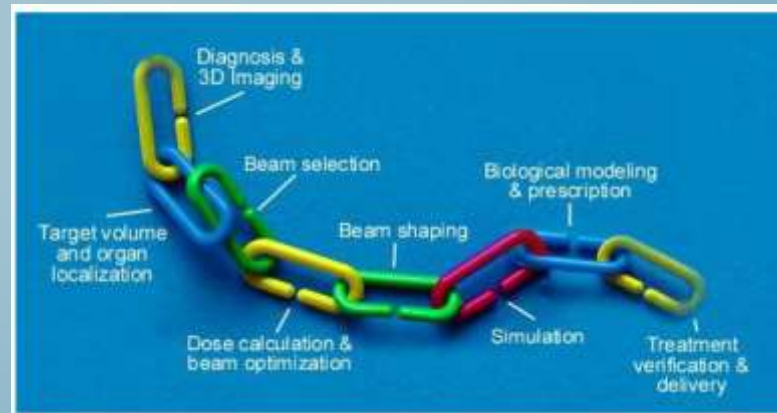


Qualitätssicherung atemgesteuerten Strahlentherapie bewegter und deformierbarer Organstrukturen

Softwarelösungen

Echtzeit Positionsbestimmungen des Tumors

Messphantome



Johann Kindlein



MEDINEX

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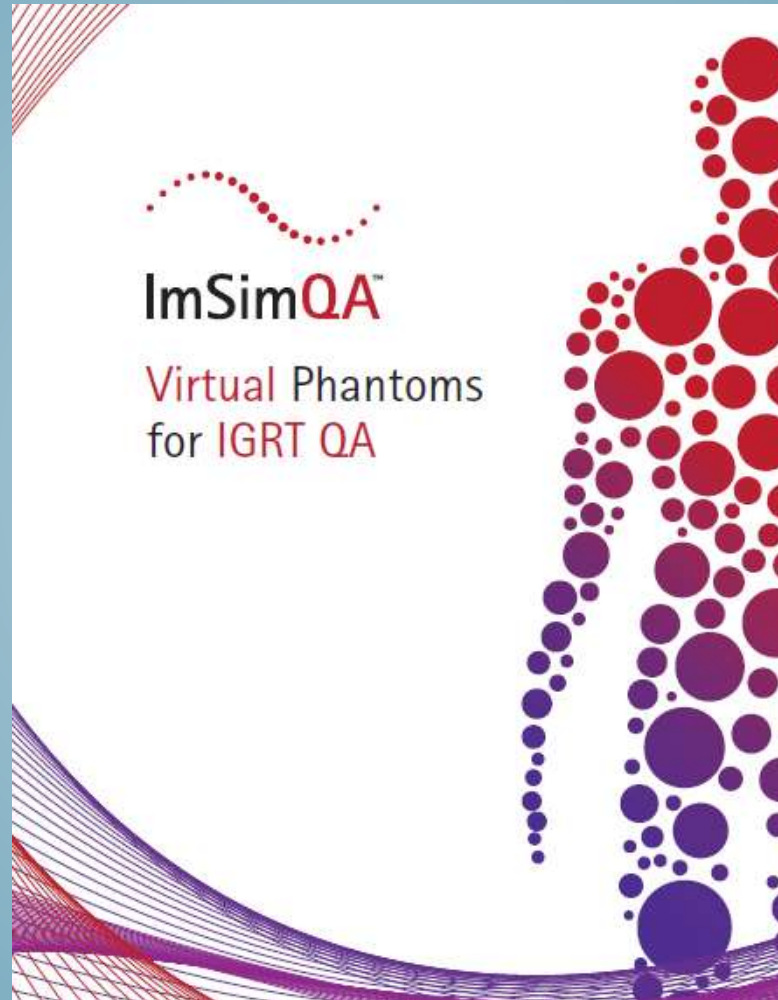
www.medinex.com.de

SOFTWARE LÖSUNGEN

ImSimQA
Mobius3D - CBCT

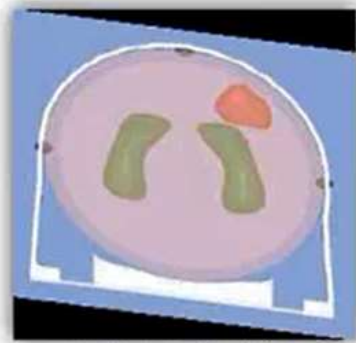


QS DEFORMIERBARER KÖRPERSTRUKTUREN MIT IMSIMQA SOFTWARE PAKET

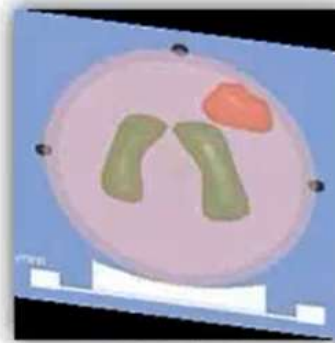


AUS VIRTUELLEN PHANTOMEN ERSTELLUNG VON DICOM BILDDATENSÄTZEN FÜR CT, PET UND MRT

From Virtual phantoms to Real DICOM images



3D Virtual Phantom



Fully editable

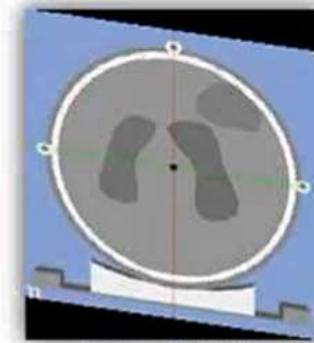
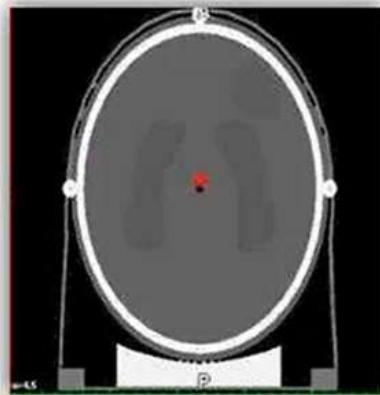


Image Modality simulation



Simulating CT modality



Simulating MR modality



Simulating PET modality



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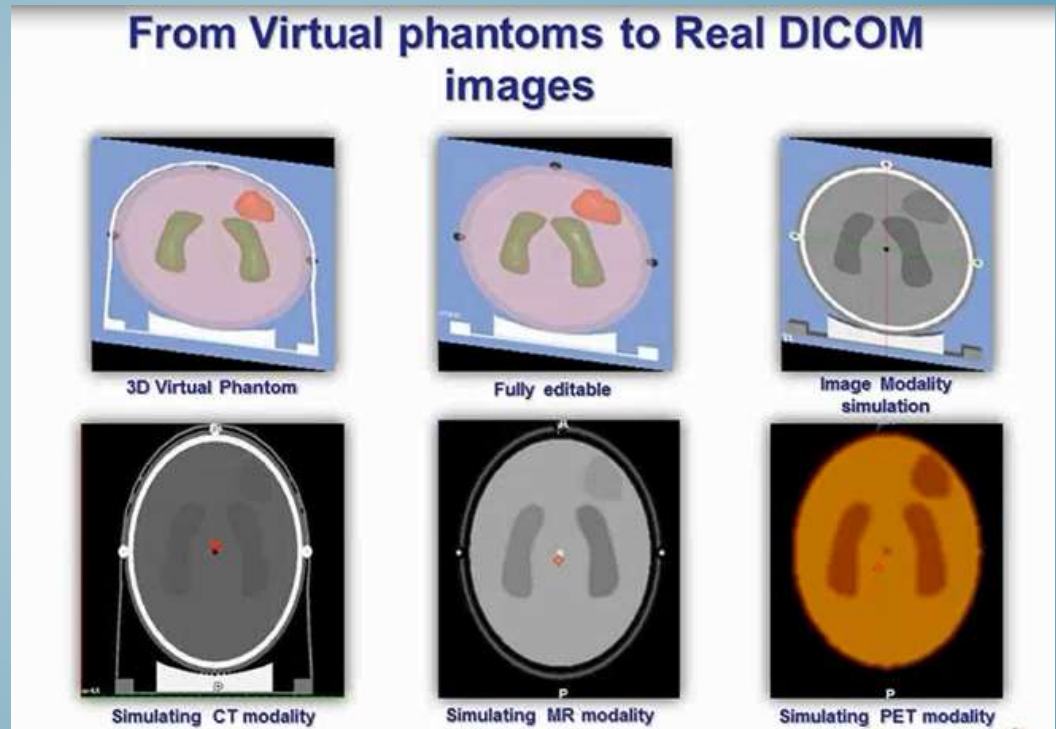
WARUM VIRTUELLE PHANTOME ?

Bekannte Parameter

- Geometrische Größen
- Definierte Deformationen
- Definierte Störeinflüsse



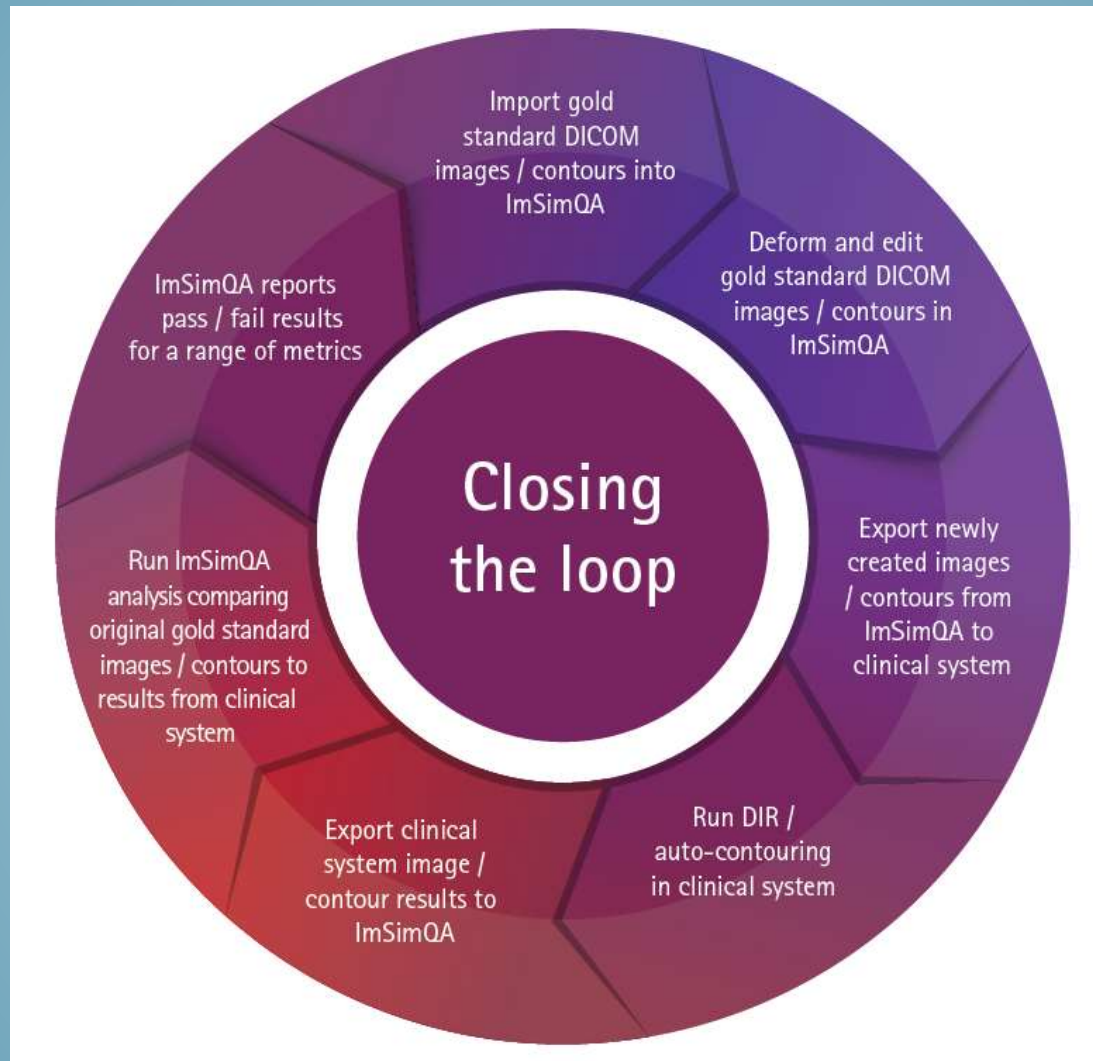
Standardisierte Test Bedingungen



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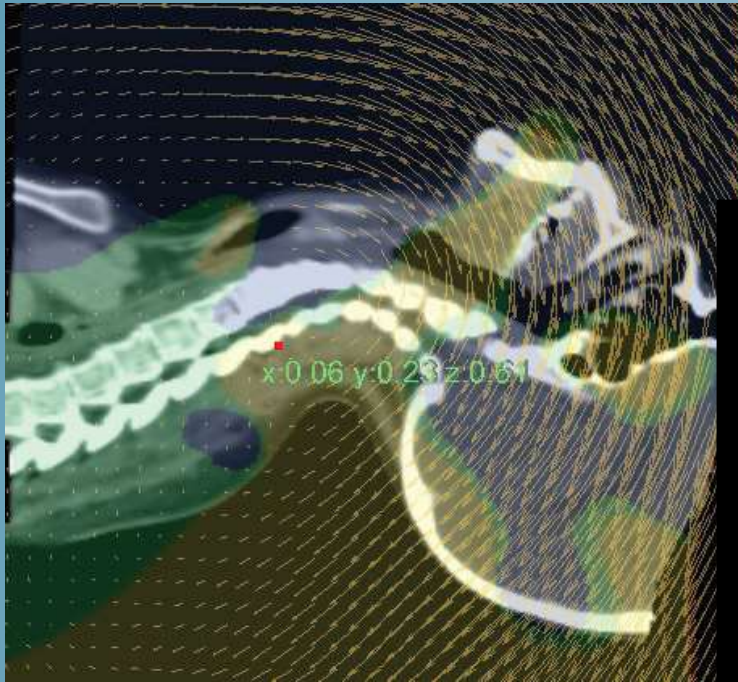
MIT IMSIMQA ZUR QS IHRER REGISTRIERUNGsalgorithmen



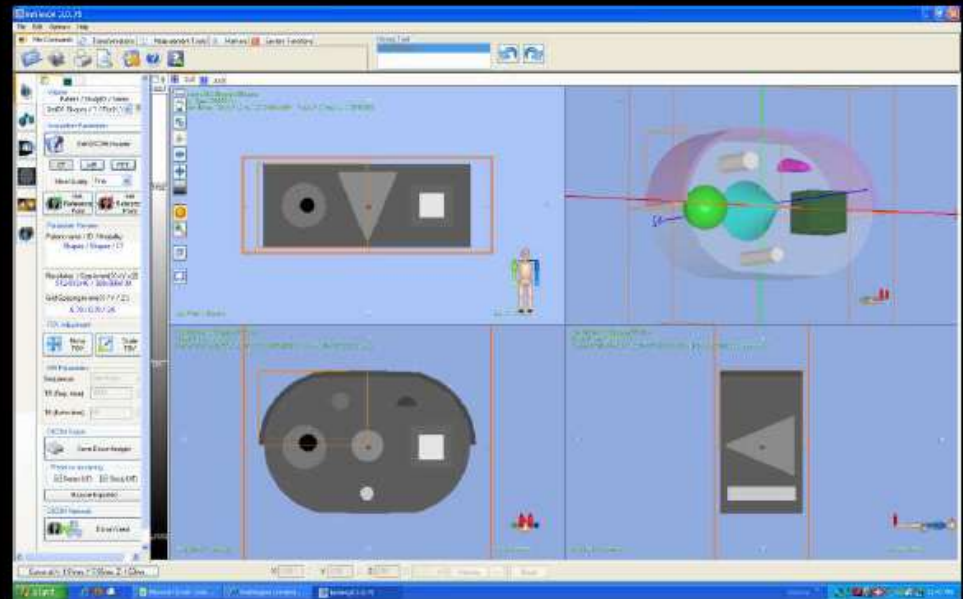
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TG-132 DIE ZUKÜNFTIGE NEUE EMPFEHLUNG FÜR DIR/RIR QUALITÄTSSICHERUNG



Example Digital Phantoms
Provided by the TG-132 via ImSimQA



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Use of Image Registration and Fusion Algorithms and Techniques in Radiotherapy

Preliminary Recommendations from TG 132*
Kristy Brock, Sasa Mutic, Todd McNutt, Hua Li, and Marc Kessler

***Report is currently under review by AAPM**



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Task Group Charge

1. Review the existing techniques and algorithms for image registration and fusion
2. Discuss issues related to effective clinical implementation of these techniques and algorithms in a variety of treatment planning and delivery situations
3. Discuss the methods to assess the accuracy of image registration and fusion
4. Discuss issues related to acceptance testing and quality assurance for image registration and fusion




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Commissioning Datasets*

- Basic geometric phantoms (multi-modality)¹
- Pelvis phantom (CT and MR)¹
- Clinical 4D CT Lung² with simulated exhale¹

*To be made publically available following the approval of TG 132 by AAPM





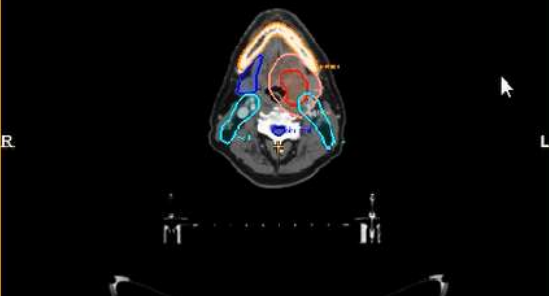

1. Courtesy of ImSim QA 
2. Courtesy of DIR Lab, MD Anderson Cancer Center



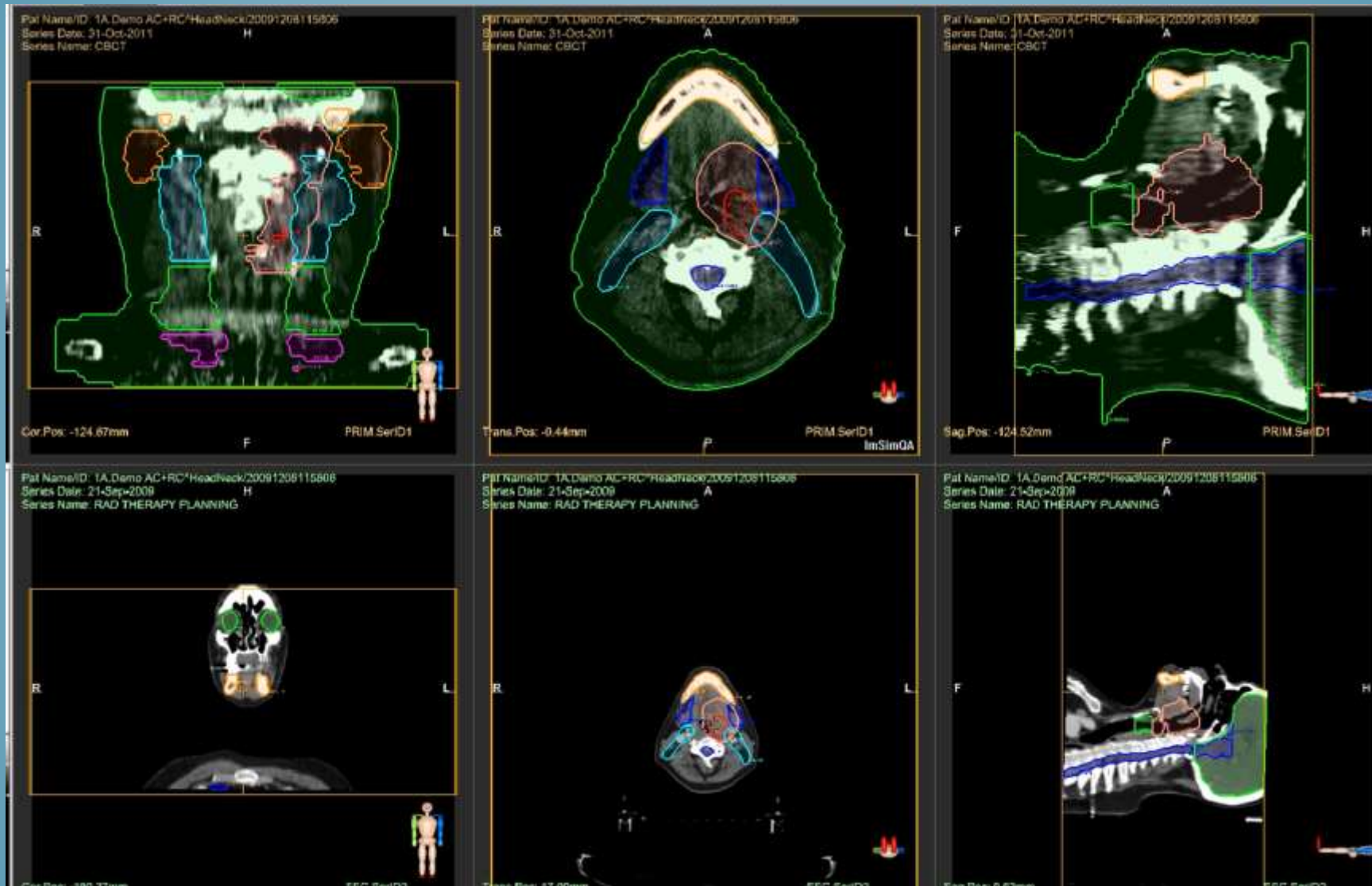
MEDINEX

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BEISPIEL EINER PLANUNG UND CBCT VERIFIKATION

| | | |
|---|---|---|
| <p>Pat Name/ID: 1A.Demo AC+RC+HeadNeck/20091208115806 Series Date: 31-Oct-2011 Series Name: CBCT</p>  <p>R L</p> <p>Performing Re-Contouring</p> <p>Preparing series for RTR ... 3D DIR Triangulate Contours Design VOI 3D Create Body Contour Initial Contour Correction</p> <p>Cor.Pos: -124.52mm F PRIM.SerID1</p> | <p>Pat Name/ID: 1A.Demo AC+RC+HeadNeck/20091208115806 Series Date: 31-Oct-2011 Series Name: CBCT</p>  <p>R L</p> <p>3D rigid MI registration...</p> <p>Trans.Pos: -0.44mm P PRIM.SerID1 ImSimQA</p> | <p>Pat Name/ID: 1A.Demo AC+RC+HeadNeck/20091208115806 Series Date: 31-Oct-2011 Series Name: CBCT</p>  <p>F H</p> <p>Sag.Pos: -124.52mm P PRIM.SerID1</p> |
| <p>Pat Name/ID: 1A.Demo AC+RC+HeadNeck/20091208115806 Series Date: 21-Sep-2009 Series Name: RAD THERAPY PLANNING</p> <p>Pat Name/ID: 1A.Demo AC+RC+HeadNeck/20091208115806 Series Date: 21-Sep-2009 Series Name: RAD THERAPY PLANNING</p> <p>Pat Name/ID: 1A.Demo AC+RC+HeadNeck/20091208115806 Series Date: 21-Sep-2009 Series Name: RAD THERAPY PLANNING</p> <p>00:30</p> <p>Abort All Steps</p> | | |
|  <p>R L</p> |  <p>R L</p> |  <p>F H</p> |

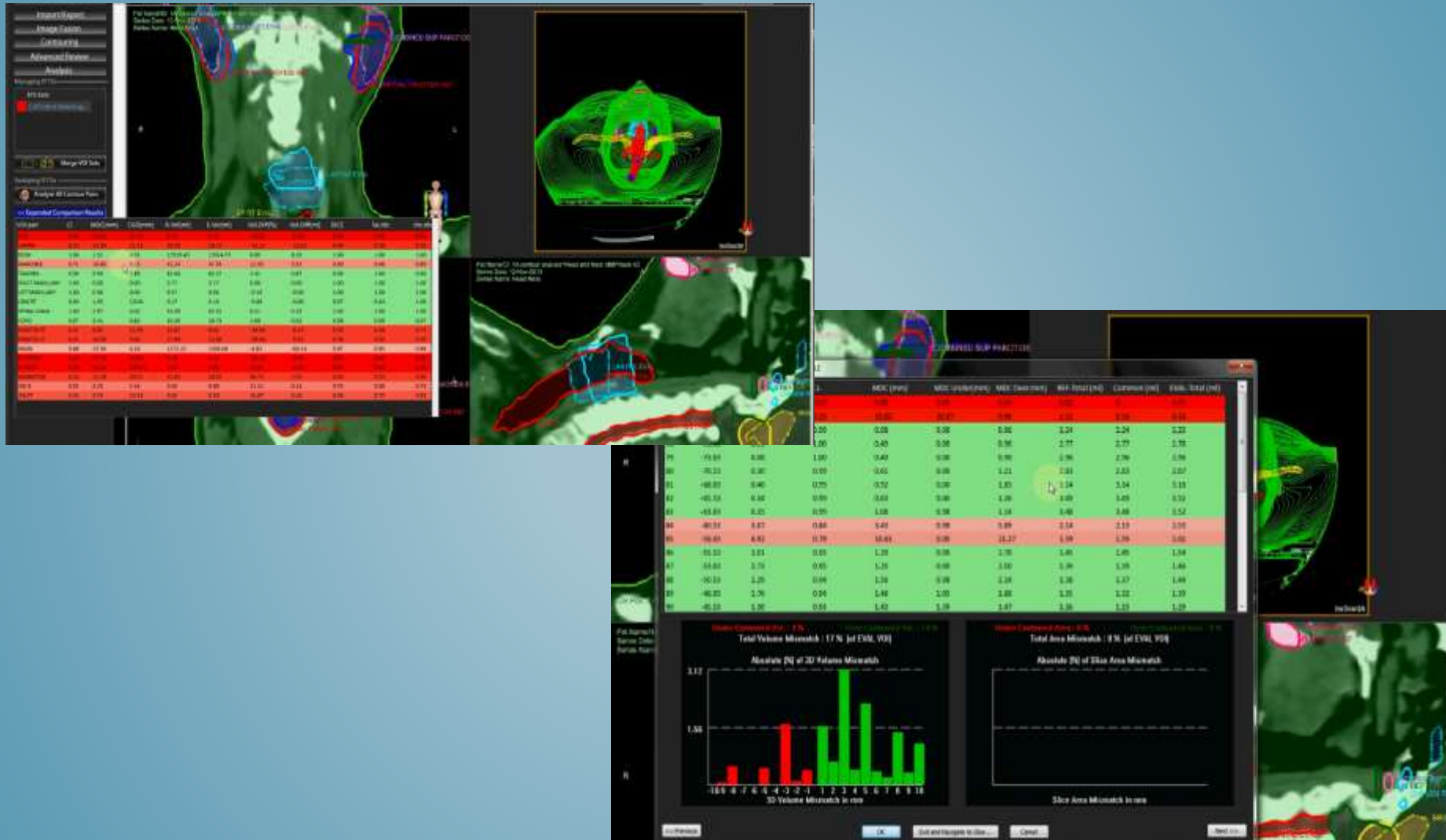
ÜBERTRAGUNG DES BESTRAHLUNGSPLANS (DIR/RIR) AUF DIE CBCT BILDER



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ANALYSE BEZÜGLICH DER NOTWENDIGKEIT EINER NEUPLANUNG



VERÖFFENTLICHUNGEN

UCL **Cambridge University Hospitals NHS Foundation Trust**

Comparison of Image Registration Packages for Use in Radiotherapy Planning

Erin K. Thomas SJ
Medical Physics Department, Addenbrooke's Hospital, Cambridge, CB2 0QQ

Abstract
Addenbrooke's Radiotherapy Department has three automatic image registration packages (all based on mutual information) available for use in multi-fractional stereotactic treatment planning: Procos, Focal and iVive. CT-MRI registration of brain images is the most common use of image registration in radiotherapy. This paper compares the performance of the three packages to see which one is most suitable for this use.

Background
Medical information is an extremely varied medium and can be used to register images from different modalities. It is common for the information that is common between two datasets (usually of CT and MRI) to be used to register images. In radiotherapy planning (Tomography) of 2010, any errors in registration will cause errors in the final treatment plan.

Methods
Aim: To compare the performance of three automatic image registration packages (Procos, Focal and iVive) using brain images. The packages were compared using a set of 100 brain CT and MRI images. The packages were compared using a set of 100 brain CT and MRI images. The packages were compared using a set of 100 brain CT and MRI images.

Results and Discussion
1. These tests did not assess any large or unexpected areas of error in the image registration packages. The tests highlighted individual and occasional errors in the automatic registration of which the user should be aware. They also showed the importance of visually checking each and every registration in all three planes before using it, especially in areas where error was not reported.

2. This test served as a test run for the tests to be carried out on clinical images and showed the context of loading, exporting, DICOMs, and saving the data to DICOMs worked adequately.

3. The data for 100 images showed that Procos showed better results of corresponding CT and MRI DICOMs over registered areas (1.5% to 10% DICOMs) when Focal was used (range 0.21-1.4% DICOMs) results of the statistical analysis and the percentage inter-observer agreement and distance between contours for the 100 pairs of CT and MRI image DICOMs and shown in the table below.

| Image pair | Procos | Focal | iVive |
|------------|--------|-------|-------|
| 100 | 1.5 | 0.21 | 1.4 |
| 100 | 1.5 | 0.21 | 1.4 |
| 100 | 1.5 | 0.21 | 1.4 |

4. A paired Student's t-test was carried out on the data to test the null hypothesis that there is no difference between Procos and Focal for the three automatic parameters, using a threshold of 0.05. For all three parameters Procos performed significantly better than Focal. The results showed that Procos had a higher percentage of agreement (3.5% higher than Focal) and an average percentage overlap (5.4% higher than Focal) and an average distance between contours (0.4% lower than Focal).

Conclusions
iVive was unable to correctly register the majority of images from our CT scans and did not work as expected so it would not be used in clinical practice.

Full Paper

The utility of atlas-assisted segmentation in the male pelvis is dependent on the interobserver agreement of the structures segmented

Abstract
To investigate the utility of atlas-assisted segmentation in the male pelvis, we segmented the prostate, bladder, rectum, and sigmoid colon in 100 male patients using a semi-automatic method. The utility of atlas-assisted segmentation was compared to manual segmentation. The results showed that atlas-assisted segmentation was significantly more accurate than manual segmentation in the prostate, bladder, and rectum, but not in the sigmoid colon. The utility of atlas-assisted segmentation was dependent on the interobserver agreement of the structures segmented.

Introduction
The utility of atlas-assisted segmentation in the male pelvis is dependent on the interobserver agreement of the structures segmented. This paper describes a method for atlas-assisted segmentation and compares it to manual segmentation. The results show that atlas-assisted segmentation is more accurate than manual segmentation in the prostate, bladder, and rectum, but not in the sigmoid colon. The utility of atlas-assisted segmentation is dependent on the interobserver agreement of the structures segmented.

Methods
We segmented the prostate, bladder, rectum, and sigmoid colon in 100 male patients using a semi-automatic method. The utility of atlas-assisted segmentation was compared to manual segmentation. The results showed that atlas-assisted segmentation was significantly more accurate than manual segmentation in the prostate, bladder, and rectum, but not in the sigmoid colon. The utility of atlas-assisted segmentation was dependent on the interobserver agreement of the structures segmented.

Results
The results showed that atlas-assisted segmentation was significantly more accurate than manual segmentation in the prostate, bladder, and rectum, but not in the sigmoid colon. The utility of atlas-assisted segmentation was dependent on the interobserver agreement of the structures segmented.

Conclusions
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JOURNAL OF APPLIED CLINICAL MEDICAL PHYSICS, VOLUME 14, NUMBER 1, 2013

A framework for deformable image registration validation in radiotherapy clinical applications

Raj Varadhan,^{1,4a} Grigoris Karangelis,² Karthik Krishnan,³ Susanta Hu^{1,4}
¹Minneapolis Radiation Oncology, ²Minneapolis, MN, USA; ³Oncology Systems Limited, ⁴Shrewsbury, Shropshire, UK, Kirwara, Inc., ⁵Clifton Park, NY, USA; ⁶Department of Therapeutic Radiology, ⁷University of Minnesota, Minneapolis, MN, USA
rvaradhan@mpopa.com

Received 11 June, 2012; accepted 19 September, 2012

Quantitative validation of deformable image registration (DIR) algorithms is extremely difficult because of the complexity involved in constructing a deformable phantom that can duplicate various clinical scenarios. The purpose of this study is to describe a framework to test the accuracy of DIR based on computational modeling and evaluating using inverse consistency and other methods. Three clinically relevant organ deformations were created in prostate (distended rectum and rectal gas), head and neck (large neck flexion), and lung (inhale and exhale lung volumes with variable contrast enhancement) study sets. DIR was performed using both B-spline and diffeomorphic demons algorithms in the forward and inverse direction. A compositional accumulation of forward and inverse deformation vector fields was done to quantify the inverse consistency error (ICE). The anatomical correspondence of tumor and organs at risk was quantified by comparing the original RT structures with those obtained after DIR. Further, the physical characteristics of the deformation field, namely the Jacobian and harmonic energy, were computed to quantify the preservation of image topology and regularity of spatial transformation obtained in DIR. The ICE was comparable in prostate case but the B-spline algorithm had significantly better anatomical correspondence for rectum and prostate than diffeomorphic demons algorithm. The ICE was 6.5 mm for demons algorithm for head and neck case when compared to 0.7 mm for B-spline. Since

Validation of Deformable Dose Registration using B-spline and Optical-flow algorithm in Head and Neck cancer patients

Erin K. Thomas SJ
Medical Physics Department, Addenbrooke's Hospital, Cambridge, CB2 0QQ

Abstract
The purpose of this study is to validate the accuracy of Deformable Image Registration (DIR) and the ability of dose transfer algorithms to transfer dose from CT to MRI. The packages were compared using a set of 100 brain CT and MRI images. The packages were compared using a set of 100 brain CT and MRI images. The packages were compared using a set of 100 brain CT and MRI images.

Methods
Aim: To compare the performance of three automatic image registration packages (Procos, Focal and iVive) using brain images. The packages were compared using a set of 100 brain CT and MRI images. The packages were compared using a set of 100 brain CT and MRI images.

Results and Discussion
1. These tests did not assess any large or unexpected areas of error in the image registration packages. The tests highlighted individual and occasional errors in the automatic registration of which the user should be aware. They also showed the importance of visually checking each and every registration in all three planes before using it, especially in areas where error was not reported.

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3. The data for 100 images showed that Procos showed better results of corresponding CT and MRI DICOMs over registered areas (1.5% to 10% DICOMs) when Focal was used (range 0.21-1.4% DICOMs) results of the statistical analysis and the percentage inter-observer agreement and distance between contours for the 100 pairs of CT and MRI image DICOMs and shown in the table below.

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| 100 | 1.5 | 0.21 | 1.4 |
| 100 | 1.5 | 0.21 | 1.4 |

4. A paired Student's t-test was carried out on the data to test the null hypothesis that there is no difference between Procos and Focal for the three automatic parameters, using a threshold of 0.05. For all three parameters Procos performed significantly better than Focal. The results showed that Procos had a higher percentage of agreement (3.5% higher than Focal) and an average percentage overlap (5.4% higher than Focal) and an average distance between contours (0.4% lower than Focal).

Conclusions
iVive was unable to correctly register the majority of images from our CT scans and did not work as expected so it would not be used in clinical practice.

Comparison of different QA metrics for deformable image registration in the brain

Erin K. Thomas SJ
Medical Physics Department, Addenbrooke's Hospital, Cambridge, CB2 0QQ

Abstract
The purpose of this study is to compare the performance of three automatic image registration packages (Procos, Focal and iVive) using brain images. The packages were compared using a set of 100 brain CT and MRI images. The packages were compared using a set of 100 brain CT and MRI images. The packages were compared using a set of 100 brain CT and MRI images.

Methods
Aim: To compare the performance of three automatic image registration packages (Procos, Focal and iVive) using brain images. The packages were compared using a set of 100 brain CT and MRI images. The packages were compared using a set of 100 brain CT and MRI images.

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1. These tests did not assess any large or unexpected areas of error in the image registration packages. The tests highlighted individual and occasional errors in the automatic registration of which the user should be aware. They also showed the importance of visually checking each and every registration in all three planes before using it, especially in areas where error was not reported.

2. This test served as a test run for the tests to be carried out on clinical images and showed the context of loading, exporting, DICOMs, and saving the data to DICOMs worked adequately.

3. The data for 100 images showed that Procos showed better results of corresponding CT and MRI DICOMs over registered areas (1.5% to 10% DICOMs) when Focal was used (range 0.21-1.4% DICOMs) results of the statistical analysis and the percentage inter-observer agreement and distance between contours for the 100 pairs of CT and MRI image DICOMs and shown in the table below.

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Conclusions
iVive was unable to correctly register the majority of images from our CT scans and did not work as expected so it would not be used in clinical practice.

A virtual phantom library for the quantification of deformable image registration uncertainties in patients with cancers of the head and neck

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¹Department of Radiation Oncology, MD Anderson Cancer Center Orlando, Orlando, Florida 32806

Frank J. Bova
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Rafael R. Mañón and Katja M. Langen
³Department of Radiation Oncology, MD Anderson Cancer Center Orlando, Orlando, Florida 32806

(Received 23 May 2013; revised 1 August 2013; accepted for publication 6 September 2013; published 2 October 2013)

Purpose: Deformable image registration (DIR) is being used increasingly in various clinical applications. However, the underlying uncertainties of DIR are not well-understood and a comprehensive methodology has not been developed for assessing a range of interfraction anatomic changes during head and neck cancer radiotherapy. This study describes the development of a library of clinically relevant virtual phantoms for the purpose of aiding clinicians in the QA of DIR software. These phantoms will also be available to the community for the independent study and comparison of other DIR algorithms and processes.



MOBIUS3D

DAS KOMPLETTE SYSTEM FÜR PATIENTEN QS



Mobius3D
THE COMPLETE PATIENT QA SYSTEM

- 3D PATIENT PLAN QA
- 3D IMRT/VMAT PRE-TREATMENT QA
- 3D *IN VIVO* DAILY TREATMENT QA
- ONLINE PATIENT POSITIONING QA



- COMPARE DOSES
3D TO 3D
- VERIFY DOSE TO
ALL VOLUMES
- CHECK EVERY
FRACTION
- CONFIRM POSITION
AND ANATOMY



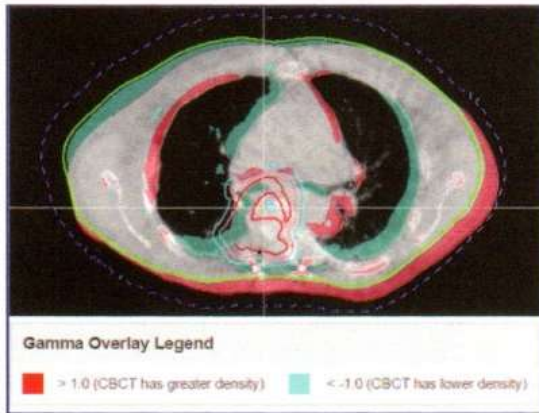
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VON QUALITATIV ZU QUANTITATIV FÜR DEFORMIERUNGEN UND POSITIONIERUNGEN



Quantitative values and color coding allow fast analysis of results



Density gamma overlay provides clear indication of positioning errors

EINE GAMMA DENSITY ANALYSE

The CBCT Module: Density gamma

- Same method as dose comparison, but now we are comparing (g/cc) per distance
- **Default criteria: 0.3 g/cc / 3 mm**
 - This value was chosen because it best distinguishes between bone, soft tissue, and air, which are the differences that will clearly show positioning errors and anatomy changes
- Three options for gamma region of interest:
 - “% Dose” + Margin
 - Isocenter + Margin
 - All Target ROIs - not recommended



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QUANTITATIVE PRE-TREATMENT POSITIONIERUNG

CBCT Analysis for Pre-treatment QA



| Passing Rate | Criteria | Planning CT Voxels | CBCT Voxels |
|--------------|-----------------|------------------------|------------------------|
| 94.9% | 0.3 g/cc / 3 mm | 2 mm, 0.97 mm, 0.97 mm | 2 mm, 0.97 mm, 0.97 mm |

| Passing Rate | Criteria | Planning CT Voxels | CBCT Voxels |
|--------------|-----------------|------------------------|------------------------|
| 76.9% | 0.3 g/cc / 3 mm | 2 mm, 0.97 mm, 0.97 mm | 2 mm, 0.97 mm, 0.97 mm |

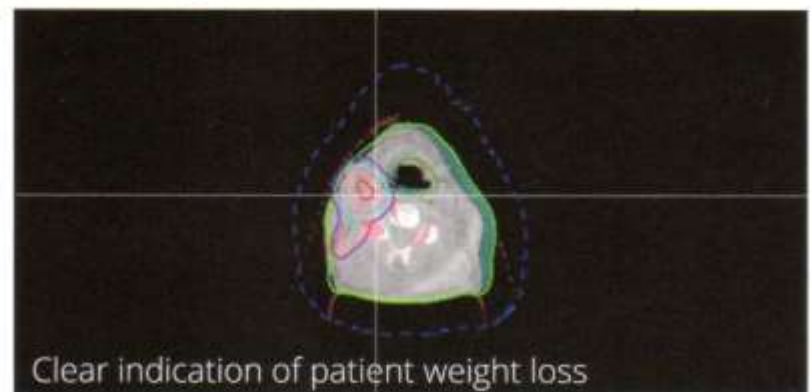


QUANTITATIVE POST-TREATMENT ANALYSE DER ANATOMISCHEN VERÄNDERUNGEN

CBCT Analysis for Post-treatment QA



| Passing Rate | Criteria | Planning CT Voxels | CBCT Voxels |
|---|-----------------|------------------------|------------------------|
| 91.5%  | 0.3 g/cc / 3 mm | 2 mm, 1.14 mm, 1.14 mm | 2 mm, 1.14 mm, 1.14 mm |



| Passing Rate | Criteria | Planning CT Voxels | CBCT Voxels |
|---|-----------------|------------------------|------------------------|
| 86.9%  | 0.3 g/cc / 3 mm | 2 mm, 1.14 mm, 1.14 mm | 2 mm, 1.14 mm, 1.14 mm |



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MOBIUS3D CBCT SPEZIFIKATION

Mobius3D CBCT Module Specifications

| | |
|-----------------------|---|
| Supported Machines | Varian and Elekta linear accelerators with cone-beam CT capabilities |
| Supported R&V Systems | Varian ARIA® and Elekta MOSAIQ® |
| Comparison Method | The CBCT and Planning CT volume comparison is completed utilizing automatic re-scaling of intensity values and user specified density (g/cc) / distance (mm) criteria |
| Views Available | Transverse Gamma, Coronal Gamma, Sagittal Gamma, and Transverse 3D Slice Viewer |



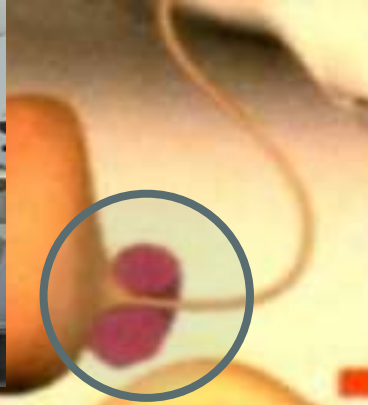
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POSITIONSBESTIMMUNGEN



SYSTEME ZUR ERFASSUNG VON BEWEGUNGEN VON KÖRPERSTRUKTUREN



MEDINEX

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ECHTZEIT ELEKTROMAGNETISCHES TUMOR TRACKING

RayPilot das System zur Erfassung von:

- Echtzeit Organbewegungen
und
- In Vivo Punktdosimetrie
während der Bestrahlung



RAYPILOT®

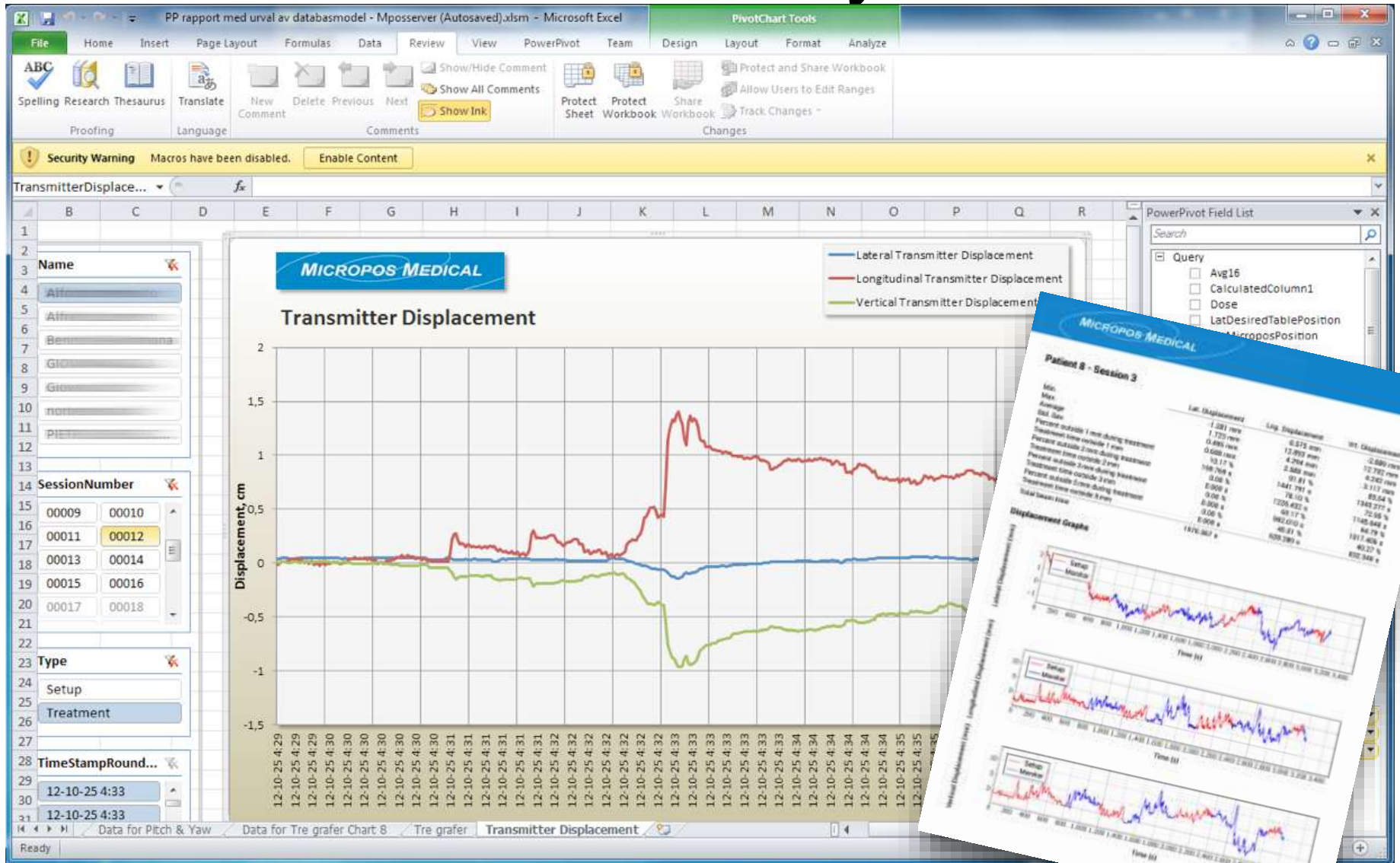
Das Echtzeit Tumortracking System
für jeden Beschleuniger

Das macht den Unterschied aus:

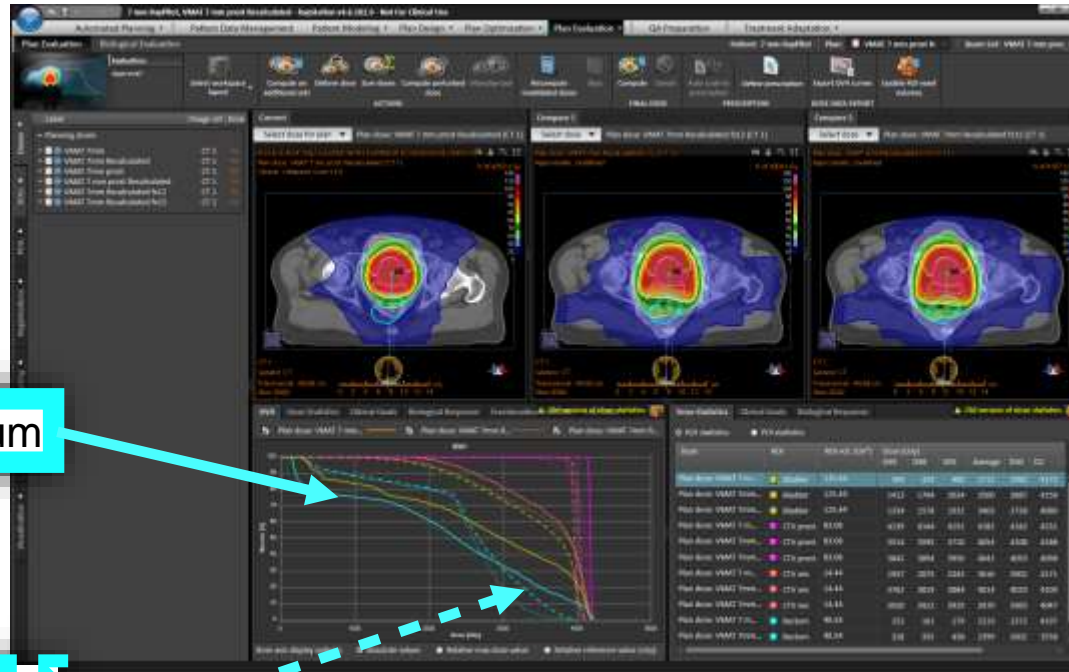
- 30 Hz Meßfrequenz
- Auch für Lagerungen aus Kohlenstoff-Faser, kein Verbleib von körperfremden Teilen im Patienten nach der Anwendung
- MRT Nachuntersuchungen möglich
- Unabhängig von Körpergewicht und Körpergröße
- Für SBRT, IMRT und VMAT Bestrahlungen



Offline analysis



Example of dose tracking performed by RayStation® from RayPilot® data. Compares the dose distribution from the plan with a recalculated dose distribution according to the motion detected.



Planned DVH Rectum

Recalculated DVH
Rectum

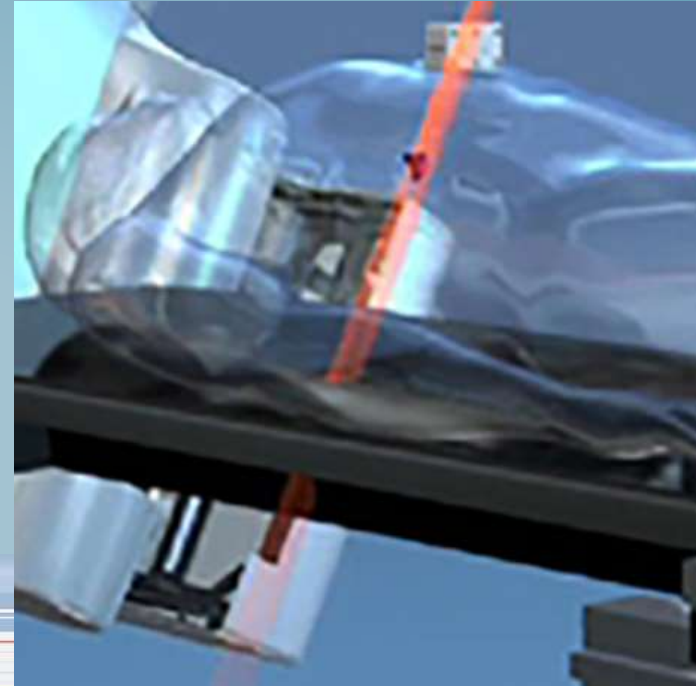
WORK IN PROGRESS

Prostate displacement monitored and recorded by RayPilot®. Dose tracking (deformableregistration, dose calculation and dose mapping) performed by RayStation® from RaySearch.

PHANTOME FÜR DOSIMETRISCHE MESSUNGEN



ATMUNGSABHÄNGIGE BEWEGUNG VON KÖRPERSTRUKTUREN



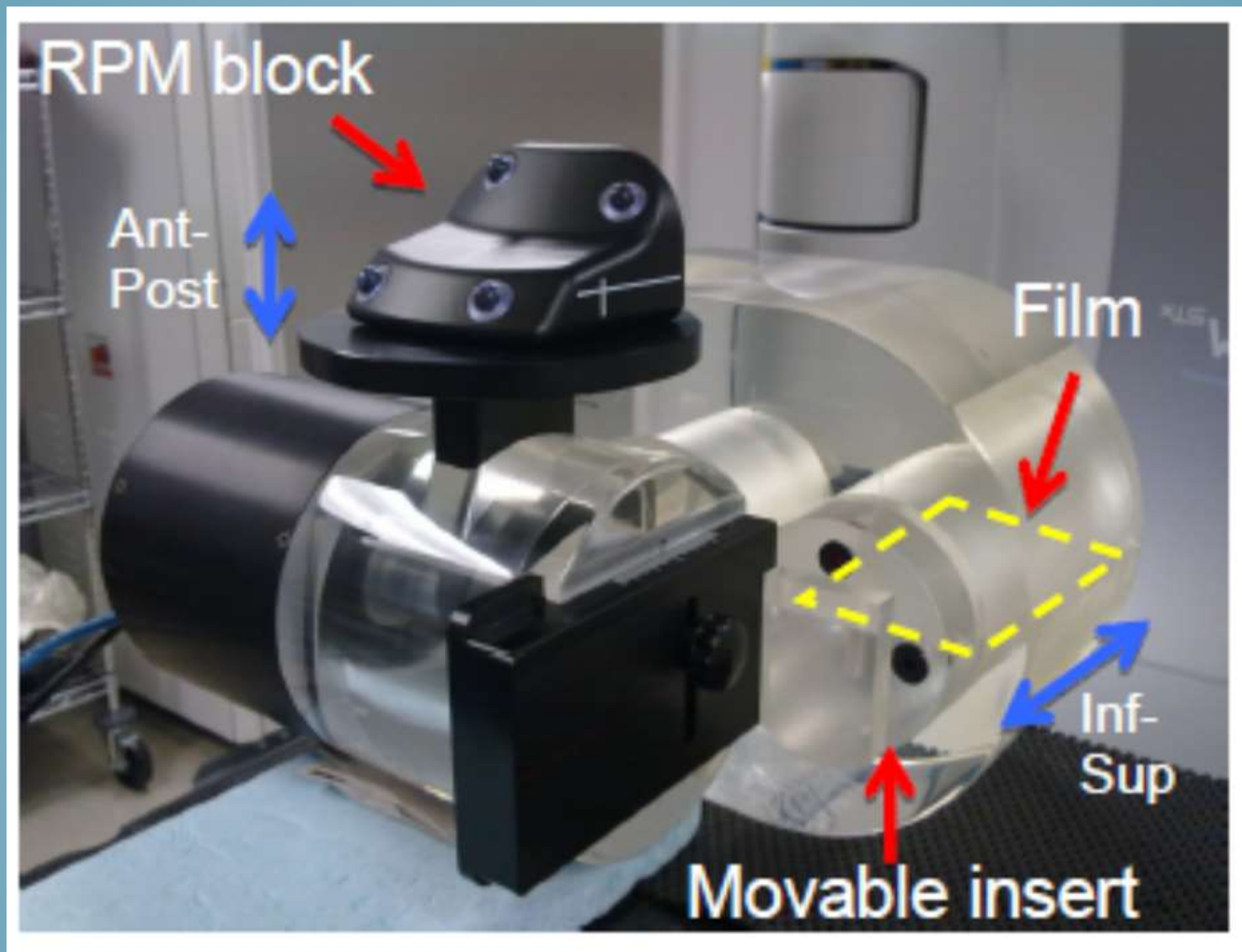
DAS MODUS QA ATMUNGSSIMULATIONS PHANTOM AUFBAUMÖGLICHKEITEN AUF EINEN BLICK EINSÄTZE UND ZUSATZTEILE



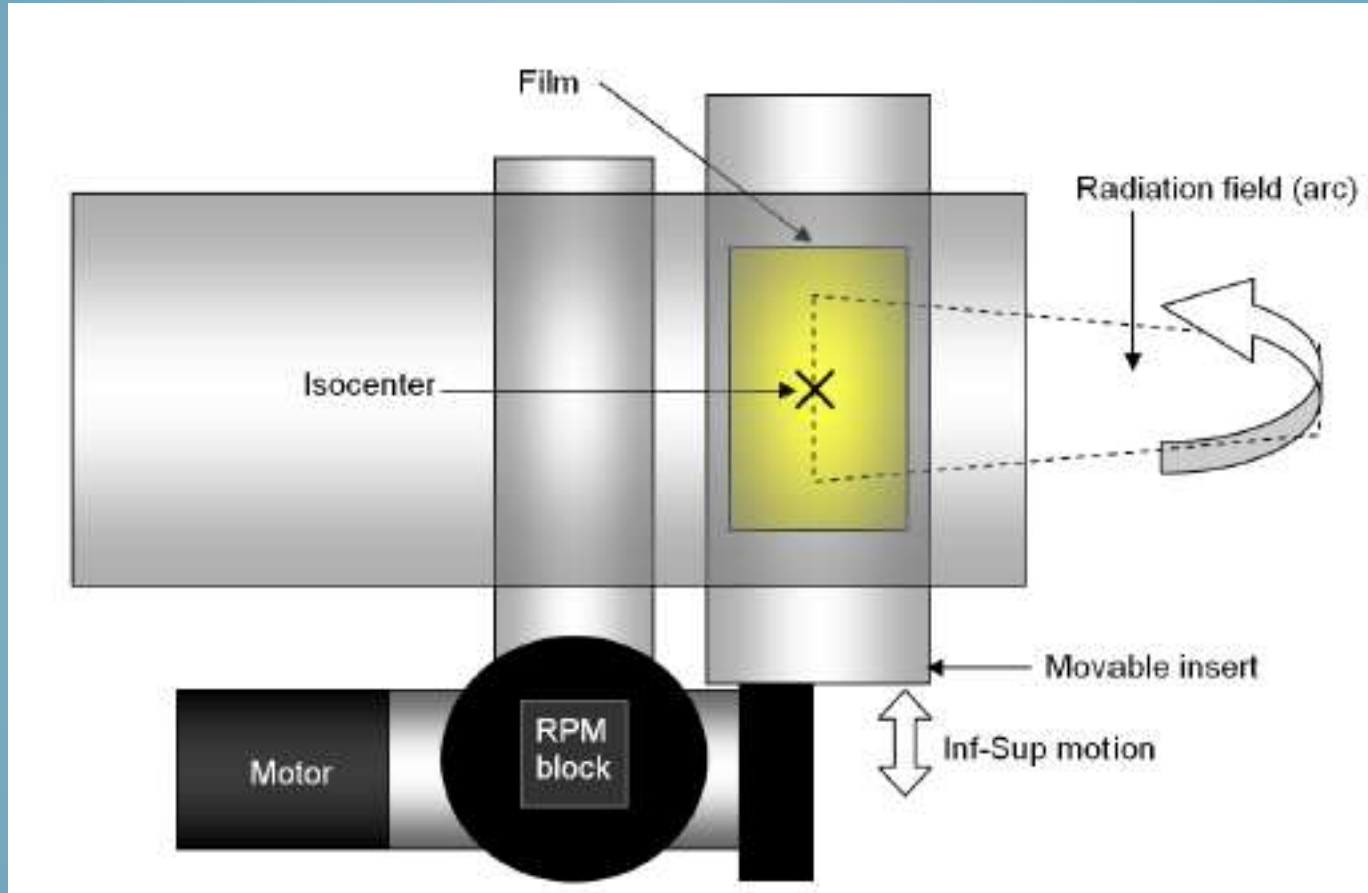
MEDINEX

MEDICAL INNOVATION EXCELLENCE

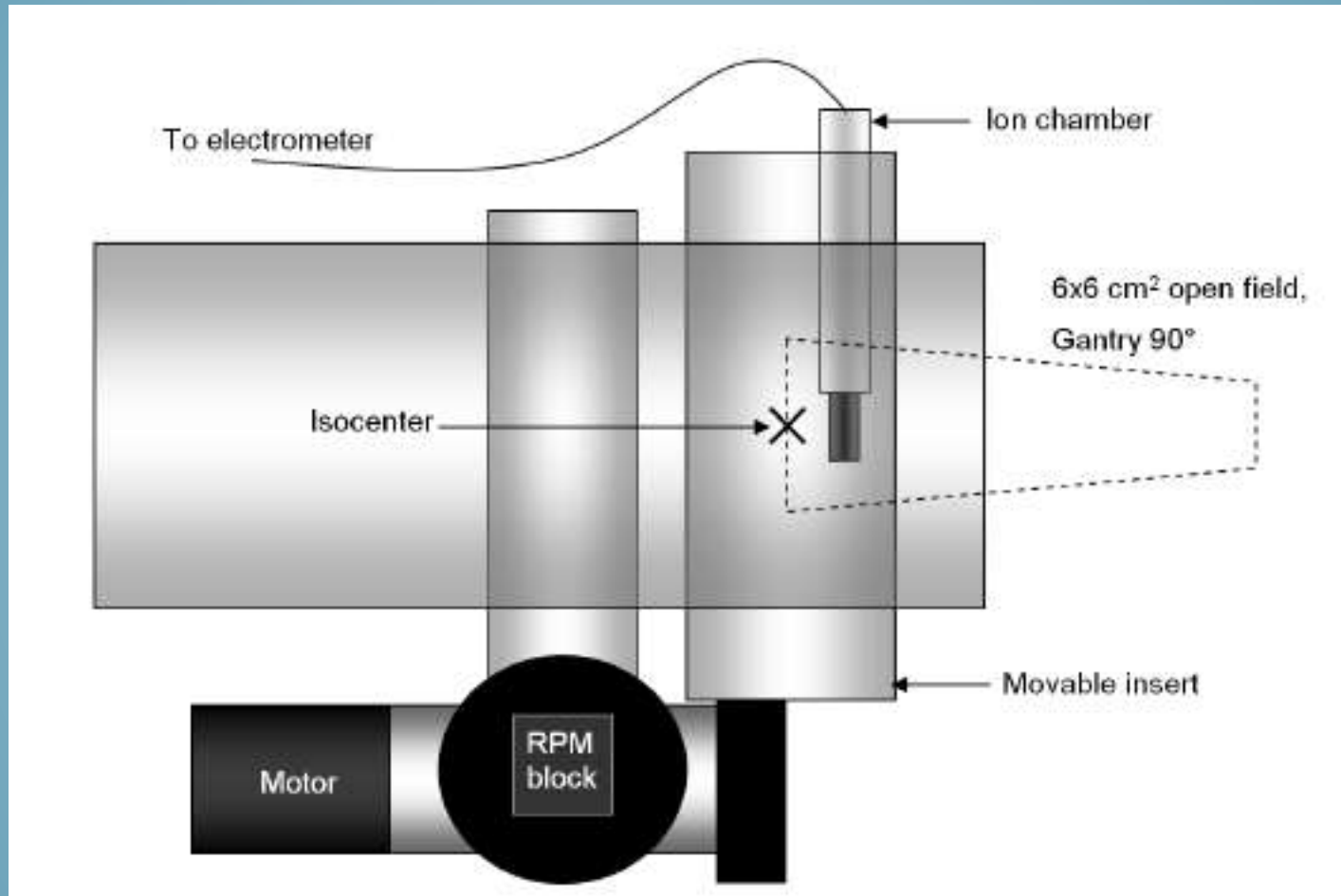
MODUS QA PHANTOM MIT VARIAN RPM SYSTEM



MODUS QA ATMUNGSSIMULATIONS PHANTOM SCHEMATISCHER AUFBAU MIT GAFCHROMIC FILM



ATMUNGSSIMULATIONS PHANTOM MIT MESSKAMMER EINSATZ



MEDINEX

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MODUS QA BEWEGUNGS PLATTFORM MIT ATMUNGSKURVEN - STEUERUNG MIT 2D BEWEGUNG



MODUS QA BEWEGUNGS PLATTFORM MIT ATMUNGSKURVEN - STEUERUNG MIT 3D BEWEGUNG



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MODUS QA PLATTFORM – SPEZIFIKATIONSPARAMETER

QUASAR™ Programmable Respiratory Motion Platform Specifications

- Moving Platform; 35 cm x 35 cm, carries up to 20 kg
- Overall dimensions; 51 cm x 35 cm x 15 cm high
- Mass; 3 kg excluding third party phantoms
- Chest wall platform: 13 cm diameter, carries up to 1 kg
- Power supply: Input, 100 – 240 V AC, 47 – 63 Hz, International power cords available
Output, 24 V DC 2.1 A, 50 W. Approvals; CE, UL/CSA 60950-1



Key Features

- Accommodates phantoms weighing up to 20 kg on a 35 x 35 cm platform
- Generates lateral hysteresis motion for phase separation testing
- Simulates patient-specific respiratory and sinusoidal motion profiles
- Communicate with the phantom through local area network (LAN)
- Compatible with motion tracking systems from multiple vendors



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