Impiego del software Planned Adaptive™ in Tomoterapia

M.G. Trovò - A. Drigo
Centro di Riferimento Oncologico - Aviano
Tomotherapy Hi ART
Highly Integrated Adaptive Radiotherapy

• La tecnica IMRT permette di creare piani di trattamento estremamente conformati anche su target complessi con notevole risparmio di organi a rischio vicini al target.

• Questo comporta la necessità di controllare cosa si sta irradiando, perché sbagliare anche di poco significa sbagliare il trattamento.

• Nel corso del trattamento possono intervenire variazioni rispetto alla situazione di pianificazione, che riguardano non solo il set up del paziente, ma anche le dimensioni del target (shrinking), la posizione degli organi a rischio circostanti, il contorno esterno del paziente (perdita di peso).

• tutti questi fattori devono essere tenuti sotto controllo ⇒ IGRT

• Risparmio degli organi a rischio e controllo della dose sono le basi per l’attuazione della “dose escalation”
Una volta preso atto delle variazioni, serve valutare quanto queste incidano sul trattamento e se necessario ripianificare

Terapia "adattativa"

Il tutto nel tempo più breve possibile
**RETROSPECTIVE ANALYSIS OF PROSTATE CANCER PATIENTS WITH IMPLANTED GOLD MARKERS USING OFF-LINE AND ADAPTIVE THERAPY PROTOCOLS**
Dale W. Litzenberg, James M. Balter, Kwok L. Lam, Howard M. Sandler, and Randall K. Ten Haken

**DEFORMABLE REGISTRATION OF THE PLANNING IMAGE (KVCT) AND THE DAILY IMAGES (MVCT) FOR ADAPTIVE RADIATION THERAPY**
Weiguo Lu, Gustavo H Olivera, Quan Chen, Kenneth J Ruchala, Jason Haimerl, Sanford L Meeks, Katja M Langen and Patrick A Kupelian

**DAILY VARIATIONS IN DELIVERED DOSES IN PATIENTS TREATED WITH RADIOTHERAPY FOR LOCALIZED PROSTATE CANCER**
Patrick A. Kpelian, Katja M. Langen, Omar A. Zeidan, Sanford L. Meeks, Twyla R. Willoughby, Thomas H. Wagner, Sam Jeswani, Kenneth J. Ruchala, Jason Haimerl, and Gustavo H. Olivera

**WITH MEGAVOLTAGE CT FOR NON–SMALL-CELL LUNG CANCER DURING INTENSITY MODULATED RADIOTHERAPY: HOW RELIABLE, CONSISTENT, AND MEANINGFUL IS THE EFFECT?**
Malika Siker, Wolfgang, Tomé, and Minesh Mehta

**A TECHNIQUE FOR ADAPTIVE IMAGE-GUIDED HELICAL TOMOTHERAPY FOR LUNG CANCER**
Chester Ramsey, Katja Langen, Patrick Kupelian, Daniel Scaperoth, Sanford Meeks, Stephen Mahan, and Rebecca Seibert

**A MOTION PHANTOM STUDY ON HELICAL TOMOTHERAPY: THE DOSIMETRIC IMPACTS OF DELIVERY TECHNIQUE AND MOTION**
Brian Kanagaki, Paul W Read, Janelle A Molloy, James M Larner and Ke Sheng

**ADAPTIVE RADIOTHERAPY PLANNING ON DECREASING GROSS TUMOR VOLUMES AS SEEN ON MEGAVOLTAGE COMPUTED TOMOGRAPHY IMAGES**
Curtis Woodford, Slav Yartsev, A. Rashid Dar, Glenn Bauman, and Jake Van Dyk

**CLINICAL IMPLEMENTATION OF ADAPTIVE HELICAL TOMOTHERAPY: A UNIQUE APPROACH TO IMAGE-GUIDED INTENSITY MODULATED RADIOTHERAPY**
HELICAL TOMOTHERAPY: Experiences Of The First 150 Patients In Heidelberg Florian Sterzing, Kai Schubert, Gabriele Sroka-Perez, Jörn Kalz, Jürgen Debus, Klaus Herfarth
Strahlentherapie und Onkologie - Original Article

INITIAL EXPERIENCE IN TREATING LUNG CANCER WITH HELICAL TOMOTHERAPY
S Yartsev,, AR Dar, C Woodford1, E Wong, G Bauman1, J Van Dyk
Available online at http://www.biij.org/2007/1/e2

ADAPTIVE FRACTIONATION THERAPY: I. BASIC CONCEPT AND STRATEGY
Weiguo Lu, Mingli Chen, Quan Chen, Kenneth Ruchala and Gustavo Olivera

ACTUAL DOSE VARIATION OF PAROTID GLANDS AND SPINAL CORD FOR NASOPHARYNGEAL CANCER PATIENTS DURING RADIOTHERAPY
Chunhui Han, Yi-jen Chen, An Liu, Timothy E. Schultheiss and Jeffrey Y. C. Wong

ASSESSMENT OF PAROTID GLAND DOSE CHANGES DURING HEAD AND NECK CANCER RADIOTHERAPY USING DAILY MEGAVOLTAGE COMPUTED TOMOGRAPHY AND DEFORMABLE IMAGE REGISTRATION
Chooinik Lee, Katja M. Langen, Weiguo Lu, Jason Haimerl, Eric Schnarr, Kenneth J. Ruchala, Gustavo Olivera, Sanford Meeks, Patrick Kupelian, Thomas Shellenberger, and Rafael Manon,

EVALUATION OF GEOMETRIC CHANGES OF PAROTID GLANDS DURING HEAD AND NECK CANCER RADIOTHERAPY USING DAILY MVCT AND AUTOMATIC DEFORMABLE REGISTRATION
Chooinik Lee, Katja M. Langen, Weiguo Lu, Jason Haimerl, Eric Schnarr, Kenneth J. Ruchala, Gustavo H. Olivera, Sanford L. Meek, Patrick A. Kupelian, Thomas D. Shellenberger, Rafael R. Manon
Radiotherapy and Oncology 89 (2008) 81–88

CONSISTENCY CHECK OF PLANNED ADAPTIVE OPTION ON HELICAL TOMOTHERAPY
M. Schirm, S. Yartsev, G. Bauman, J. Battista, J. Van Dyk

COMPARISON OF FIXED-BEAM IMRT, HELICAL TOMOTHERAPY, AND IMPT FOR SELECTED CASES
Jan Muzik , Martin Soukup and Markus Alber
Med. Phys. 35 ,4 , April 2008
bibliografia

SPARING THE PAROTID GLANDS AND SURGICALLY TRANSFERRED SUBMANDIBULAR GLAND WITH HELICAL TOMOTHERAPY IN POST-OPERATIVE RADIATION OF HEAD AND NECK CANCER: A PLANNING STUDY
Elantholi P. Saibishkumar, Naresh Jha., Rufus A. Scrimger, Marc A. MacKenzie, H. Daly, Colin Field, Gino Fallone, Matthew B. Parliament
Radiotherapy and Oncology 85 (2007) 98–104 Canada

REAL-TIME MOTION-ADAPTIVE DELIVERY (MAD) USING BINARY MLC: I. STATIC BEAM (TOMOTHERAPY) DELIVERY
Weiguo Lu

REAL-TIME MOTION-ADAPTIVE DELIVERY (MAD) USING BINARY MLC: II. ROTATIONAL BEAM (TOMOTHERAPY) DELIVERY
Weiguo Lu

CONSISTENCY CHECK OF PLANNED ADAPTIVE(R) OPTION ON HELICAL TOMOTHERAPY
Schirm M, Yartsev S, Bauman G, Battista J, Van Dyk J.

IS DAILY COMPUTED TOMOGRAPHY IMAGE GUIDANCE NECESSARY FOR NASAL CAVITY AND NASOPHARYNGEAL RADIOThERAPY? AN INVESTIGATION BASED ON HELICAL TOMOTHERAPY
Ke Sheng, Jennifer Chow, Grant Hunter, James Larner, and Paul Read
Journal of applied clinical medical physics, volume 9, number 1, 2008

DEFORMABLE REGISTRATION OF ABDOMINAL KILOVOLTAGE TREATMENT PLANNING CT AND TOMOTHERAPY DAILY MEGAVOLTAGE CT FOR TREATMENT ADAPTATION
Yang D, Chaudhari SR, Goddu SM, Pratt D, Khullar D, Deasy JO, El Naqa I.
Department of Radiation Oncology, Washington University, St. Louis, Missouri 63110, USA.

ADAPTIVE RADIATION THERAPY FOR LOCALIZED MESOTHELIOMA WITH MEDIASTINAL METASTASIS USING HELICAL TOMOTHERAPY
James Renaud, Slav Yartev, Rashid Dar, and Jake Van Dyk
Medical Dosimetry, Vol. xx, No. x, pp. xxx, 2009 – in press

Ecc.
gli studi sono Studi volti a:

- Quantificare la variazione volumetrica dei vari organi;
- Valutare quanto le variazioni incidono sulla distribuzione di dose in riferimento ai vari organi;
- Individuare quali sono i parametri più significativi ($V_{20}$, $D_5$, ecc)
- Verificare se esistono correlazioni tra i diversi parametri ($V$, $D$, organo, malattia)
- Individuare strategie di lavoro (quando applicare adaptive, con che frequenze, ecc)
- stabilire dei criteri per la ripianificazione
A TECHNIQUE FOR ADAPTIVE IMAGE-GUIDED HELICAL TOMOTHERAPY FOR LUNG CANCER

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Purpose: The gross tumor volume (GTV) for many lung cancer patients can decrease during the course of radiation therapy. As the tumor reduces in size during treatment, the margin added around the GTV effectively becomes larger, which can result in the excessive irradiation of normal lung tissue. The specific goal of this study is to evaluate the feasibility of using image-guided adaptive radiation therapy to adjust the planning target volume weekly based on the previous week’s CT image sets that were used for image-guided patient setup.

Methods and Materials: Megavoltage computed tomography (MVCT) images of the GTV were acquired daily on a helical tomotherapy system. These images were used to position the patient and to measure reduction in GTV volume. A planning study was conducted to determine the amount of lung-sparing that could have been achieved if adaptive therapy had been used. Treatment plans were created in which the target volumes were reduced after tumor reduction was measured.

Results: A total of 158 MVCT imaging sessions were performed on 7 lung patients. The GTV was reduced by 60-80% during the course of treatment. The tumor reduction in the first 60 days of treatment can be modeled using the second-order polynomial \( R = 0.0002t^2 - 0.0219t + 1.0 \), where \( R \) is the percent reduction in GTV, and \( t \) is the number of elapsed days. Based on these treatment planning studies, the absolute volume of ipsilateral lung receiving 20 Gy can be reduced between 17% and 23% (21% mean) by adapting the treatment delivery. The benefits of adaptive therapy are the greatest for tumor volumes \( \geq 25 \text{ cm}^3 \) and are directly dependent on GTV reduction during treatment.

Conclusions: Megavoltage CT-based image guidance can be used to position lung cancer patients daily. This has the potential to decrease margins associated with daily setup error. Furthermore, the adaptive therapy technique described in this article can decrease the volume of healthy lung tissue receiving above 20 Gy. However, further study is needed to determine whether adaptive therapy could result in the underdosing of microscopic extension.
ART

\[ V_{20} \downarrow 21\% \]
PHYSICS CONTRIBUTION

ADAPTIVE RADIOTHERAPY PLANNING ON DECREASING GROSS TUMOR VOLUMES AS SEEN ON MEGAVOLTAGE COMPUTED TOMOGRAPHY IMAGES

CURTIS WOODFORD,† SLAV YARTSEV, PH.D.,* A. RASHID DAR, M.D.,*‡ GLENN BAUMAN, M.D.,*‡ AND JAKE VAN DYK, M.S.C.*,†

*London Regional Cancer Program, London Health Sciences Centre, London, Ontario, Canada; and
†The University of Western Ontario, London, Ontario, Canada

Purpose: To evaluate gross tumor volume (GTV) changes for patients with non-small-cell lung cancer by using daily megavoltage (MV) computed tomography (CT) studies acquired before each treatment fraction on helical tomotherapy and to relate the potential benefit of adaptive image-guided radiotherapy to changes in GTV.

Methods and Materials: Seventeen patients were prescribed 30 fractions of radiotherapy on helical tomotherapy for non-small-cell lung cancer at London Regional Cancer Program from Dec 2005 to March 2007. The GTV was contoured on the daily MVCT studies of each patient. Adapted plans were created using merged MVCT-kilovoltage CT image sets to investigate the advantages of replanning for patients with differing GTV regression characteristics.

Results: Average GTV change observed over 30 fractions was ~38%, ranging from ~12 to ~87%. No significant correlation was observed between GTV change and patient’s physical or tumor features. Patterns of GTV changes in the 17 patients could be divided broadly into three groups with distinctive potential for benefit from adaptive planning.

Conclusions: Changes in GTV are difficult to predict quantitatively based on patient or tumor characteristics. If changes occur, there are points in time during the treatment course when it may be appropriate to adapt the plan to improve sparing of normal tissues. If GTV decreases by greater than 30% at any point in the first 20 fractions of treatment, adaptive planning is appropriate to further improve the therapeutic ratio. © 2007 Elsevier Inc.
PHYSICS CONTRIBUTION

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

CHOONK LEE, PH.D.,* KATJA M. LANGEN, PH.D.,* WENGUI 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. SHELENBERGER, M.D., D.M.D.,§
AND RAFAEL R. MANON, 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

Purpose: To analyze changes in parotid gland dose resulting from anatomic changes throughout a course of radiotherapy in a cohort of head-and-neck cancer patients.

Methods and Materials: The study population consisted of 10 head-and-neck cancer patients treated definitively with intensity-modulated radiotherapy on a helical tomotherapy unit. A total of 330 daily megavoltage computed tomography images were retrospectively processed through a deformable image registration algorithm to be registered to the planning kilovoltage computed tomography images. The process resulted in deformed parotid contours and voxel mappings for both daily and accumulated dose-volume histogram calculations. The daily and cumulative dose deviations from the original treatment plan were analyzed. Correlations between dosimetric variations and anatomic changes were investigated.

Results: The daily parotid mean dose of the 10 patients differed from the plan dose by an average of 15%. At the end of the treatment, 3 of the 10 patients were estimated to have received a greater than 10% higher mean parotid dose than in the original plan (range, 13–42%), whereas the remaining 7 patients received doses that differed by less than 10% (range, ~6–8%). The dose difference was correlated with a migration of the parotids toward the high-dose region.

Conclusions: The use of deformable image registration techniques and daily megavoltage computed tomography imaging makes it possible to calculate daily and accumulated dose-volume histograms. Significant dose variations were observed as result of interfractional anatomic changes. These techniques enable the implementation of dose-adaptive radiotherapy. © 2008 Elsevier Inc.
PHYSICS CONTRIBUTION

ACTUAL DOSE VARIATION OF PAROTID GLANDS AND SPINAL CORD FOR NASOPHARYNGEAL CANCER PATIENTS DURING RADIOTHERAPY

CHUNHUI HAN, PH.D., YI-JEN CHEN, M.D., PH.D., AN LIU, PH.D., TIMOTHY E. SCHULTHEISS, PH.D., F.A.C.R., AND JEFFREY Y. C. WONG, M.D.

Division of Radiation Oncology, City of Hope National Medical Center, Duarte, CA

Purpose: For intensity-modulated radiotherapy of nasopharyngeal cancer, accurate dose delivery is crucial to the success of treatment. This study aimed to evaluate the significance of daily image-guided patient setup corrections and to quantify the parotid gland volume and dose variations for nasopharyngeal cancer patients using helical tomotherapy megavoltage computed tomography (CT).

Methods and Materials: Five nasopharyngeal cancer patients who underwent helical tomotherapy were selected retrospectively. Each patient had received 70 Gy in 35 fractions. Daily megavoltage CT scans were registered with the planning CT images to correct the patient setup errors. Contours of the spinal cord and parotid glands were drawn on the megavoltage CT images at fixed treatment intervals. The actual doses delivered to the critical structures were calculated using the helical tomotherapy Planned Adaptive application.

Results: The maximal dose to the spinal cord showed a significant increase and greater variation without daily setup corrections. The significant decrease in the parotid gland volume led to a greater median dose in the later phase of treatment. The average parotid gland volume had decreased from 20.5 to 13.2 cm³ by the end of treatment. On average, the median dose to the parotid glands was 83 cGy and 145 cGy for the first and the last treatment fractions, respectively.

Conclusions: Daily image-guided setup corrections can eliminate significant dose variations to critical structures. Constant monitoring of patient anatomic changes and selective replanning should be used during radiotherapy to avoid critical structure complications. © 2008 Elsevier Inc.
• Maggio 2006: inizio trattamenti con Tomoterapia
• Marzo 2007: software Planned Adaptive
• Tipologia casi: craniospinali, polmoni, ORL, esofago, sarcomi (distretti differenziati), encefalo, prostata
• 400 piani di trattamento ad oggi
Le cause più comuni per l’ applicazione del Planned Adaptive sono:

- Variazioni nel target (tumor shrinking)
- Variazioni anatomiche (OAR, body)
- Perdita di peso
- Presenza di artefatti dovuti a materiali ad alta densità

L’ impiego del Planned Adaptive è finalizzato alla:

- Valutazione delle variazioni della dose erogata tramite gli istogrammi dose – volume, con particolare riguardo alla copertura del target e alla eventuale irradiazione di organi a rischio

- Ripianificazione (se necessario)
Planned Adaptive è stato utilizzato per 16 pazienti (5 %)

- 8 casi per problemi di artefatti
- 8 casi per variazioni anatomiche (7 ripianificazioni)
Carcinoma del seno mascellare
dose prescritta:
50 Gy in 25 frazioni

Planning Image

MVCT dopo 10 giorni
dall’ inizio del trattamento
Esofago Cervicale
- 50 Gy al PTV
- 60 Gy al GTV
- 25 frazioni
- chemioterapia concomitante

MVCT alla prima seduta
Massiva recidiva linfonodale da ca mammella
DOSE PRESCRITTA 45 Gy in 15 frazioni
ART at C.R.O - IGRT

Planned dose

Delivered dose
PROGETTO N. 6

TOMOTHERAPY TECHNOLOGY ASSESSMENT IN RADIATION ONCOLOGY

Valutare il valore aggiunto e l'impatto clinico, organizzativo ed economico dell'apparecchiatura di Tomoterapia (IMRT elicoidale + IGRT + ADAPTIVE) rispetto ad una apparecchiatura convenzionale per IMRT

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<th>unità partecipanti</th>
<th>responsabili scientifici</th>
<th>tema sottoprogetti</th>
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<td>M.G. Trovò</td>
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<td>HSR MILANO</td>
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<td>ASMN R. EMILIA</td>
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<td>Tomotherapy TBI</td>
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Obbiettivi e Finalità

• Valutare le prestazioni offerte dal software

• Definire dei protocolli di applicazione del software

• Valutare le conseguenze dosimetriche (efficacia)

• Valutare le conseguenze organizzative (efficienza)
Il software permette:

- Il confronto giornaliero tra l'anatomia di pianificazione e l'anatomia di trattamento
- Il calcolo della dose effettivamente rilasciata al paziente
- La correzione delle discrepanze tra dose pianificata e dose effettivamente impartita
PLANNED ADAPTIVE

KVCT Treatment Plan

Treatment

MVCT

Re-optimization

Manual re-contour

Dose recalculation

Planning Station

Tomotherapy Unit

Operator Station
- Paziente
- Piano di riferimento
- Immagine MVCT
- Scegliere piano di riferimento (KVCT associata), immagine MVCT, strutture
- Registrare
- Completare (FOV MVCT ridotto)
- Correggere le strutture
- Calcolare
RED Curve MVCT

Dose (cGy)

Volume %

Coarse
Normal
Fine
The use of megavoltage CT (MVCT) images for dose recomputations

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Consistency Check of Planned Adaptive® Option on Helical Tomotherapy

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Glenn Bauman, MD.¹,²
Jerry Battista, Ph.D.¹,²
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This study aims to evaluate a new Planned Adaptive® software (TomoTherapy Inc., Madison, WI) of the helical tomotherapy system by retrospective verification and adaptive re-planning of radiation treatment. Four patients with different disease sites (brain, nasal cavity, lungs, prostate) were planned in duplicate using the diagnostic planning MVCT data set and MVCT studies of the first treatment fraction with the same optimization parameters for both plan types. The planning isocenter of the initial, maximum, and mean dose to the targets as well as to organs at risk were compared. Both sets of plans were used for calculation of dose distributions in a water-equivalent phantom. Corresponding measurements of these plans in phantom were carried out with the use of radiographic film and ion chamber. In the case of the lung and prostate cancer patients, changes in dose-distribution parameters compared to data generated with the MVCT study were less than 2%. Certain changes for the nasal cavity and brain cancer patients were greater than 2%, but they were explained in part by anatomy changes that occurred during the time between MVCT and MVCT studies. The Planned Adaptive software allows for adaptive radiotherapy planning using the MVCT studies obtained by the helical tomotherapy imaging system.
Product Advisory Notice
TomoTherapy Hi•ART Systems

April 27, 2009

Dear TomoTherapy Customer,

As a result of input received from TomoTherapy Hi-ART customers, an MVCT planning issue has been identified that we would like to bring to your attention.

**Issue:**
An issue has been discovered when generating treatment plans created from MVCT images. This issue does not affect treatment plans created with diagnostic CT images. Specifically, CT pixel values for MVCT images may drift over time due to changes of the MVCT beam quality which results from variations in machine performance, e.g. target wear. In specific cases, month to month checks of the CT pixel values have shown changes as large as 3%, with 4% changes over the course of a year.

Treatment plans which use the MVCT images without an updated Image Value to Density Table (IVDT) could result in inaccurate dose calculations. A 4% change in pixel values could result in a 1-3% change in calculated dose, depending on the depth.

**Product Affected:**
This only affects treatment plans created with MVCT images for all Hi-ART System configurations. This does not affect treatment plans created with diagnostic CT images.

**Recommended User Action:**
1. Check existing IVDT's created for MVCT images with a new MVCT image of the TomoPhantom with density plugs inserted to ensure the table values are still correct.
2. Periodically verify the accuracy of the IVDTs created for MVCT images.
3. Verify the accuracy of IVDTs created for MVCT images following target or linac replacement.
4. Continue to perform patient DQA, as this will detect dose discrepancies prior to treatment.

Reference: 4065

www.TomoTherapy.com
WARNING: Deformation is not considered in the summation process!

Select Type and Overlap Priority for New ROI

Please select the Type and Overlap Priority for the given ROI:

ROI name: scatdiasaggio
ROI color: 
ROI type: Tumor
Overlap priority: 4

OK
IGRT con riposizionamento giornaliero del paziente

- Modifica dei contorni al cambiare delle strutture anatomiche
- Valutazione della Dose basata su un’immagine giornaliera MVCT
- Adattamento della dose di un piano non più corretto
- Sistema integrato
- Rapido confronto tra dose pianificata e dose erogata (per frazione)
- Disponibilità del set di contorni di pianificazione
- Somma su frazioni diverse
- Possibilità di individuare aree di sovradosaggio o sottodosaggio

- Qualità dell' immagine non ottimale per la ricontornazione
- No possibilità di confrontare con PET o NMR
- Necessità di acquisire immagini MVCT estese
- Ricontrornazione manuale
- Procedure ridondanti
- No possibilità di confrontare tra loro immagini MVCT successive
- Attenzione nell' interpretazione dei DVH
- No disponibilità di funzioni statistiche
- Revisione dosi e vicoli nel nuovo piano
grazie per l'attenzione