROBP 2004 Brain

3D MRSI FOR RESECTED HIGH-GRADE GLIOMAS BEFORE RT: TUMOR EXTENT ACCORDING TO METABOLIC ACTIVITY IN RELATION TO MRI

ANDREA PIRZKALL, M.D.,* XIAOJUAN LI, M.S.,† JOONMI OH, PH.D.,† SUSAN CHANG, M.D.,‡ MITCHEL S. BERGER, M.D.,‡ DAVID A. LARSON, M.D., PH.D.,*‡ LYNN J. VERHEY, PH.D.,* WILLIAM P. DILLON, M.D.,† AND SARAH J. NELSON, DR.RER.NAT.†

Departments of *Radiation Oncology, †Radiology, Magnetic Resonance Science Center, and ‡Neurologic Surgery, University of California, San Francisco, School of Medicine, San Francisco, CA

Purpose: To evaluate the presence of residual disease after surgery but before radiotherapy (RT) in patients with high-grade glioma by MRI and magnetic resonance spectroscopy imaging (MRSI) and to estimate the impact of MRSI on the definition of postoperative target volumes for RT treatment planning.

Conclusion: MRSI is a valuable diagnostic tool for the assessment of residual disease after surgical resection in high-grade glioma. The incorporation of areas of metabolic abnormality into treatment planning for postoperative patients would produce different sizes and shapes of target volumes for both primary and boost volumes. It also may encourage the use of nonuniform margins to define the extent of tumor cell infiltration, rather than the current use of uniform margins.

Use of MR spectroscopy and functional imaging in the treatment planning of gliomas

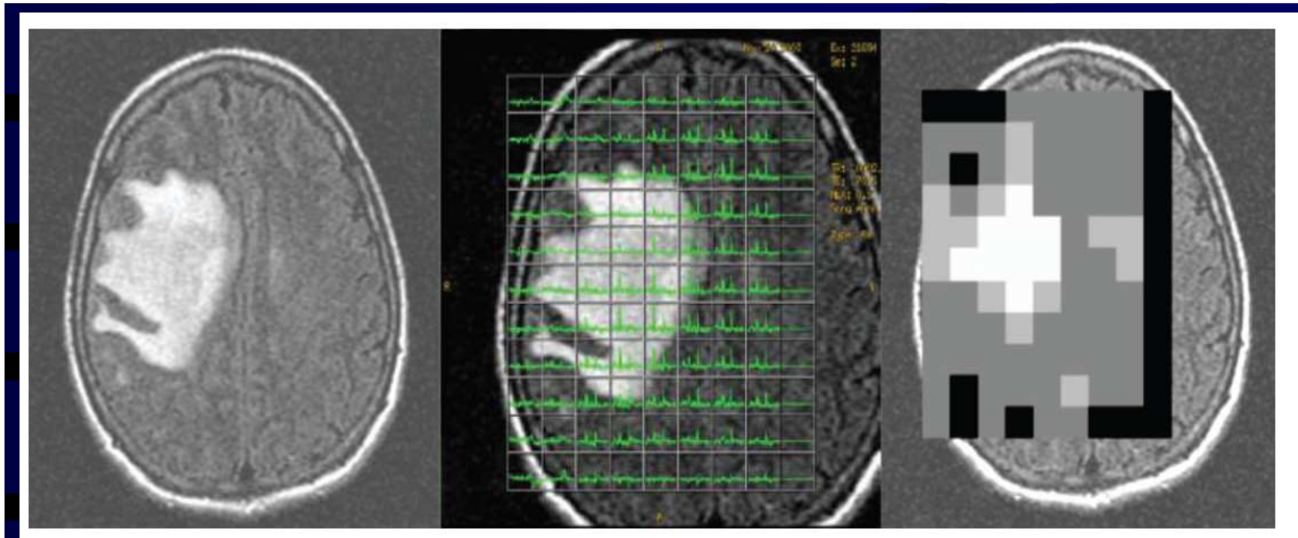
[1]A NARAYANA, MD, [2]J CHANG, PhD, [2]S THAKUR, PhD, [2,3]W HUANG, PhD, [3]S KARIMI, MD, [2,3]B HOU, PhD, [2]A KOWALSKI, MS, [2]G PERERA, MS, [3]A HOLODNY, MD and [4,5]P H GUTIN, MD

Departments of [1]Radiation Oncology, [2]Medical Physics, [3]Radiology and [4]Surgery, Memorial Sloan-Kettering Cancer Center and [5]Department of Neuro-Surgery, Weill Medical College of Cornell University, 1275 York Avenue, New York, NY 10021, USA

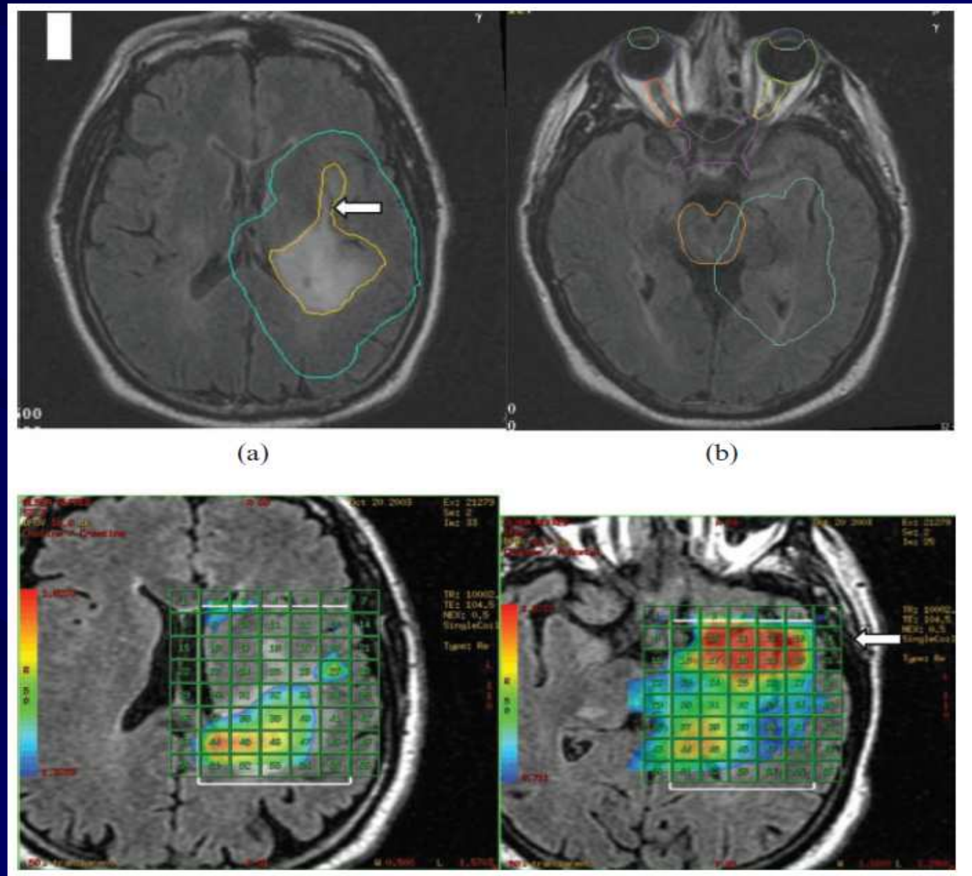
ABSTRACT. Routine anatomical imaging with CT and MRI does not reliably indicate the true extent or the most malignant areas of gliomas and cannot identify the functionally critical parts of the brain. The aim of the study was to see if the use of MR spectroscopic imaging (MRSI) along with functional MRI (fMRI) can better define both the target and the critical structures to be avoided to improve radiation delivery in gliomas. 12 patients with gliomas underwent multivoxel MRS and functional imaging using GE processing software. The choline to creatine ratio (Cho:Cr), which represents the degree of abnormality for each individual voxel on MRSI, was derived, converted into a grayscale grading system, fused to the MRI images and then transferred to the planning CT images. An intensity-modulated radiation therapy (IMRT) plan was developed using the dose constraints based on both the anatomical and the functionally critical regions. Cho:Cr consistently identified the gross tumour volume (GTV) within the microscopic disease (clinical target volume, CTV) and allowed dose painting using IMRT. No correlation between MRSI based Cho:Cr $\geqslant 2$ and MR defined CTV nor their location was noted. However, MRSI defined Cho:Cr $\geqslant 3$ was smaller by 40% compared with post-contrast T_1 weighted MRI defined GTV volumes. fMRI helped in optimizing the orientation of the beams. In conclusion, both MRSI and fMRI provide additional information to conventional imaging that may guide dose painting in treatment planning of gliomas. A Phase I IMRT dose intensification trial in gliomas using this information is planned.

Received 10 May 2006
Revised 15 September 2006
Accepted 15 September 2006

DOI: 10.1259/bjr/65349468



Esempio conversione MR-MRS



CTV: confronto RM (FLAIR)-RMS

CLINICAL INVESTIGATION IJROBP 2008 Brain

PROTON MAGNETIC RESONANCE SPECTROSCOPIC IMAGING IN NEWLY DIAGNOSED GLIOBLASTOMA: PREDICTIVE VALUE FOR THE SITE OF POSTRADIOTHERAPY RELAPSE IN A PROSPECTIVE LONGITUDINAL STUDY

ANNE LAPRIE, M.D., PH.D,[*†] ISABELLE CATALAA, M.D., PH.D,[†§] EMMANUELLE CASSOL, PH.D.,[†] TRACY R. MCKNIGHT, PH.D.,[¶] DELPHINE BERCHERY, M.D.,[||] DELPHINE MARRE, PH.D.,[*] JEAN-MARC BACHAUD, M.D.,[*] ISABELLE BERRY, M.D., PH.D,[†] AND ELIZABETH COHEN-JONATHAN MOYAL, M.D., PH.D[*‡]

[*]Department of Radiation Oncology, Institut Claudius Regaud, Toulouse, France; [†]Laboratory of Biophysics and Medical Imaging, Universite Toulouse III Paul Sabatier, Toulouse, France; [‡]Department of Therapeutic Innovation and Molecular Oncology, Institut Claudius Regaud, INSERM, U563, Toulouse, France; [§]Department of Neuroradiology, Hôpital Rangueil, CHU Toulouse, Toulouse, France; [¶]Center for Molecular and Functional Imaging, University of California–San Francisco, San Francisco, CA; and [||]Department of Medical Information, Institut Claudius Regaud, Toulouse, France

Conclusion: Metabolically active regions represented a small percentage of pretreatment MRI abnormalities and were predictive for the site of post-RT relapse. The incorporation of MRSI data in the definition of RT target volumes for selective boosting may be a promising avenue leading to increased local control of glioblastomas.

MRS

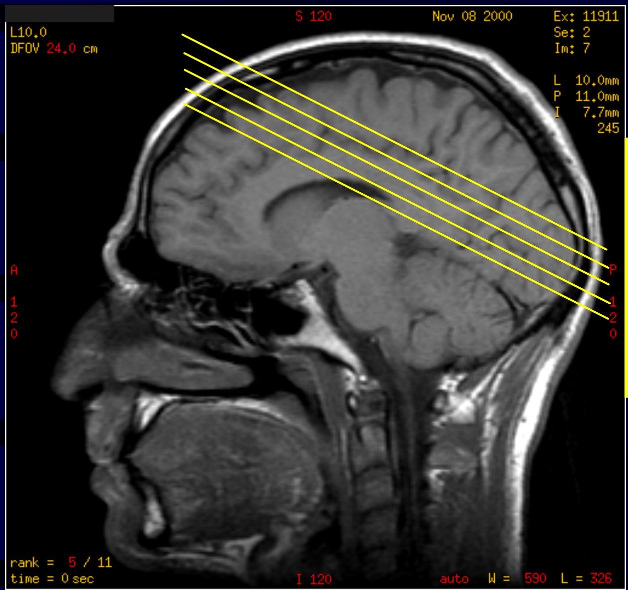
Vantaggi:

- Modifica volumi RT definiti dalla RM
- Possibile uso 3T
- Def. volumi su FLAIR evitando ventricoli e osso
- Uso rapporto cho: cr e cho: NAA (riproducibile e ripetibile)

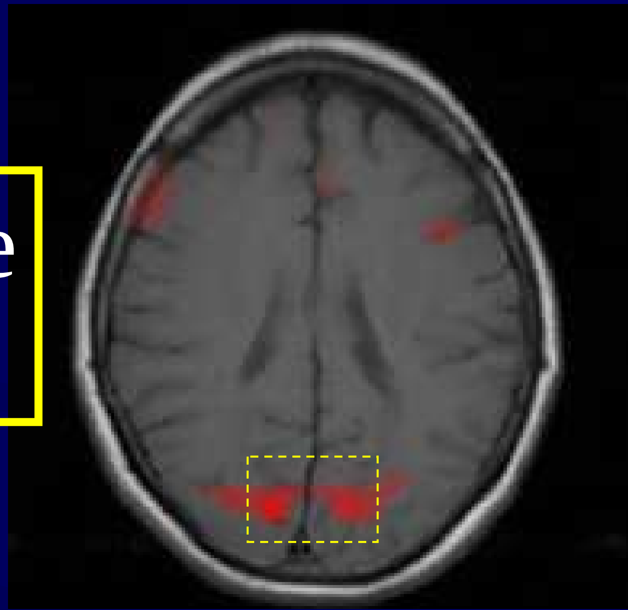
Svantaggi:

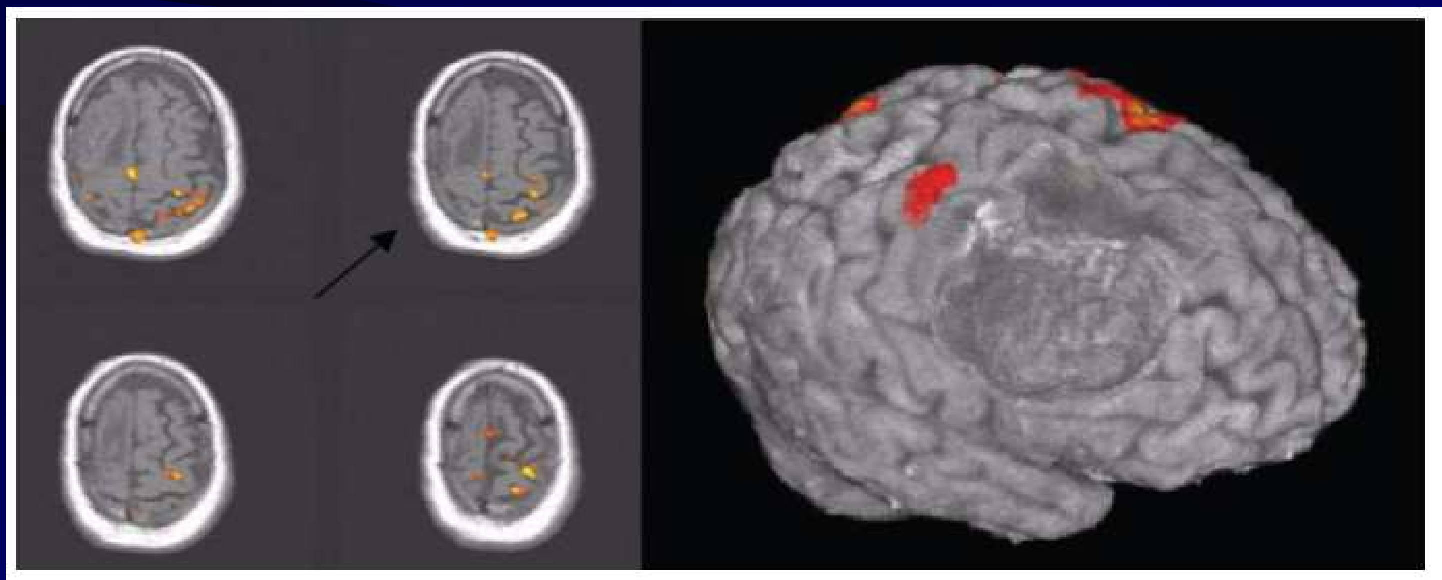
- Presenza clips
- Presenza sangue
- Sede esame: base cranica
- Problemi tecnici fusione con TC/RM

RM funzionale



Ottimizzazione
tecnica RT





Tumori ORL: RM e Radioterapia

Migliore definizione diagnostica rispetto TC:

- Infiltrazione longitudinale del tumore lungo la via aero-digestiva superiore e piani fasciali adiacenti (es.fascia pre-vertebrale)
- Infiltrazione di tessuti molli (ca. lingua), perineurale, intracranica (ca. rinofaringe: 50% dei casi stadiazione modificata da RM)
- Metastasi linfonodali

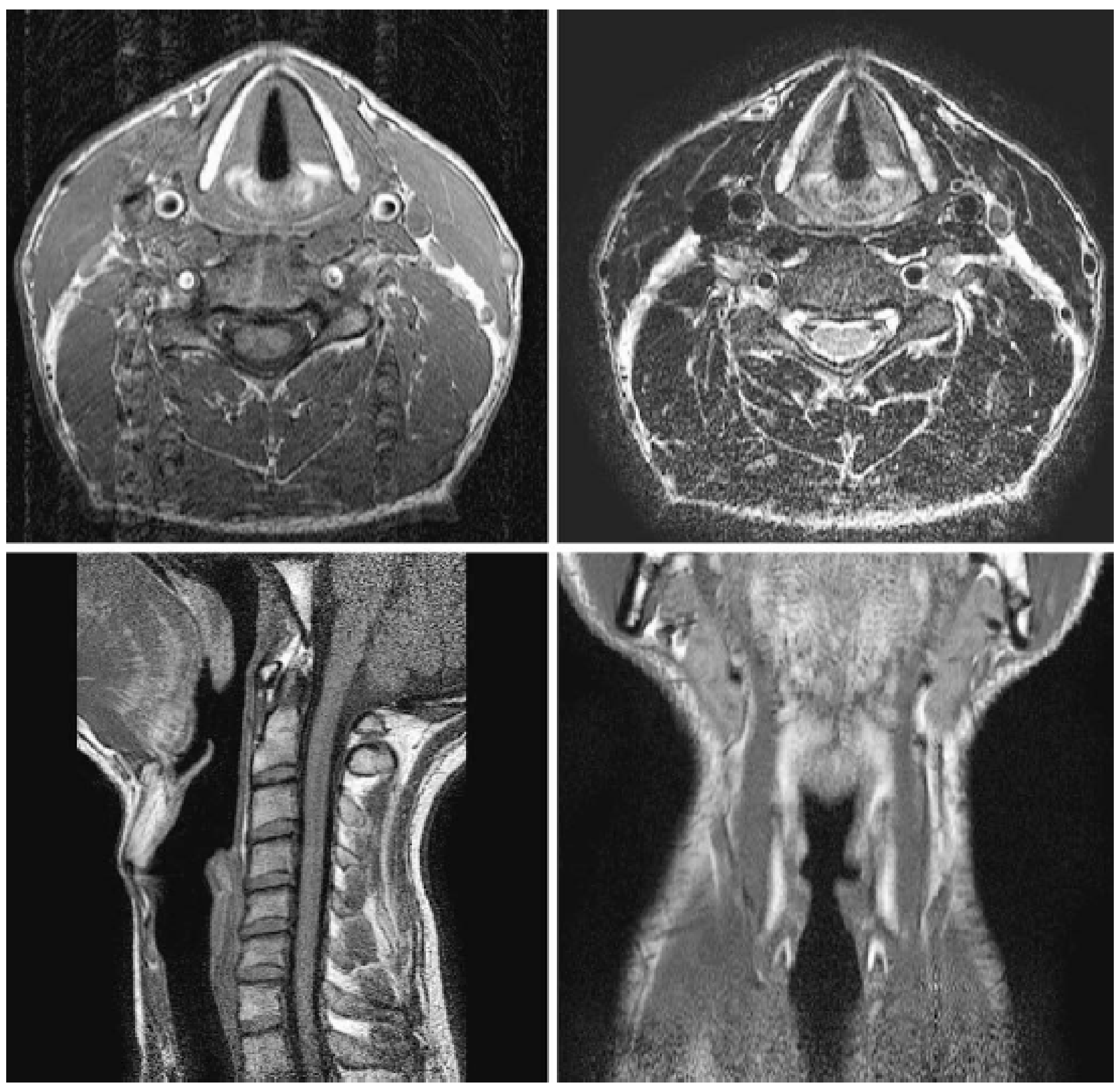
Rasch IJROBP 1997, Emami IJROBP 2003,
Manavis Clin Imaging 2005, Lee IJROBP 2005, Khoo Br J Radiol 2006

Tumori ORL: RM e Radioterapia

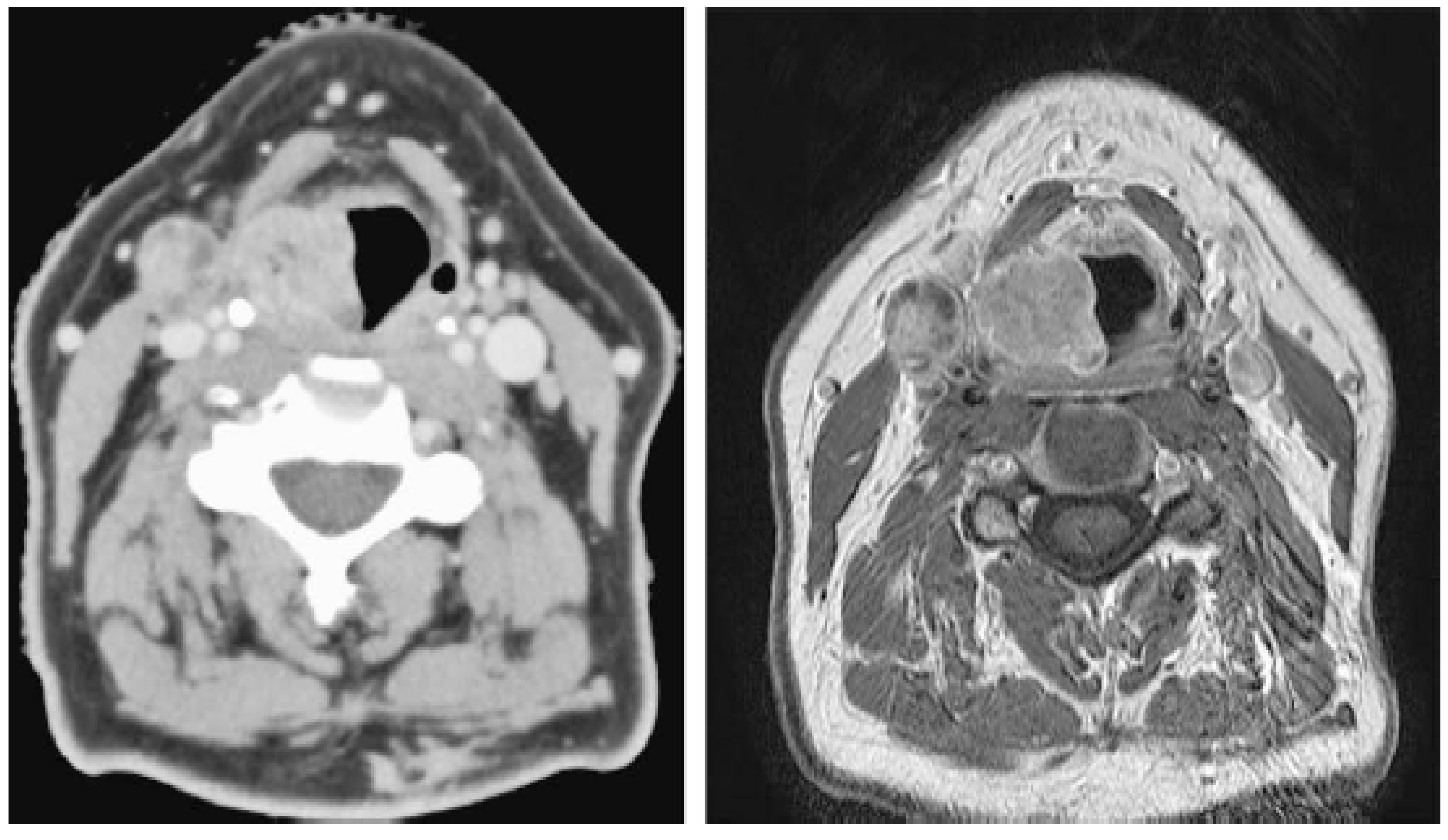
Rispetto alla TC, la co-registrazione TC-RM:

- Migliore definizione GTV/CTV (specie nella definizione estensione ossea delle neoplasie rinofaringee)
- Volumi GTV più piccoli
- Riduzione variabilità interosservazionale (fattore prognostico)

Rasch IJROBP 1997, Emami IJROBP 2003, Daisne Radiology 2004, Chung Head Neck 2004, Lee IJROBP 2005, Pimentel Serra Eur J Cancer 2005, Khoo Br J Radiol 2006



Studio RM distretto ORL



RM vs TC:
Migliore definizione estensione neoplasia

Neoplasie ipofaringee e laringee: RM e RT

- Importanza RM definizione tessuti molli (ipofaringe) e invasione cartilagine (laringe)
- RM: artefatti di movimento (deglutizione, movimento lingua) dovuto lungo tempo di scansione rispetto TC
- Risultati contrastanti ruolo RM definizione GTV

Rasch IJROBP 1997, Gordon Am J Neuroradiol 2004, Geets Radiother Oncol 2005

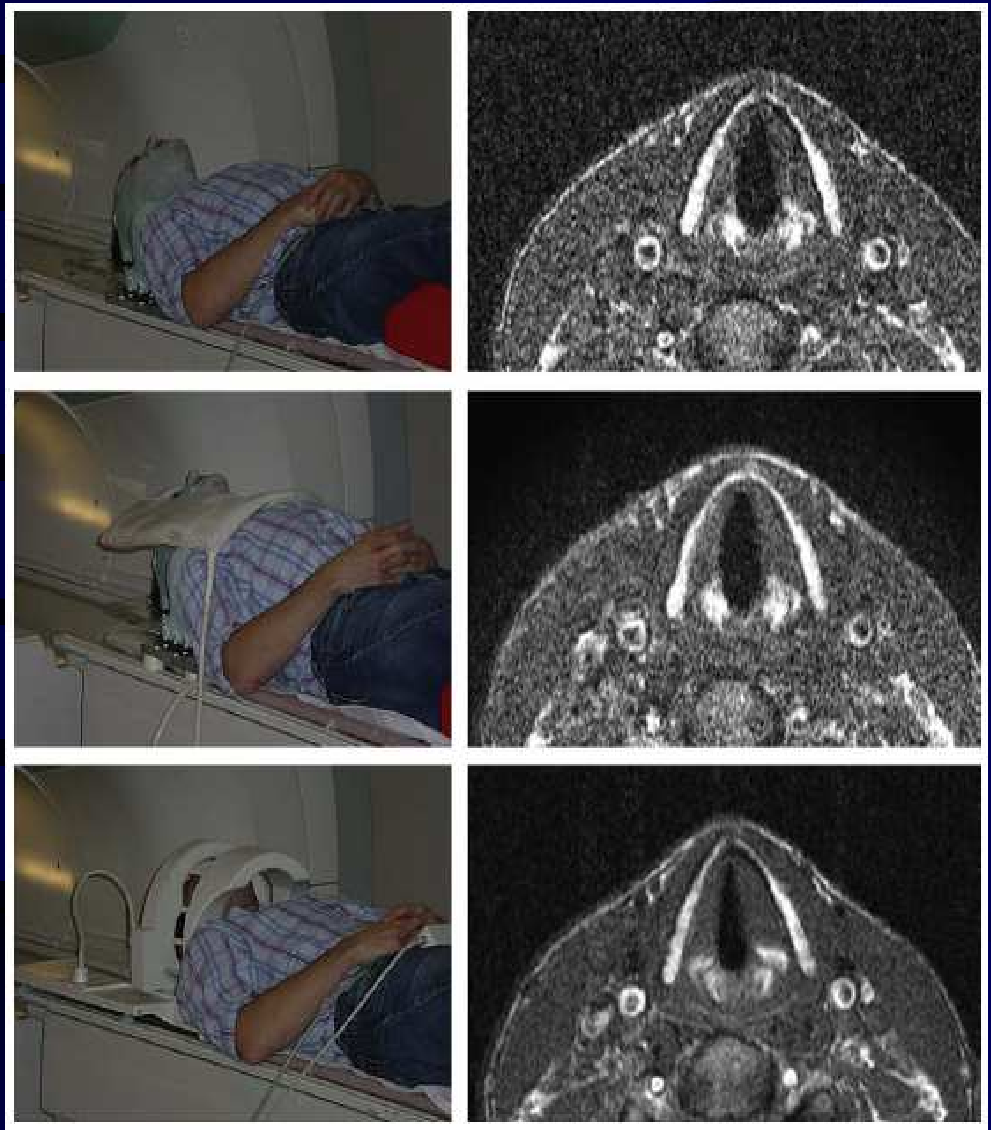
MAGNETIC RESONANCE IMAGING PROTOCOL OPTIMIZATION FOR DELINEATION OF GROSS TUMOR VOLUME IN HYPOPHARYNGEAL AND LARYNGEAL TUMORS

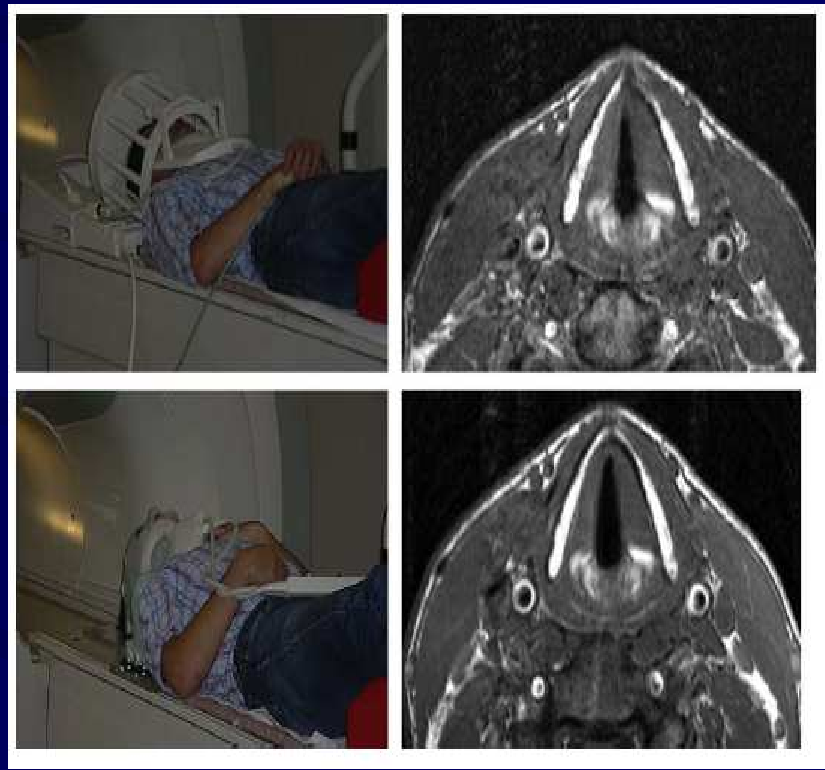
GERDA M. VERDUIJN, M.D.,* LAMBERTUS W. BARTELS, PH.D.,† CORNELIS P. J. RAAIJMAKERS, PH.D.,* CHRIS H. J. TERHAARD, PH.D.,* FRANK A. PAMEIJER, PH.D.,† AND CORNELIS A. T. VAN DEN BERG, PH.D.*

*Department of Radiotherapy, and †Image Sciences Institute/Department of Radiology, University Medical Center Utrecht, Utrecht, The Netherlands

IJROBP 2009

Purpose: To optimize the use of MRI for delineation of gross tumor volume for radiotherapy treatment planning purposes in hypopharyngeal and laryngeal tumors.
Methods and Materials: Magnetic resonance images (T1 weighted and T2 weighted) of a healthy volunteer were acquired using a 1.5 T and 3.0 T MR scanner. Various receiver coils were investigated that were compatible with the immobilization mask needed for reliable coregistration with computed tomography data. For the optimal receiver coil, the influence of resolution, slice thickness, and strength of magnetic field on the signal-to-noise ratio (SNR) was studied. Feasibility of the definitive protocol was tested on patients with hypopharyngeal (n = 19) and laryngeal (n = 42) carcinoma.
Results: Large differences in SNR were obtained for the various coils. The SNR values obtained using surface coils that were compatible with the immobilization mask were three times higher than those obtained using a standard head-and-neck coil and five times higher than those obtained using a body coil. High-resolution images ($0.4 \times 0.4 \times 4\ mm^3$) showed superior anatomic detail and resulted in a 4-min scan time. Image quality at 3.0 T was not significantly better compared with 1.5 T. In 3 patients the MR study could not be performed; for 5 patients images were severely deteriorated by motion artefacts. High-quality MR images were obtained in 53 patients.
Conclusions: High-resolution MR images of the hypopharynx and larynx can be obtained in the majority of patients using surface receiver coils in combination with the radiotherapy mask. These MR images can be successfully used for tumor delineation in radiotherapy.





RM (sequenza T1-pesata)
con bobine di superficie differenti

RESEARCH Open Access

Decreased 3D observer variation with matched CT-MRI, for target delineation in Nasopharynx cancer

RADIATION ONCOLOGY 2010

Coen RN Rasch[1*], Roel JHM Steenbakkers[2], Isabelle Fitton[3], Joop C Duppen[1], Peter JCM Nowak[4], Frank A Pameijer[5], Avraham Eisbruch[6], Johannes HAM Kaanders[7], Frank Paulsen[8], Marcel van Herk[1]

Abstract

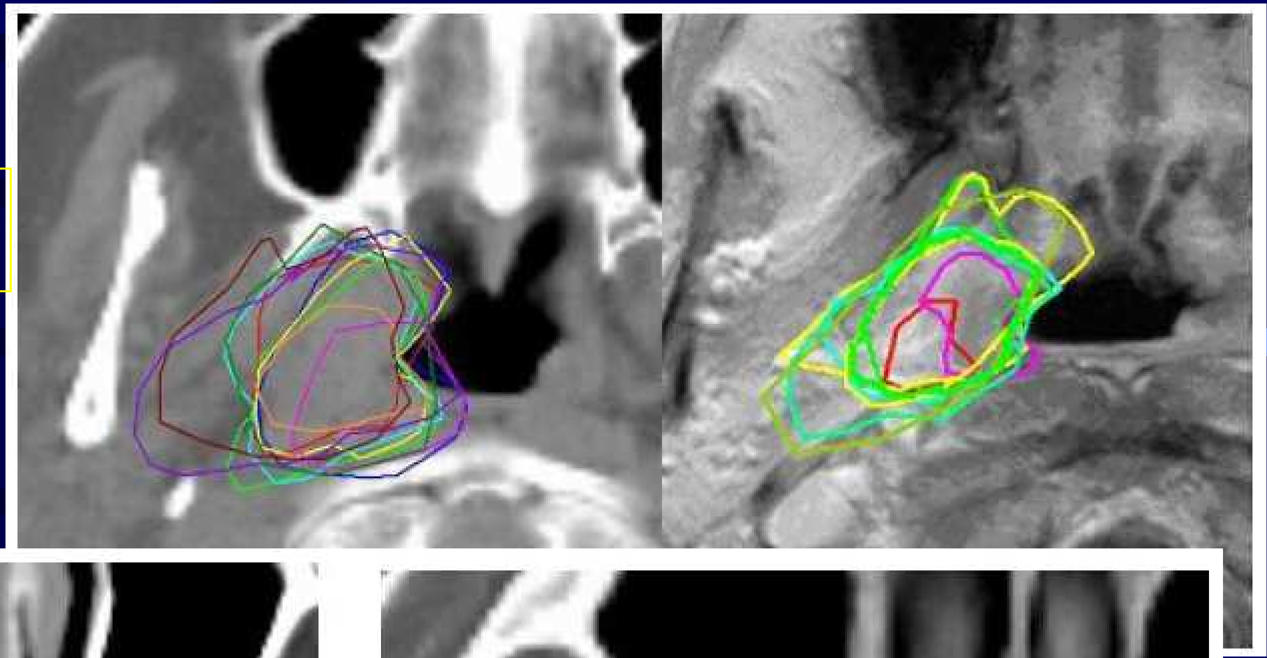
Purpose: To determine the variation in target delineation of nasopharyngeal carcinoma and the impact of measures to minimize this variation.

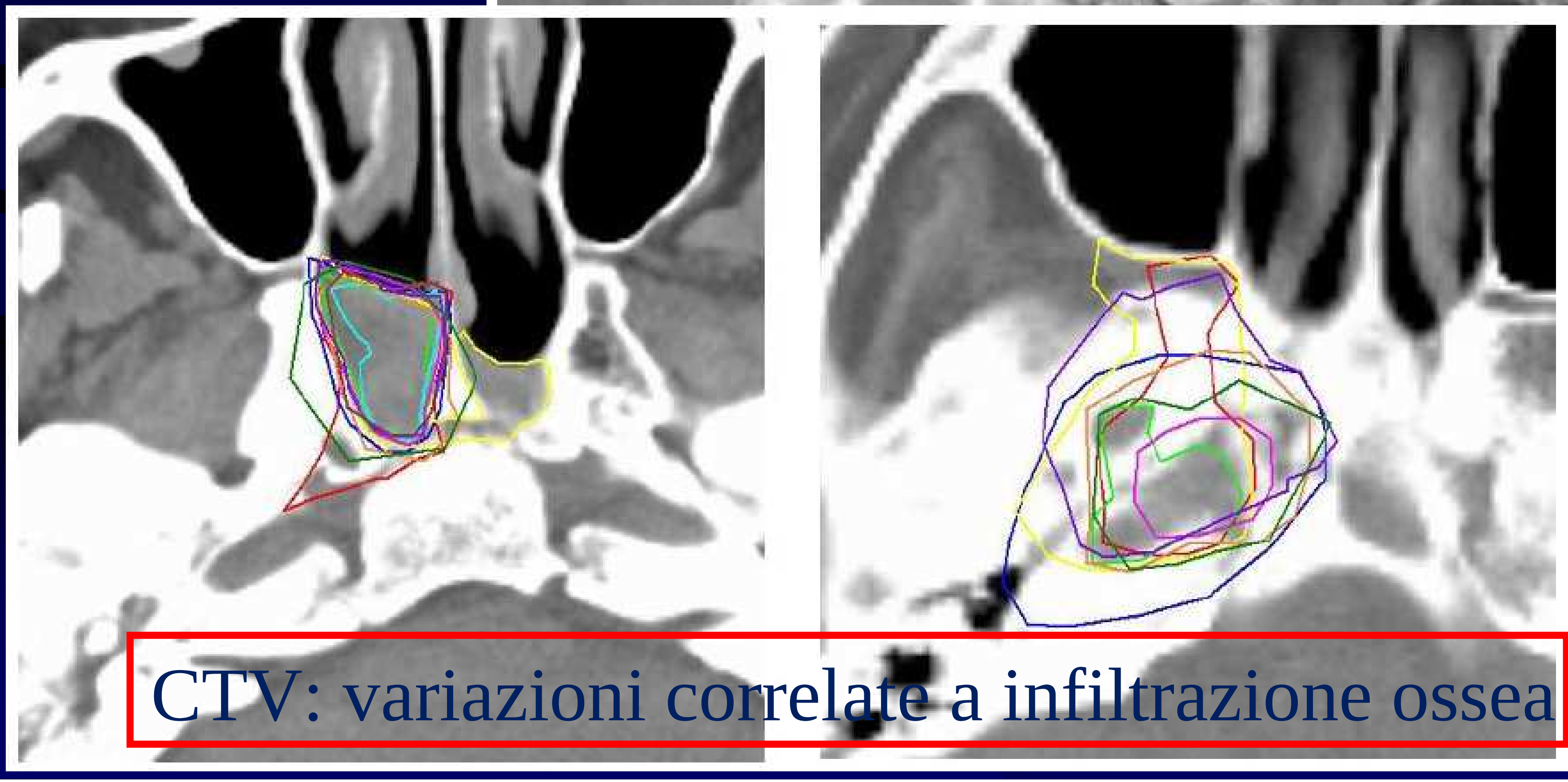
Materials and methods: For ten nasopharyngeal cancer patients, ten observers each delineated the Clinical Target Volume (CTV) and the CTV elective. After 3D analysis of the delineated volumes, a second delineation was performed. This implied improved delineation instructions, a combined delineation on CT and co-registered MRI, forced use of sagittal reconstructions, and an on-line anatomical atlas.

Results: Both for the CTV and the CTV elective delineations, the 3D SD decreased from Phase 1 to Phase 2, from 4.4 to 3.3 mm for the CTV and from 5.9 to 4.9 mm for the elective. There was an increase agreement, where the observers intended to delineate the same structure, from 36 to 64 surface % ($p = 0.003$) for the CTV and from 17 to 59% ($p = 0.004$) for the elective. The largest variations were at the caudal border of the delineations but these were smaller when an observer utilized the sagittal window. Hence, the use of sagittal side windows was enforced in the second phase and resulted in a decreased standard deviation for this area from 7.7 to 3.3 mm ($p = 0.001$) for the CTV and 7.9 to 5.6 mm ($p = 0.03$) for the CTV elective.

Discussion: Attempts to decrease the variation need to be tailored to the specific causes of the variation. Use of delineation instructions multimodality imaging, the use of sagittal windows and an on-line atlas result in a higher agreement on the intended target.

CTV: TC vs RM





CTV: variazioni correlate a infiltrazione ossea

Neoplasie distretto ORL: RM e RT

- Migliore definizione neoplasia
- Criticità: co-registrazione TC-RM in alcune sedi anatomiche

↓

Necessità di studi ulteriori

Pelvi: RM e Radioterapia

Migliore delineazione del Target:

- Neoplasie apparato urologico
- Neoplasie ginecologiche
- Neoplasie rettali

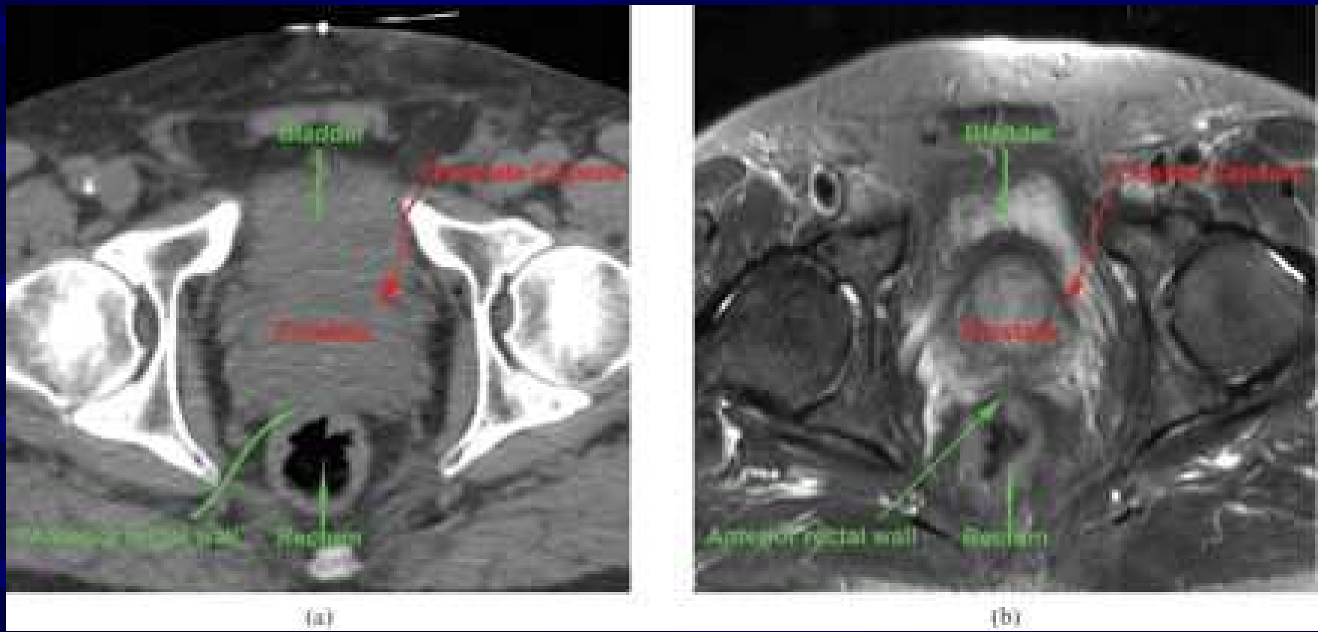
Neoplasia prostatica: RM e RT

Migliore definizione rispetto alla TC

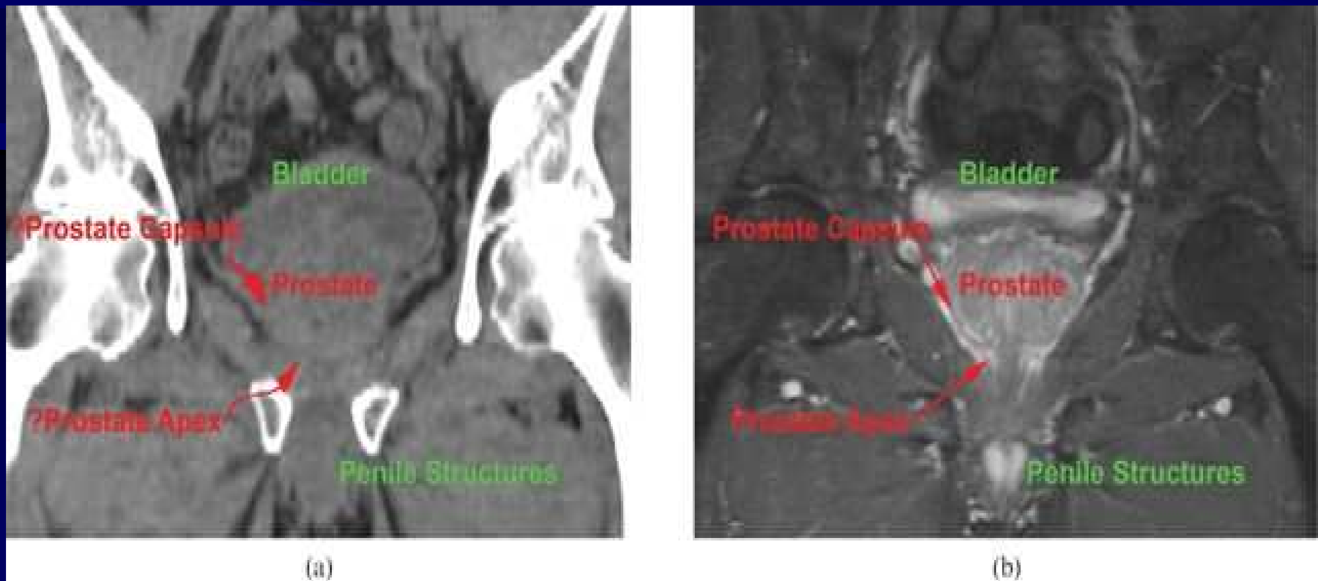
- Estensione di malattia
- Coinvolgimento capsulare e delle vescichette seminali
- Apice prostatico (immagini sagittali)
- Eventuale infiltrazione della base della vescica e della parete rettale

⇓

Volumi-TC: sovrastima del 27-43% (incertezza legata ai tessuti molli)



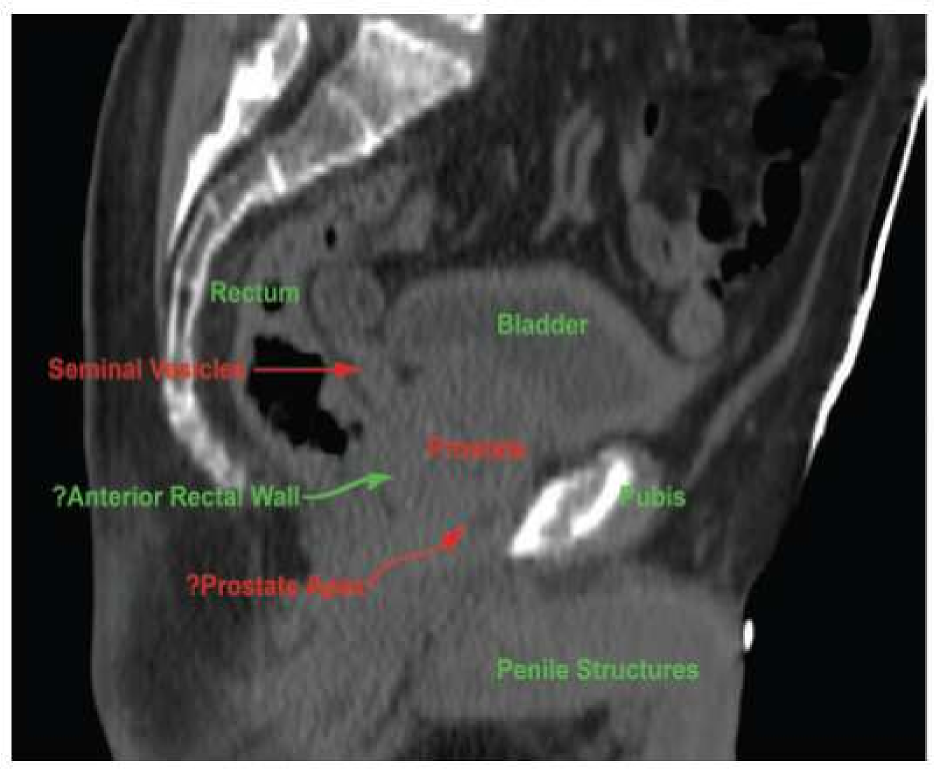
TC (2.5 mm) **RM**



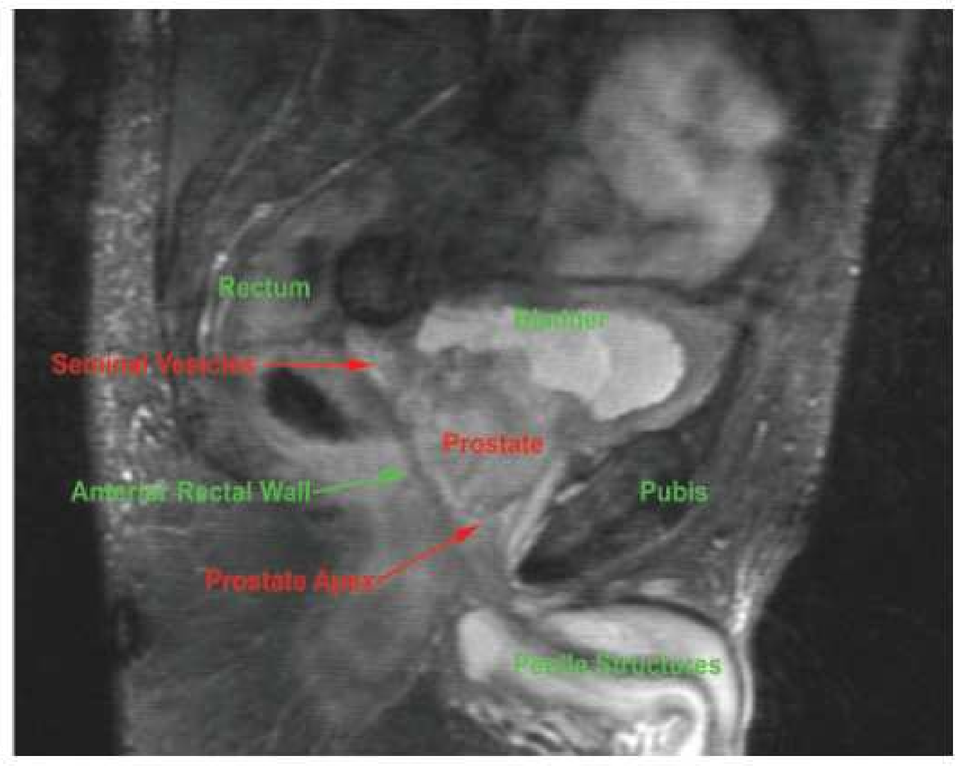
Migliore definizione del CTV e OAR

Riduzione volume CTV e OAR

TC



RM



Riduzione variabilità intra- e interosservazionale

Roach IJROBP 1996, Kagawa IJROBP 1997, Rasch IJROBP 1999

Debais IJROBP 1999, Steenbakkers IJROBP 2003, Khoo Br J Radiol 2006

CT–MRI image fusion for delineation of volumes in three-dimensional conformal radiation therapy in the treatment of localized prostate cancer

[1]G L SANNAZZARI, MD, [1]R RAGONA, PhD, [1]M G RUO REDDA, MD, [2]F R GIGLIOLI, PhD, [1]G ISOLATO, MD and [1]A GUARNERI, MD

Abstract. The objective of this study was to assess the utility of CT–MRI image fusion software and compare both prostate volume and localization with CT and MRI studies. We evaluated the differences in clinical volumes in patients undergoing three-dimensional conformal radiation therapy for localized prostate cancer. After several tests performed to ensure the quality of image fusion software, eight patients suffering from prostate adenocarcinoma were submitted to CT and MRI studies in the treatment position within an immobilization device before the start of radiotherapy. The clinical target volume (CTV) (prostate plus seminal vesicles) was delineated on CT and MRI studies and image fusion was obtained from the superimposition of anatomical fiducial markers. A comparison of dose–volume histograms relative to CTV, rectum, bladder and femoral heads was performed for both studies. Image fusion showed a mean overestimation of CTV of 34% with CT compared with MRI. Along the anterior–posterior and superior–inferior direction, CTV was a mean 5 mm larger with CT study compared with MRI. The dose–volume histograms resulting from CT and MRI comparison showed that it is possible to spare a mean 10% of rectal volume and approximately 5% of bladder and femoral heads, respectively. This study confirmed an overestimation of CTV with CT images compared with MRI.

Br J Radiol 2002

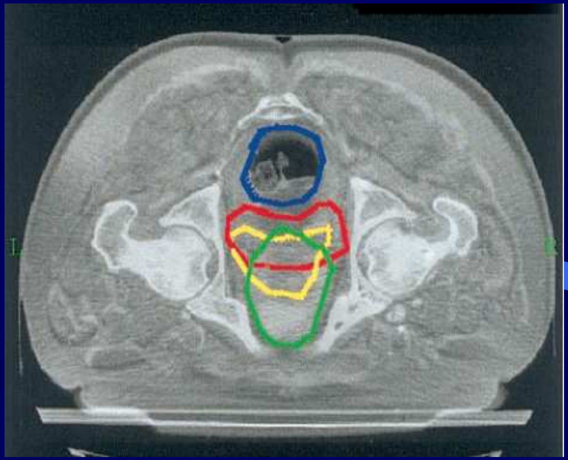


Table 1. Comparision of prostate volume studies on image fusion

Study	No. of patients	CTV	CT prostate volume (cm^3)	MRI prostate volume (cm^3)	Mean difference (%)
Kagawa et al [11]	22	p±sv	63±25.8	50.9±22.9	27 (p=0.0001)
Rasch et al [12]	18	p	63.7	44.5	43.1 (p<0.005)
Roach et al [13]	10	p	8.4	29.6	32
This study	8	p+sv	85.8±15.6	63.9±16.9	34.3 (p<0.01)

Distortion-corrected T_2 weighted MRI: a novel approach to prostate radiotherapy planning

Br J Radiol 2007

[1]A S N JACKSON, FRCR, [2]S A REINSBERG, PhD, [3]S A SOHAIB, FRCR, [2]E M CHARLES-EDWARDS, MSc, [1]S A MANGAR, FRCR, [4]C P SOUTH, MSc, [2]M O LEACH, PhD and [1]D P DEARNALEY, MD, FRCR

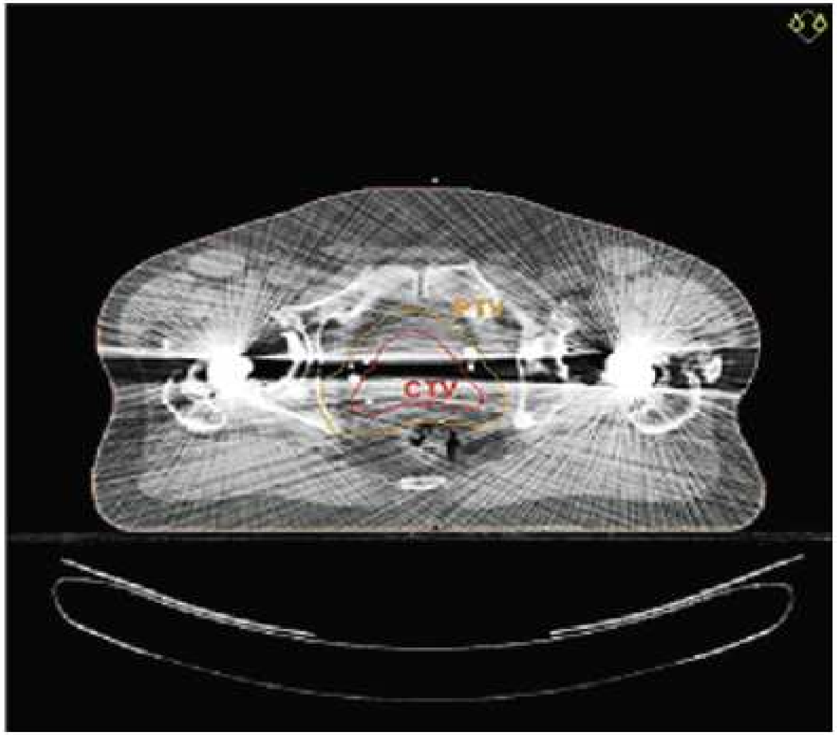
ABSTRACT. The purpose of this study was to evaluate distortion-corrected MRI as a radiotherapy planning tool for prostate cancer and the resultant implications for dose sparing of organs at risk. 11 men who were to be treated with radical conformal radiotherapy for localized prostate cancer had an MRI scan under radiotherapy planning conditions, which was corrected for geometric distortion. Radiotherapy plans were created for planning target volumes derived from the MRI- and CT-defined prostate. Dose volume histograms were produced for the rectum, bladder and penile bulb. The mean volume of the prostate as defined on CT and MRI was 41 cm^3 and 36 cm^3, respectively ($p=0.009$). The predicted percentage of the rectum treated to dose levels of 45–65 Gy was significantly lower for plans delineating the prostate with MRI than for those with CT. The rectal-sparing effect was confined to the lowermost 4 cm of the rectum (anal canal). There were no differences between the predicted doses to bladder or penile bulb (as defined using MRI) between plans. In conclusion, prostate radiotherapy planning based on distortion-corrected MRI is feasible and results in a smaller target volume than does CT. This leads to a lower predicted proportion of the rectum, in particular the lower rectum (anal canal), treated to a given dose than with CT.

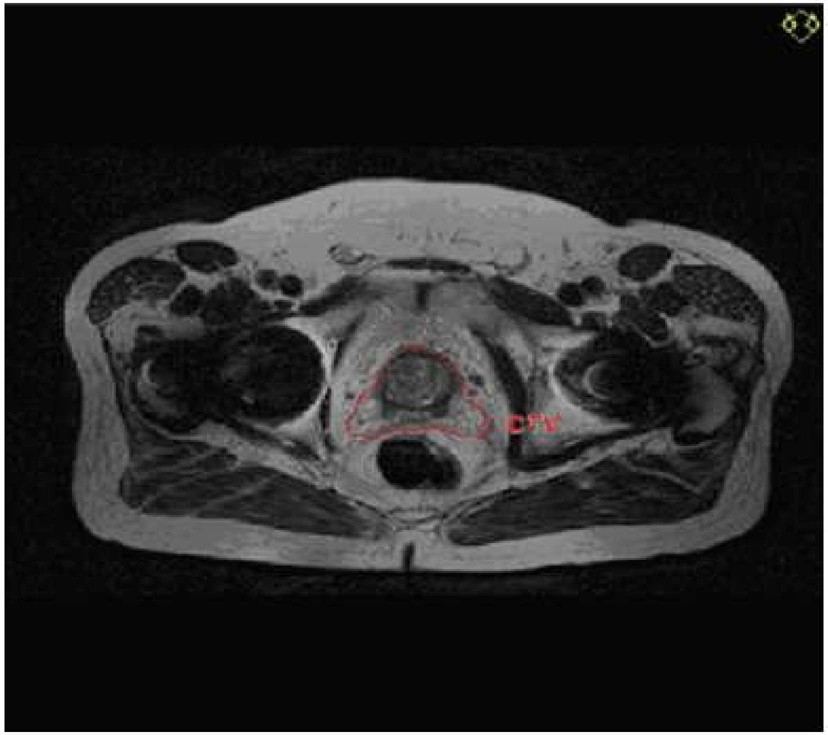
Study	CT prostate volume (cm^3)	MRI prostate volume (cm^3)	p-value	% reduction with MRI
Roach [7]	38.4	29.6	0.0004	23
Rasch/Steenbakkers [3, 8]	63.7	44.5 (axial)	–	30
Kagawa [10]	63	50.9	0.0001	19
Debois [9]	48.4	34.7	–	28
Sannazzari [2]	85.8[a]	63.9[a]	<0.01	19
Krempien [6]	135.9[a]	81.6[a]	<0.001	40
Parker [5]	–	–	0.2	2
Current study	38	33	0.04	13

The use of CT-MR image registration to define target volumes in pelvic radiotherapy in the presence of bilateral hip replacements

Br J Radiol 2005

[1]N CHARNLEY, FRCR, [2]A MORGAN, BSc MSc, [1]E THOMAS, FRCR, [2]S WILSON, [2]S BACON, MPhys, MSc, [2]D WILSON, BSc, MSc and [1]D BOTTOMLEY, FRCR

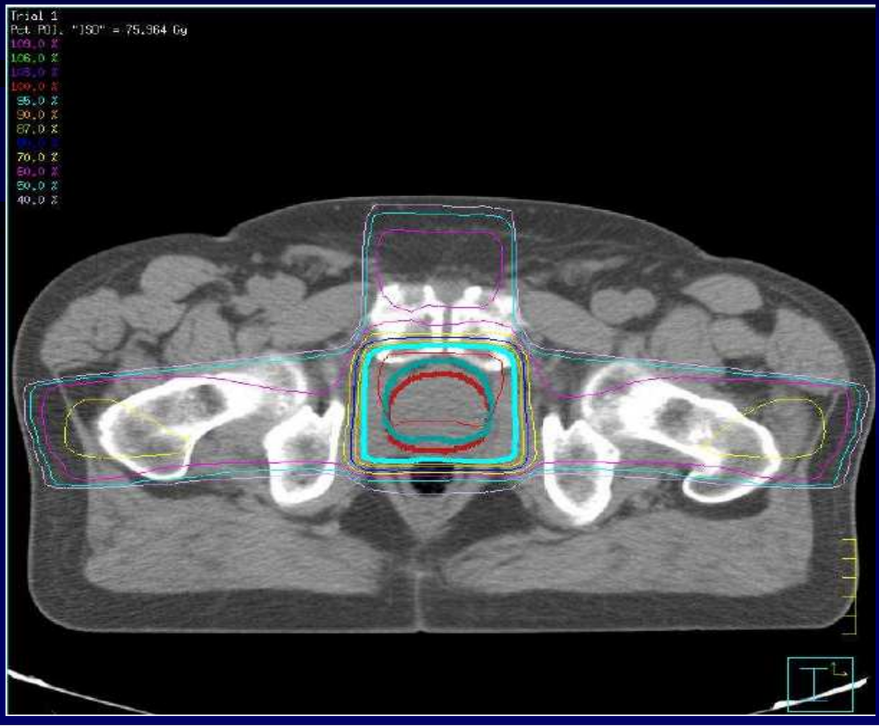


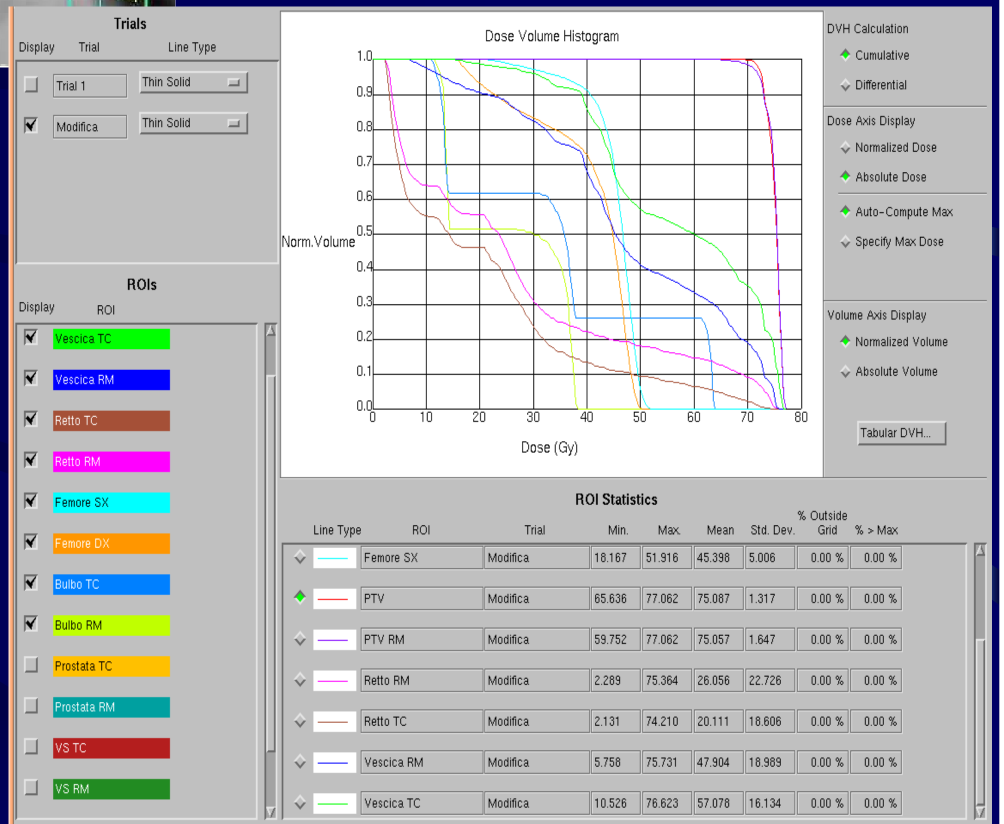


Abstract. Increasing numbers of patients with hip replacements are presenting for pelvic radiotherapy, which is usually planned using CT images. Image artefacts caused by the presence of metallic implants tend not to be severe for single hip replacements and allow for adequate definition of target volumes. When bilateral hip replacements are present, the image artefacts can render CT images useless for target definition, particularly for tumours of the prostate and bladder. MR images are not susceptible to such severe artefacts. This note describes a small series of patients with bilateral hip replacements on whom CT-MR image registration has been used to successfully define adequate target volumes.

Definizione CTV: TC-RM

Piano di trattamento





Confronto DVH TC-RM

RMS e RT

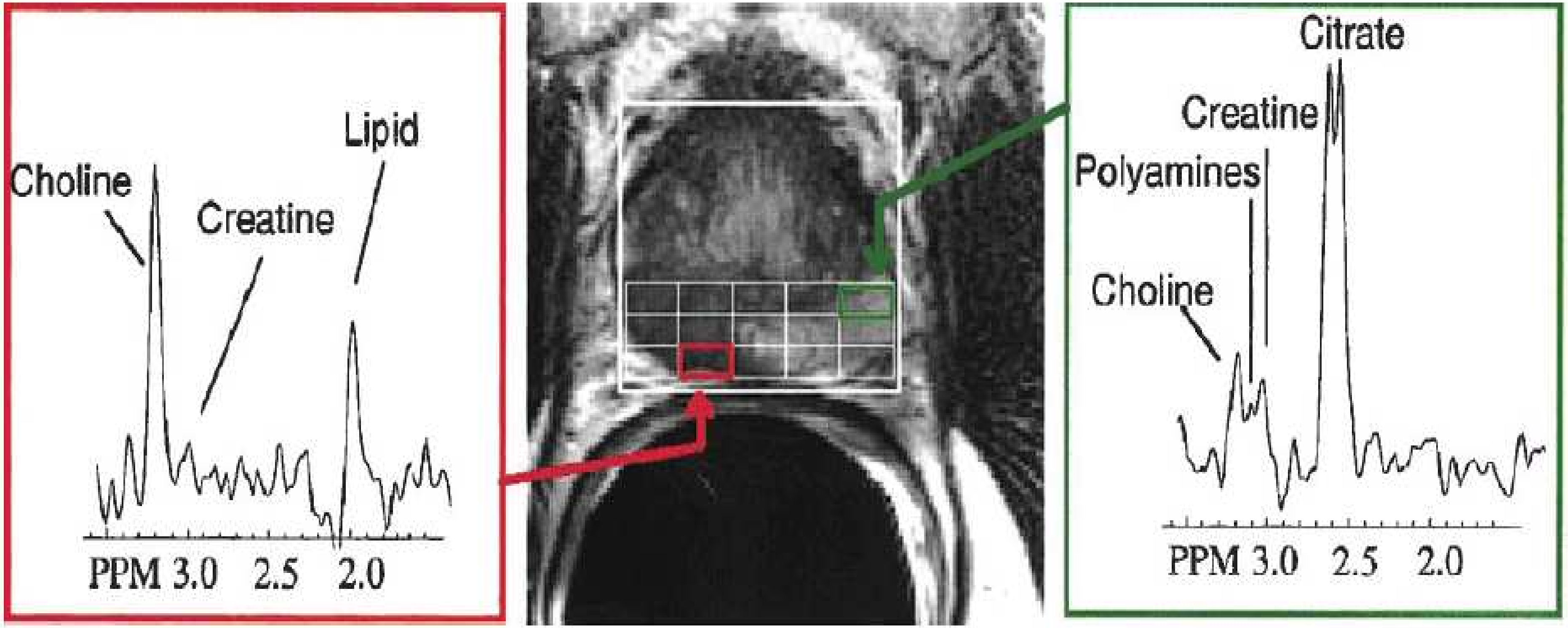


Figure 4. Centre: T_2 weighted transverse image of prostate with tumour in right mid-gland, overlain with grid of voxels from which spectra were acquired. Left: Spectrum acquired from region of tumour, illustrating dramatically elevated choline and absence of citrate and polyamines. Right: Spectrum from healthy peripheral zone tissue with high citrate and presence of polyamines. (Reproduced with permission from J Kurhanewicz et al [46]).

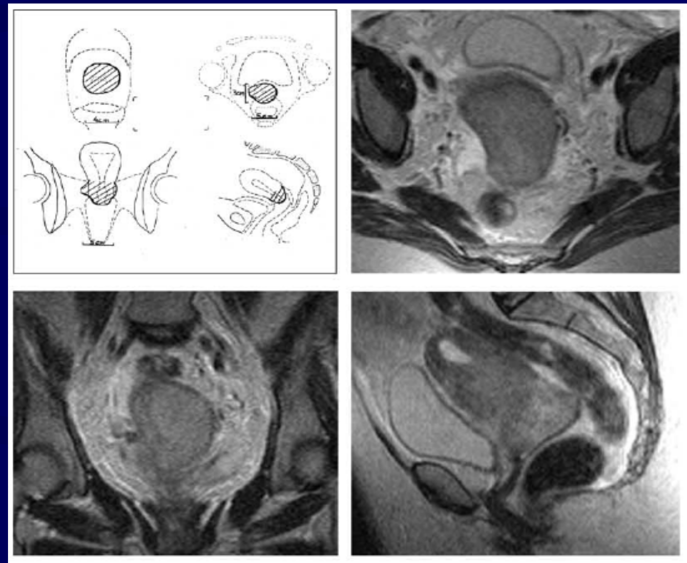
Esperienze limitate

Neoplasia prostatica: RM e RT

- Numerosi studi hanno valutato integrazione RM nel RTP
- Maggiorparte limitati a defizione anatomica CTV/OAR e analisi differenze volumetriche
- Pochi dati su analisi dosimetrica nel rispetto riproducibilità set-up trattamento

Neoplasia dell' utero: RM e RT

Migliore definizione estensione di malattia, superiore rispetto a esame clinico e TC.



Esperienze pubblicate limitate utilizzo co-registrazione TC-RM "planning" RTE: dimostrazione di fattibilità.

Numerose esperienze pubblicate utilizzo RM "planning" brachiterapia.

Barillot, Cancer Imaging 2006

Neoplasia dell' utero: RM e Brachiterapia

TC: limiti definizione estensione GTV e estensione-posizione applicatore vaginale.

RM: migliore definizione GTV e organi a rischio in relazione all'applicatore in più 90% casi

RM: migliore definizione distribuzione dose rispetto TC

Schoeppel IJROBP 1992, Narayan Am J Clin Oncol 2003, Wachter-Gerstner Radiother Oncol 2003

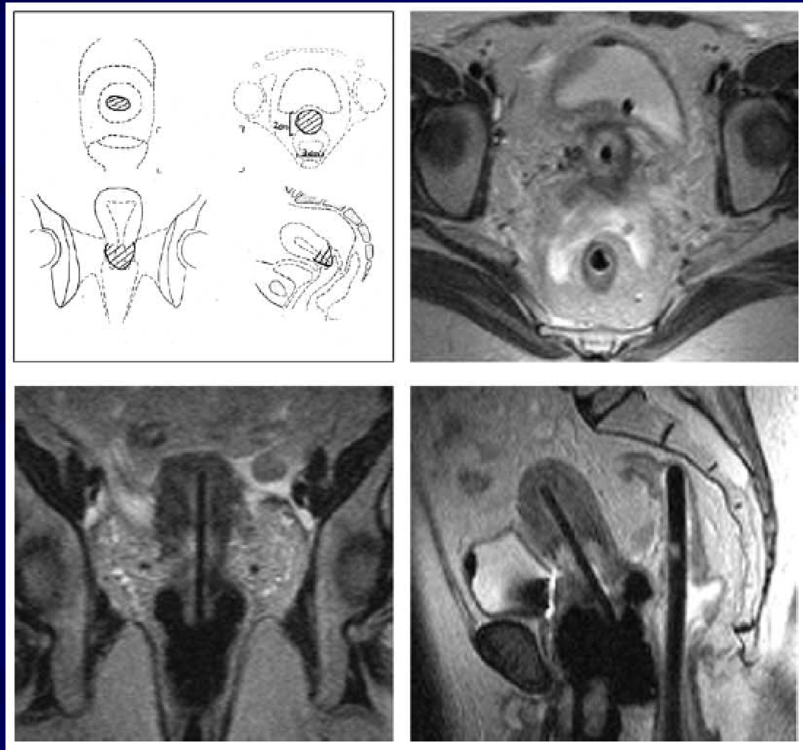
Recommendations from Gynaecological (GYN) GEC-ESTRO Working Group☆ (I): concepts and terms in 3D image based 3D treatment planning in cervix cancer brachytherapy with emphasis on MRI assessment of GTV and CTV

Christine Haie-Meder[a,*], Richard Pötter[b], Erik Van Limbergen[c], Edith Briot[a], Marisol De Brabandere[c], Johannes Dimopoulos[b], Isabelle Dumas[a], Taran Paulsen Hellebust[d], Christian Kirisits[b], Stefan Lang[b], Sabine Muschitz[b], Juliana Nevinson[e], An Nulens[c], Peter Petrow[f], Natascha Wachter-Gerstner[b]

Utilizzo RM (sequenza T2)
Applicatori compatibili

↓

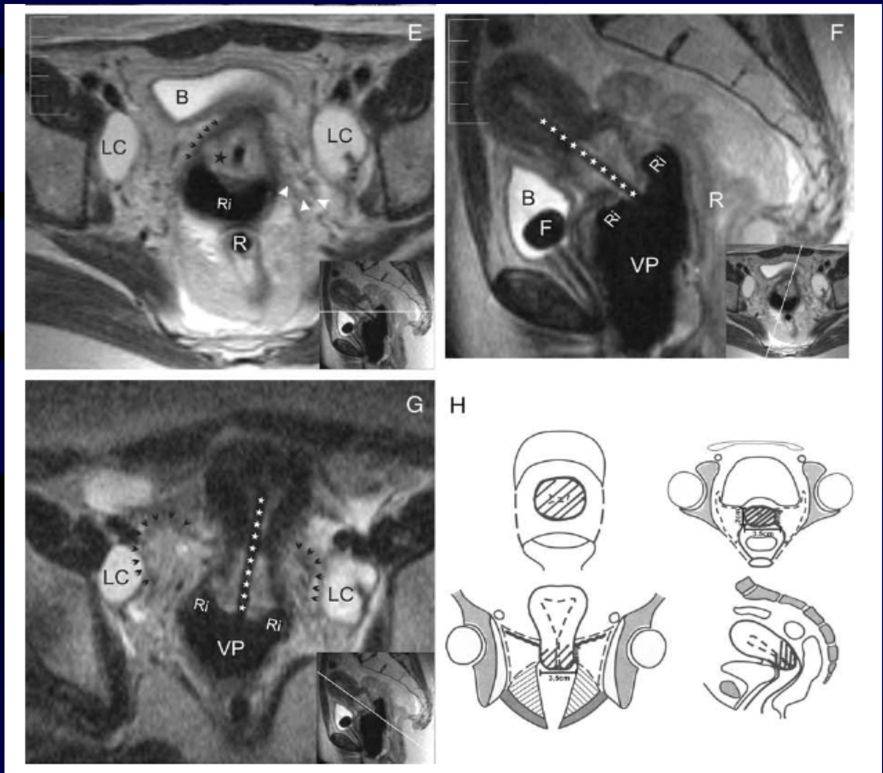
"treatment planning"
brachiterapia

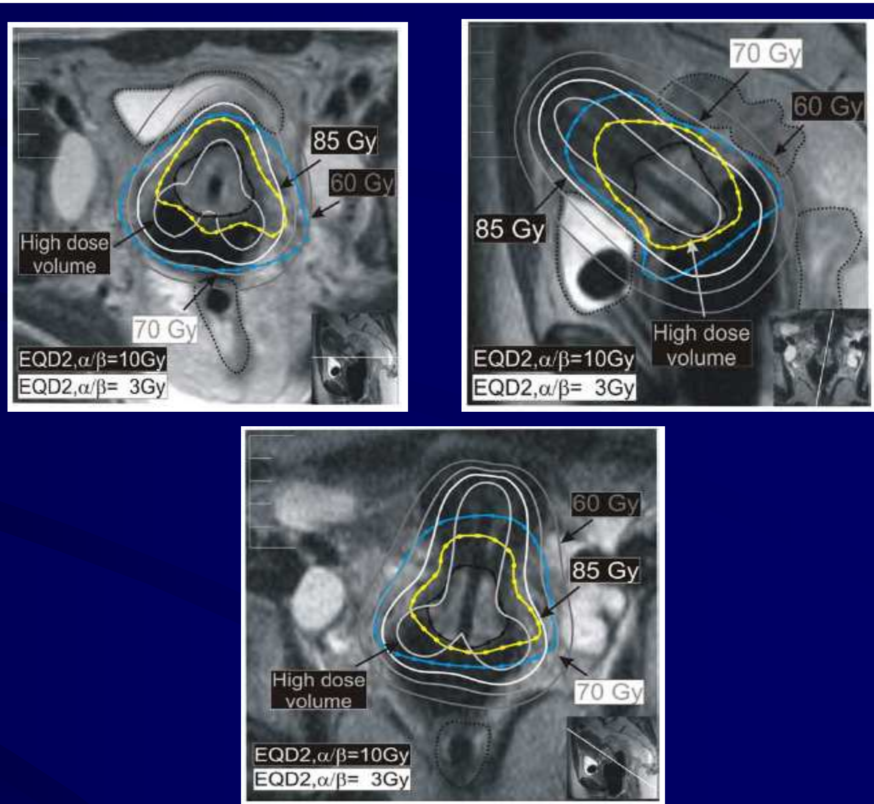


Nag IJROBP 2004, Haie-Meder Radiother Oncol 2005

Recommendations from gynaecological (GYN) GEC ESTRO working group (II): Concepts and terms in 3D image-based treatment planning in cervix cancer brachytherapy—3D dose volume parameters and aspects of 3D image-based anatomy, radiation physics, radiobiology

Richard Pötter[a,*], Christine Haie-Meder[b], Erik Van Limbergen[c], Isabelle Barillot[d], Marisol De Brabandere[c], Johannes Dimopoulos[a], Isabelle Dumas[b], Beth Erickson[e], Stefan Lang[a], An Nulens[c], Peter Petrow[f], Jason Rownd[e], Christian Kirisits[a]

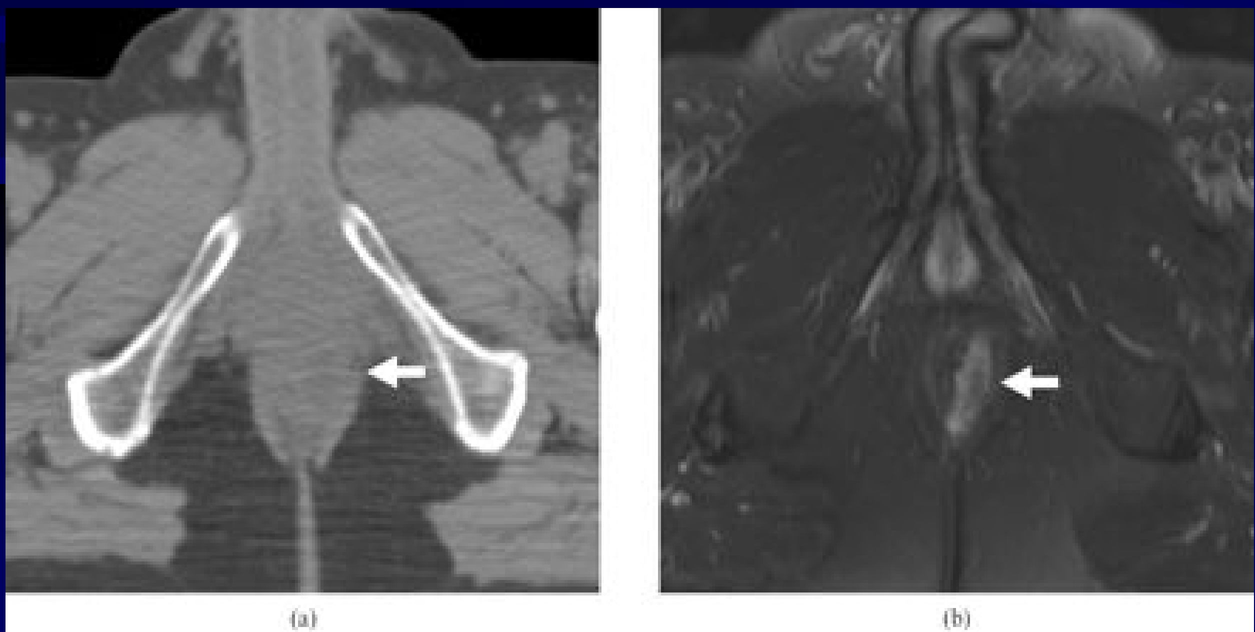




It is expected that the therapeutic ratio including target coverage and sparing of organs at risk can be significantly improved, if radiation dose is prescribed to a 3D image-based CTV taking into account dose volume constraints for OAR. However, prospective use of these recommendations in the clinical context is warranted, to further explore and develop the potential of 3D image-based cervix cancer brachytherapy.

Neoplasia del retto: RM e RT

Migliore definizione di: invasione parete rettale, estensione longitudinale, mesoretto, organi circostanti, ano. Beets Tan Eur J Surg Oncol 2005, Khoo 2008



TC/RM:

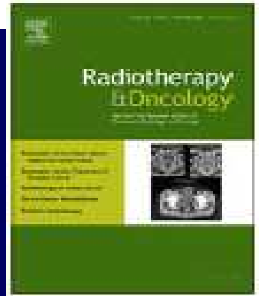
CR.retto inf. esteso alla giunzione ano-rettale

Rectal cancer radiotherapy

MR-guided simultaneous integrated boost in preoperative radiotherapy of locally advanced rectal cancer following neoadjuvant chemotherapy

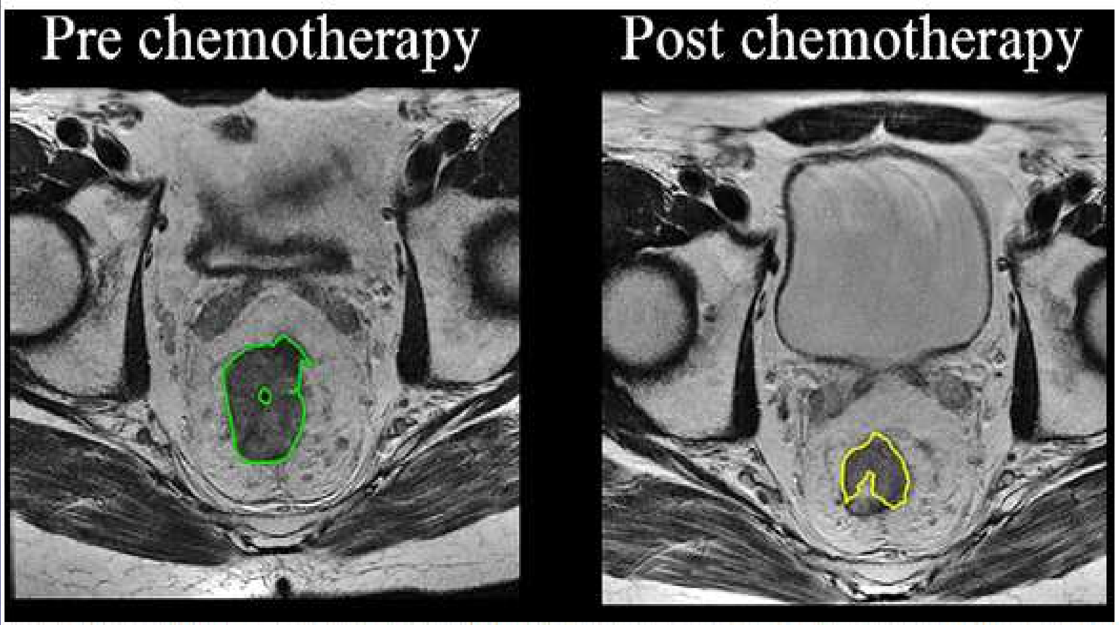
Therese Seierstad[a,b,*], Knut Håkon Hole[c], Erik Sælen[a], Anne Hansen Ree[d,e], Kjersti Flatmark[d,f,g], Eirik Malinen[h]

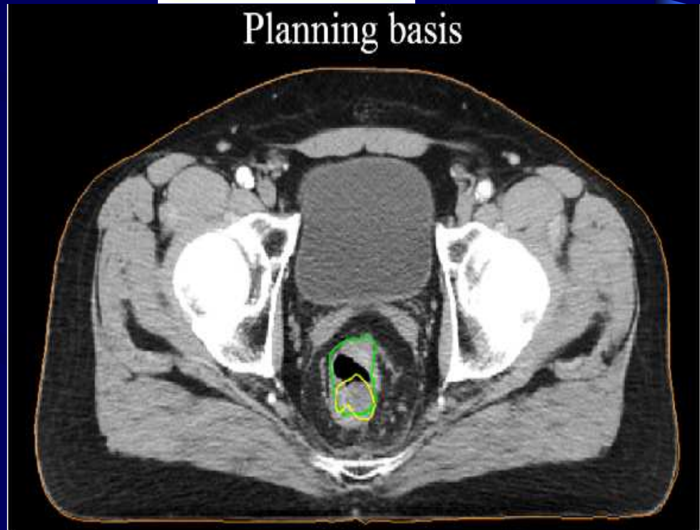
[a] Department of Radiation Biology, Institute for Cancer Research, Oslo University Hospital, Norway; [b] Department of Health Sciences, Buskerud University College, Drammen, Norway; [c] Department of Radiology, and [d] Department of Tumor Biology, Oslo University Hospital, Norway; [e] Faculty Division, Akershug University Hospital, University of Oslo, Lørenskog, Norway; [f] Faculty Division, The Norweigan Radium Hospital, University of Oslo, Norway; [g] Department of Surgical Oncology, and [h] Department of Medical Physics, Oslo University Hospital, Norway



2009

Purpose: To evaluate a simultaneous integrated boost (SIB) strategy in preoperative radiotherapy of rectal cancer patients following neoadjuvant chemotherapy using pre- and post-chemotherapy tumor volumes assessed by MRI.





Conclusions: Tumor volume reduction for rectal cancer patients following neoadjuvant chemotherapy allows for increased tumor dose using a SIB strategy without increased OAR toxicity.

Neoplasia del retto: RM e RT

Integrazione

↓

Investigazionale

Integrazione RM-RT: criticità

- Tipo sequenza per sede anatomica e tipo neoplasia
- FOV ottimale
- Tipo risoluzione
- Modalità esecuzione esame
- Tipo software acquisizione e trasferimento dati
- Tipo Scanner (1,5 vs 3 T)
- Tipo bobina
- Contrasto
- “Timing” esame rispetto TC
- Posizione paziente
- Istruzioni seguite dal paziente (es. stato vescica)
- Algoritmo per co-registrazione

Prospettive

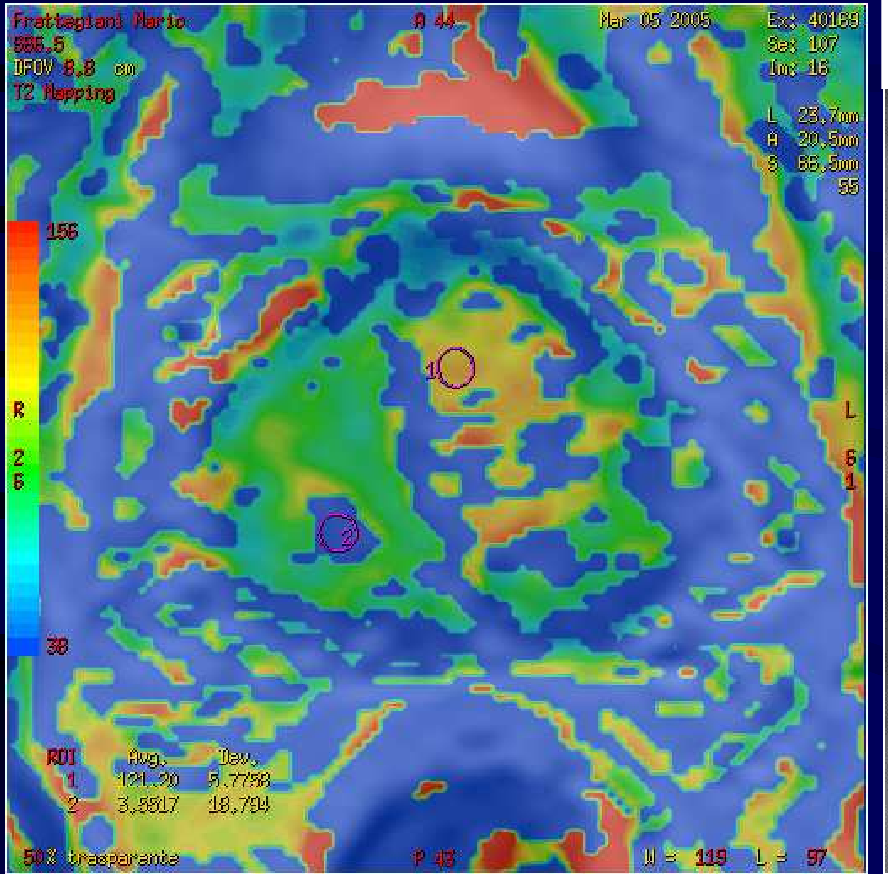
- Tecniche innovative:

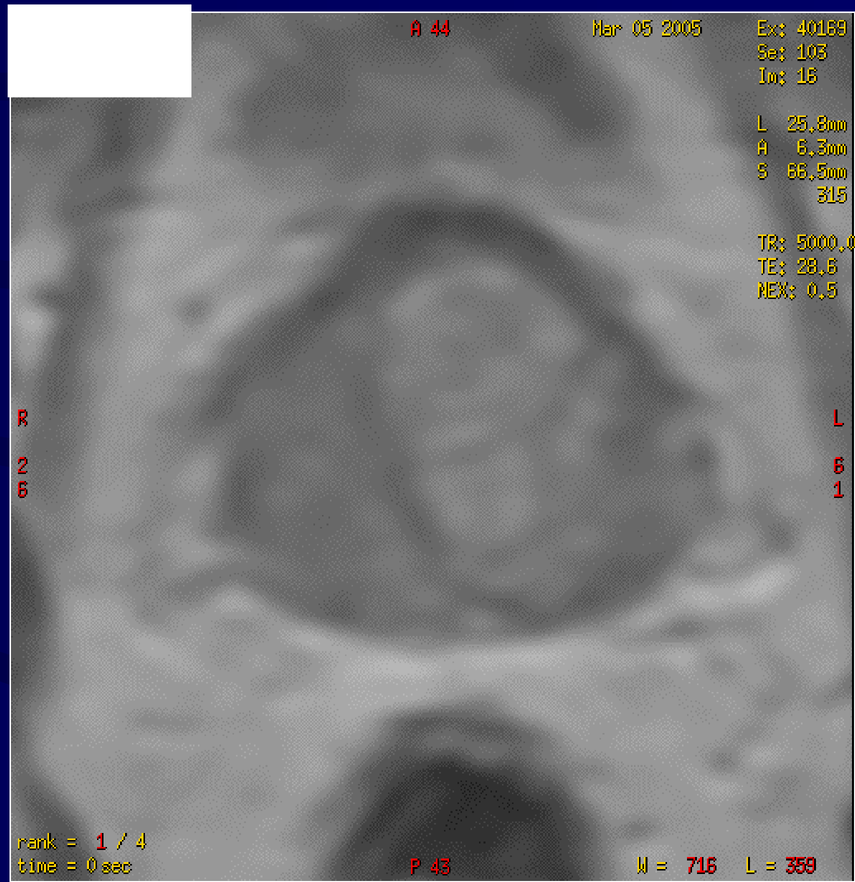
RM diffusione

RM dinamica

- Evoluzione tecnologica (Scanner 3 T)
- Esperienze pubblicate
- Risorse

PROSPETTIVE





RM funzionale

RM

PROSPETTIVE

Riduzione variabilità intra- e interosservazionale def. GTV-CTV:

- Linee-guida di contornazione/ATLANTI
- Utilizzo “imaging” morfologico-funzionale-biologico

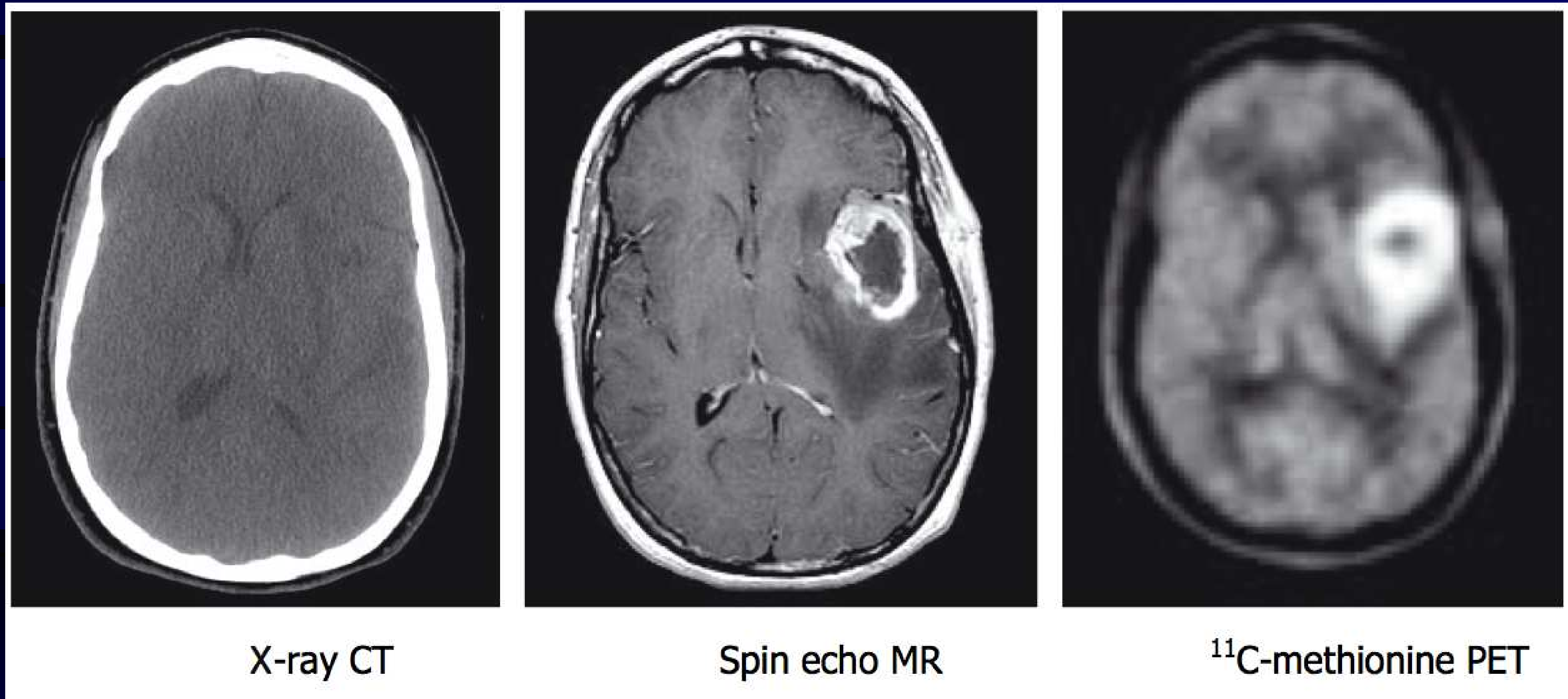
Contornazione: criticità

Delimitazione automatica TARGET

Previene variabilità interosservazionale ma …..
estrema irregolarità forma “Target”

Mazzara IJROBP 2004, Bondiau IJROBP 2005, Lee IJROBP 2005
Payne Br J Radiol 2006

"IMAGING" INTEGRATO



Calcolo Morfologia Biochimica

ESPERIENZA e “TEAM” INTERDISCIPLINARE !