



Deutsche Gesellschaft für Medizinische Physik e.V.

DGMP

Dr. Franco Canestri
C-RAD GmbH

Medizinische Anwendungsmöglichkeiten und
Beiträge zur Patientensicherheit durch präzise C-RAD
Patientenlagerungsüberwachung und Atem Gating
während der Strahlentherapie.

Treffen des AK IMRT der DGMP
30. und 31.05.2016
Leipzig

Agenda

Background

C-RAD methods used in optical triangulation

Workflow CT → RT

Clinical Benefits and Published Results

Discussion

Background of the Presenter

- Ph.D in Medical Physics from University of Genoa and National Cancer Institute of Milan - Italy („Lasers in Surgery and Oncology“)
- Since 32 Years in Germany
- Professional Experiences with Hewlett-Packard Medical and Agilent Technologies Optical Division in Böblingen (Product Design). With C-RAD since beginning 2013.
- Scientific Publications : www.franco-canestri.de

Background of the Company



- *Product ideas based on specific studies about patient positioning and monitoring during radiation therapy at the :*

Karolinska Institutet, Stockholm



- *Research and first developments by Anders Brahme started back in 1997*
- *C-RAD company was founded in 2003, now with Main Subsidiaries in USA, Germany, France and China plus 20+ Distributors world-wide.*



→ C-RAD GmbH in Germany : 3 Offices in Berlin, Karlsruhe and Lüneburg.

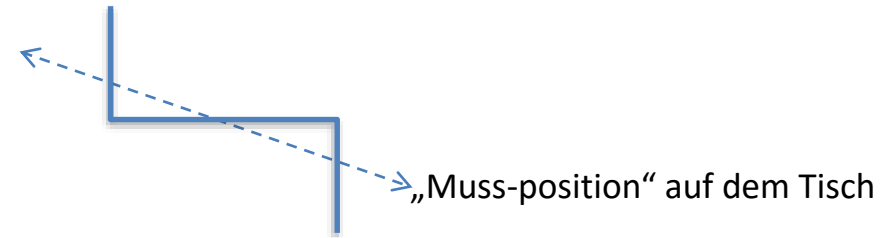
Ziel :



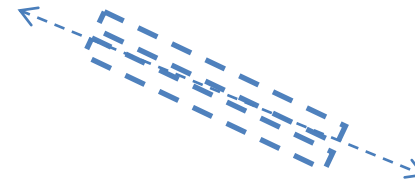
**Mehr Patienten pro Tag,
besser und
mit mehr Sicherheit behandeln.**

Strahlentherapie : Herausforderungen

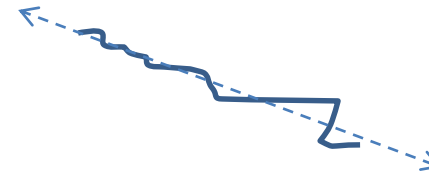
„Posture Errors“ (Haltung)



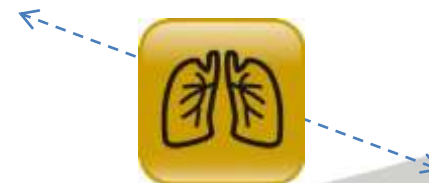
Genauigkeit



Bewegungen



„Respiratory Gating (DIBH)“ vs. „Free Breathing“



End-to-end treatment solution

Sentinel 4DCT
in CT room



For all CT
Manufacturers



Catalyst/HD/PT in
RT room



SETUP AND
POSITIONING
OF PATIENTS



INTRA-FRACTION
MOTION DETECTION



RESPIRATORY
GATING



Multi Vendor
Support



Siemens

C-RAD Approach to precise and safer patient positioning

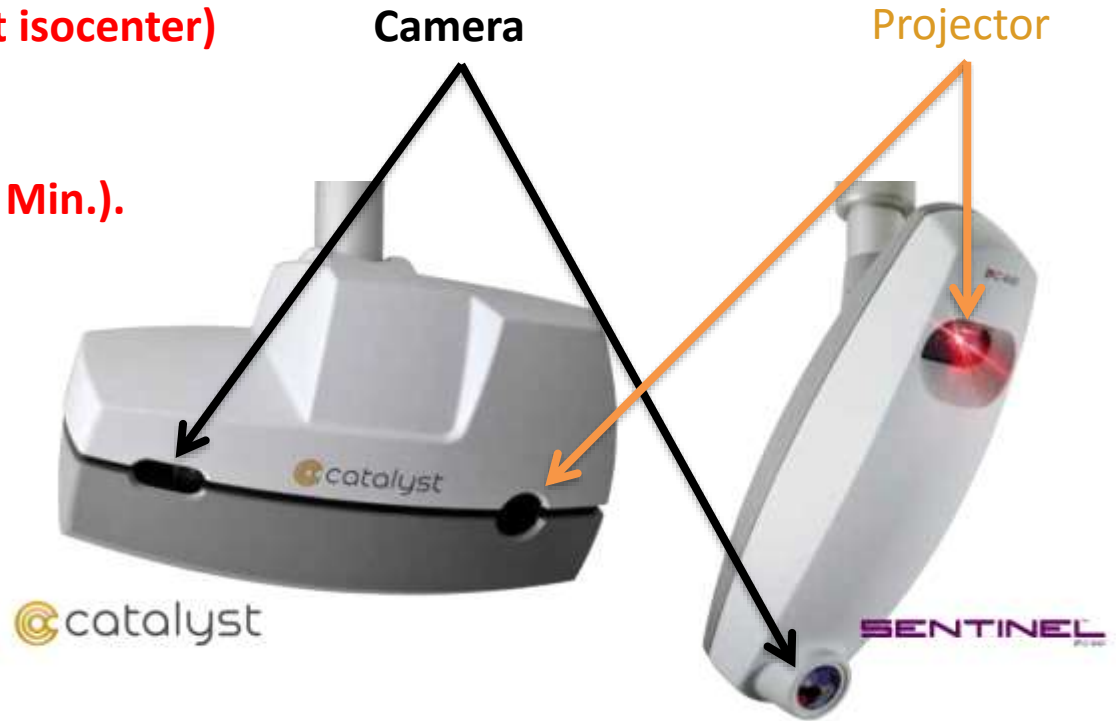
C-RAD ultra-precise (~ 0.1 mm at isocenter)

Room Lasers :

-) with dual-diode (red + green)
-) and automatic calibration (< 9 Min.).



For CT + RT Rooms



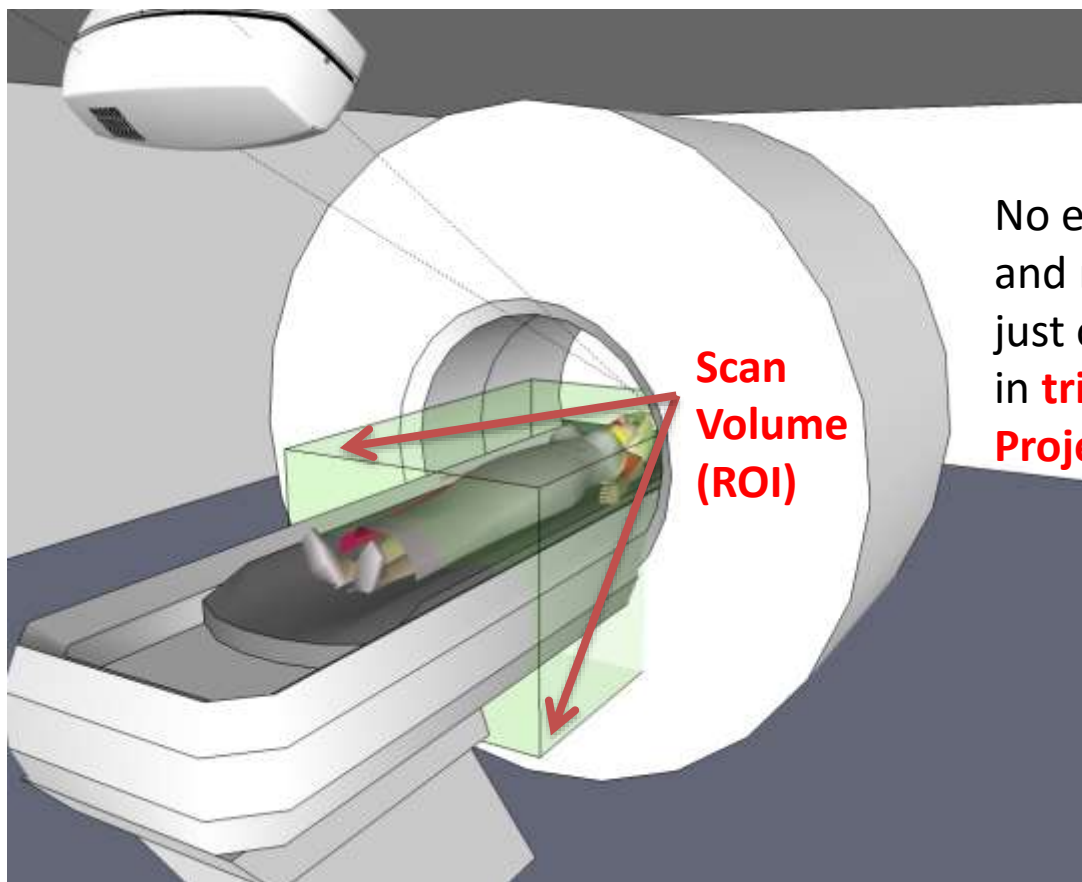
For RT Room

For CT Room

Measurement Principles and Patient ID

Projector

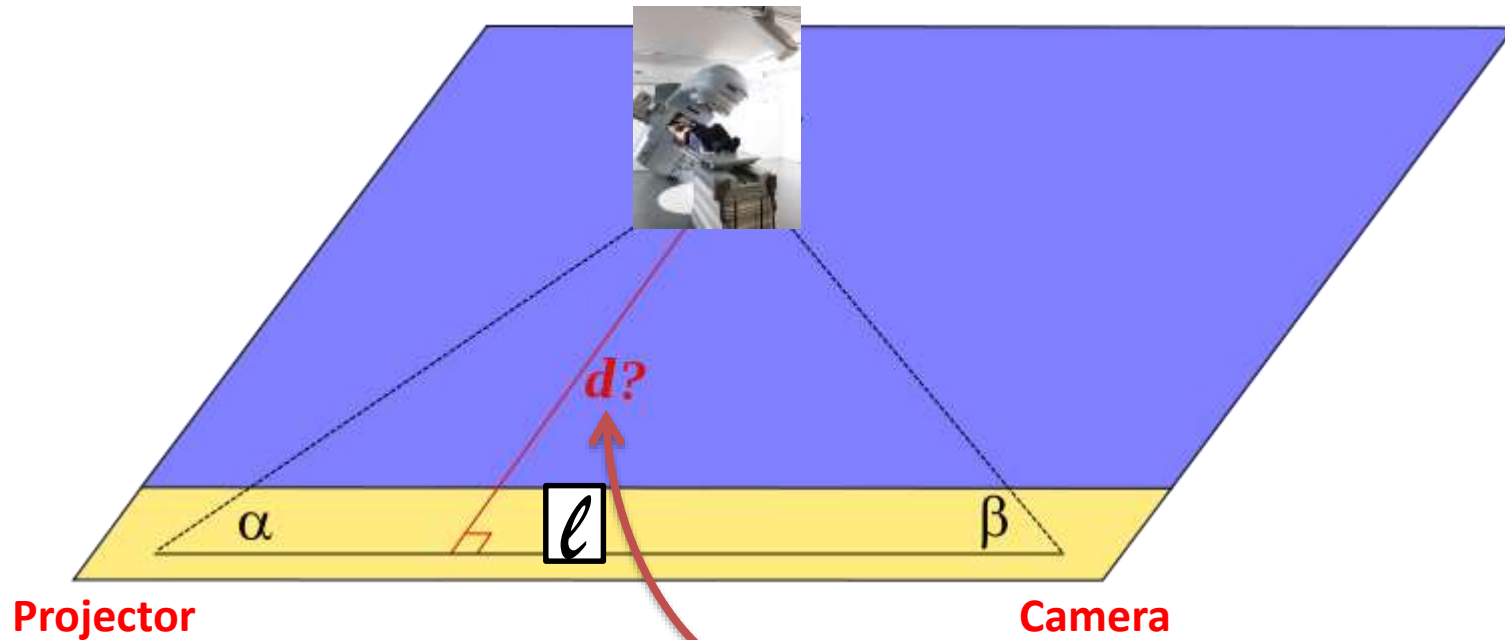
Camera



No extra ionizing radiation and no lasers, just optical LED cameras in **triangulation between Projector – Kamera – ROI**

Patient Vicinity and Safety infos also ...

Triangulation Method



We know that :

$$\tan \alpha = \sin \alpha / \cos \alpha$$

and that :

$$\sin(\alpha + \beta) = \sin \alpha \cos \beta + \cos \alpha \sin \beta$$

therefore :

$$\ell = \frac{d}{\tan \alpha} + \frac{d}{\tan \beta}$$

$$d = \ell / \left(\frac{1}{\tan \alpha} + \frac{1}{\tan \beta} \right)$$

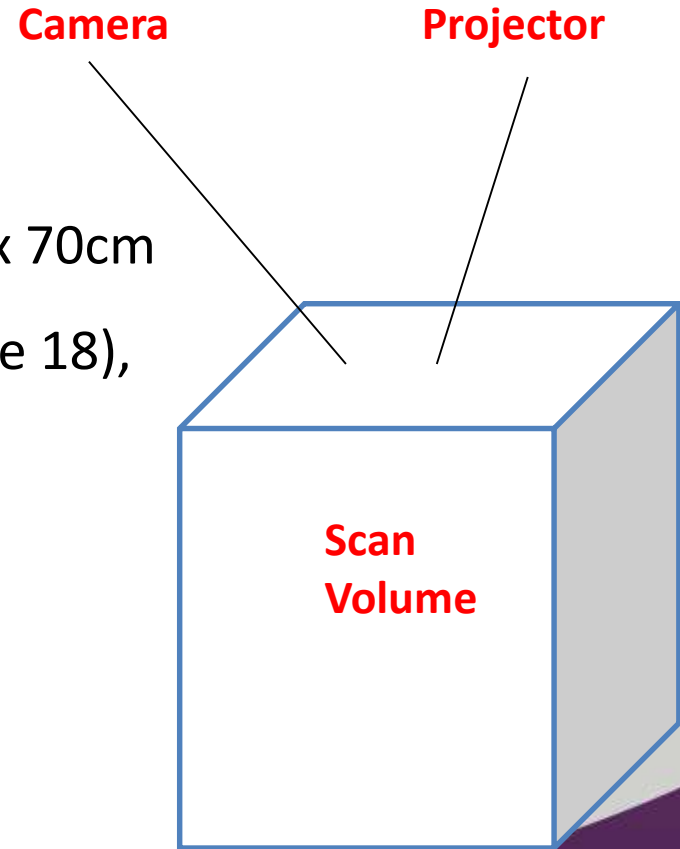
$$d = \frac{\ell \sin \alpha \sin \beta}{\sin(\alpha + \beta)}$$

Technical performances

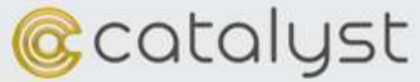
One Scan Volume (ROI): up to 80cm x 130cm x 70cm with elastic, non-rigid patient registration (Slide 18), and “crop” functionality.

Position & Safety accuracy: <1mm

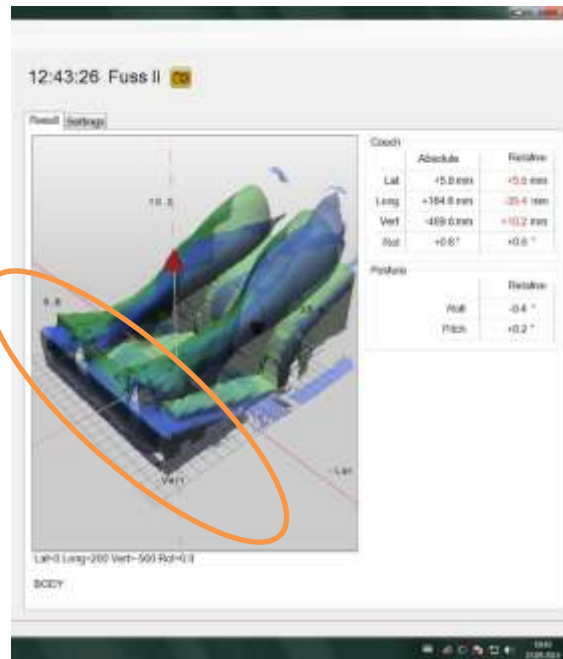
Motion detection & Safety accuracy: <1mm



Patient Vicinity and Safety



THE HIGH END
SOLUTION FOR
MOTION MANAGEMENT



SENTINEL

Workflow : Step 1 - CT



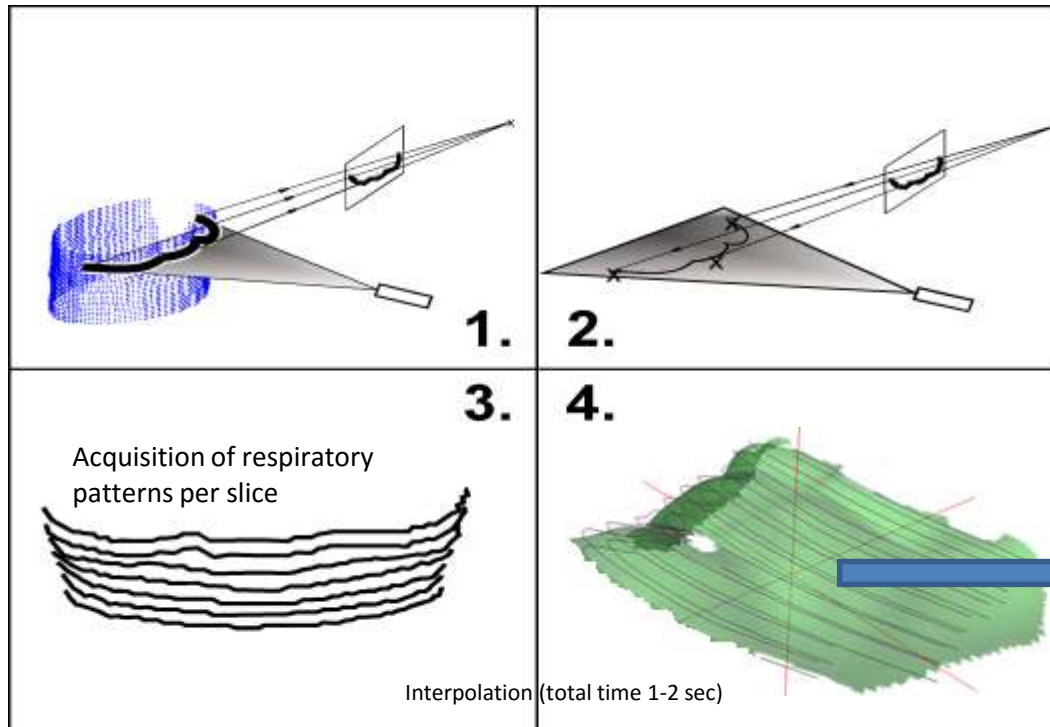
FOR YOUR CT-ROOM

***Sentinel addresses
two major 4DCT
tasks ... :***

SENTINEL

Workflow : Start am CT 1 of 2 : Surface detection as first reference image.

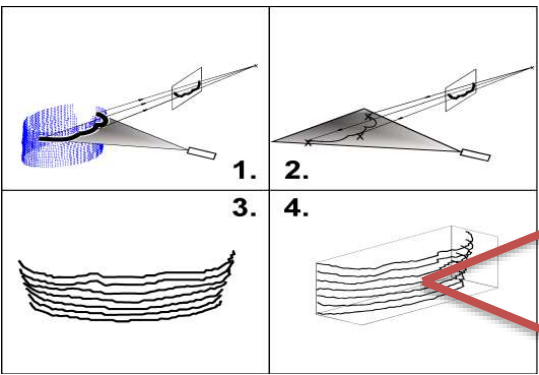
Optical triangulation via Sentinel in
CT Room



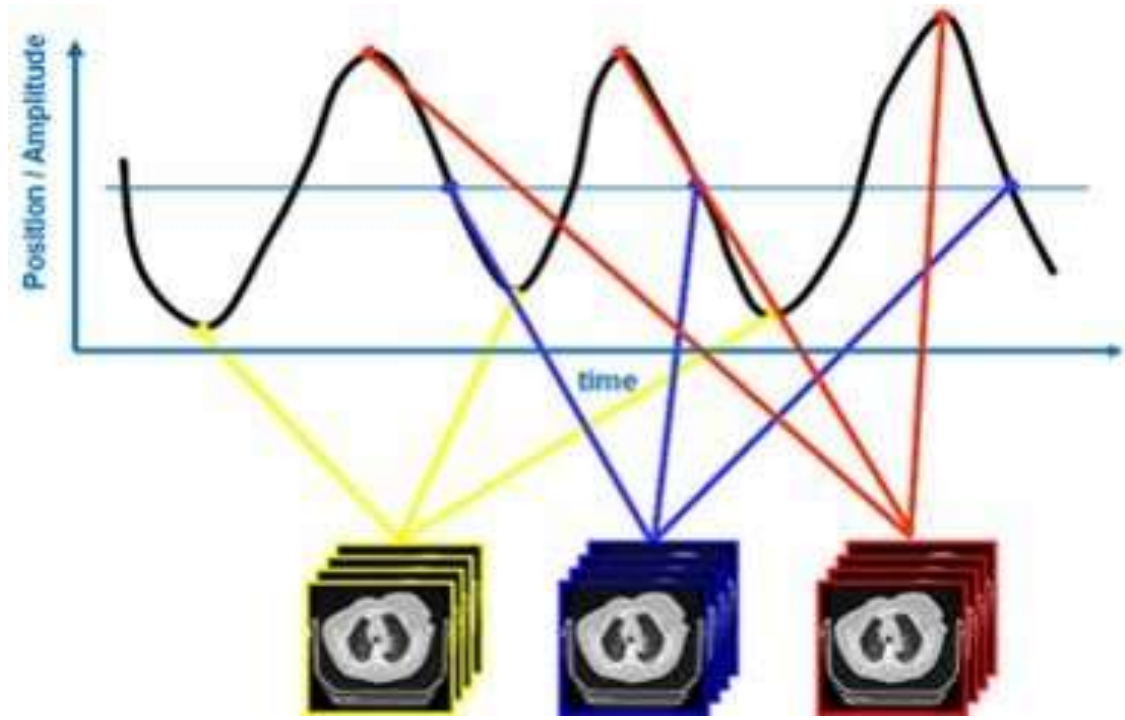
Multiple 3D point tracking with one unit, up to 50 times per second.

2 of 2 : Correlation CT <-> Breathing curves (Gating)

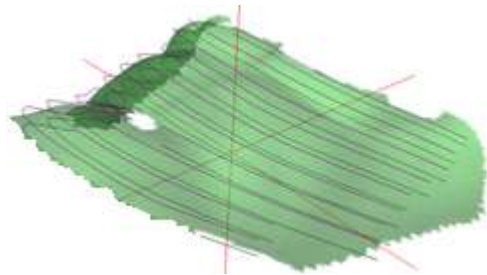
Sentinel



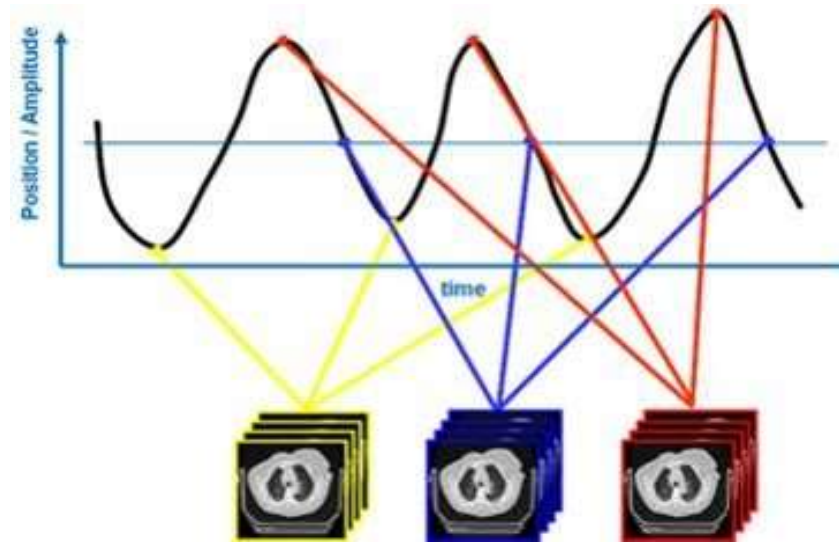
CT



Two Sentinel's Contributions are now available :



+



TPS informations !

First CTs Patient's Surface

+

Gating correlation

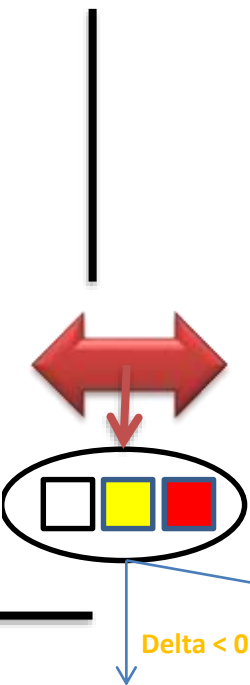
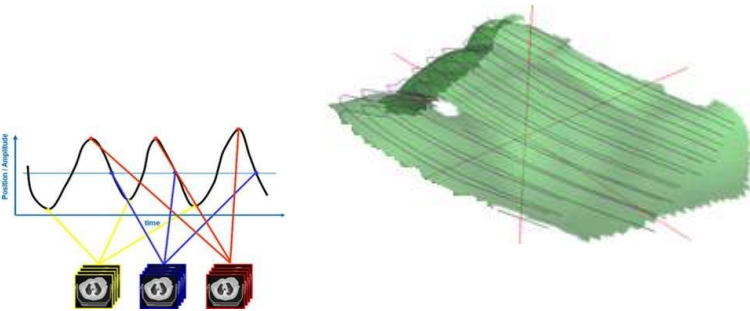
DICOM

to the
Catalyst
at Linac.

from CT Room
SENTINEL

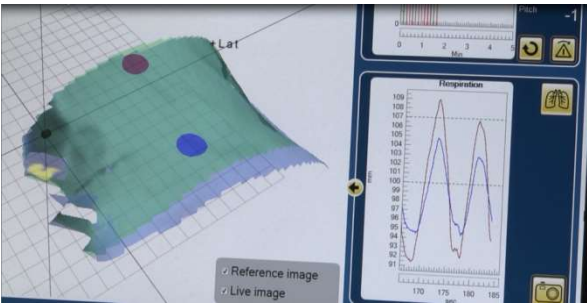
in RT Room
@catalyst

- **Again** : Patient's Surface (now, first fraction at the Linac)
+ local Gating



Delta < 0

Delta = 0
Delta > 0

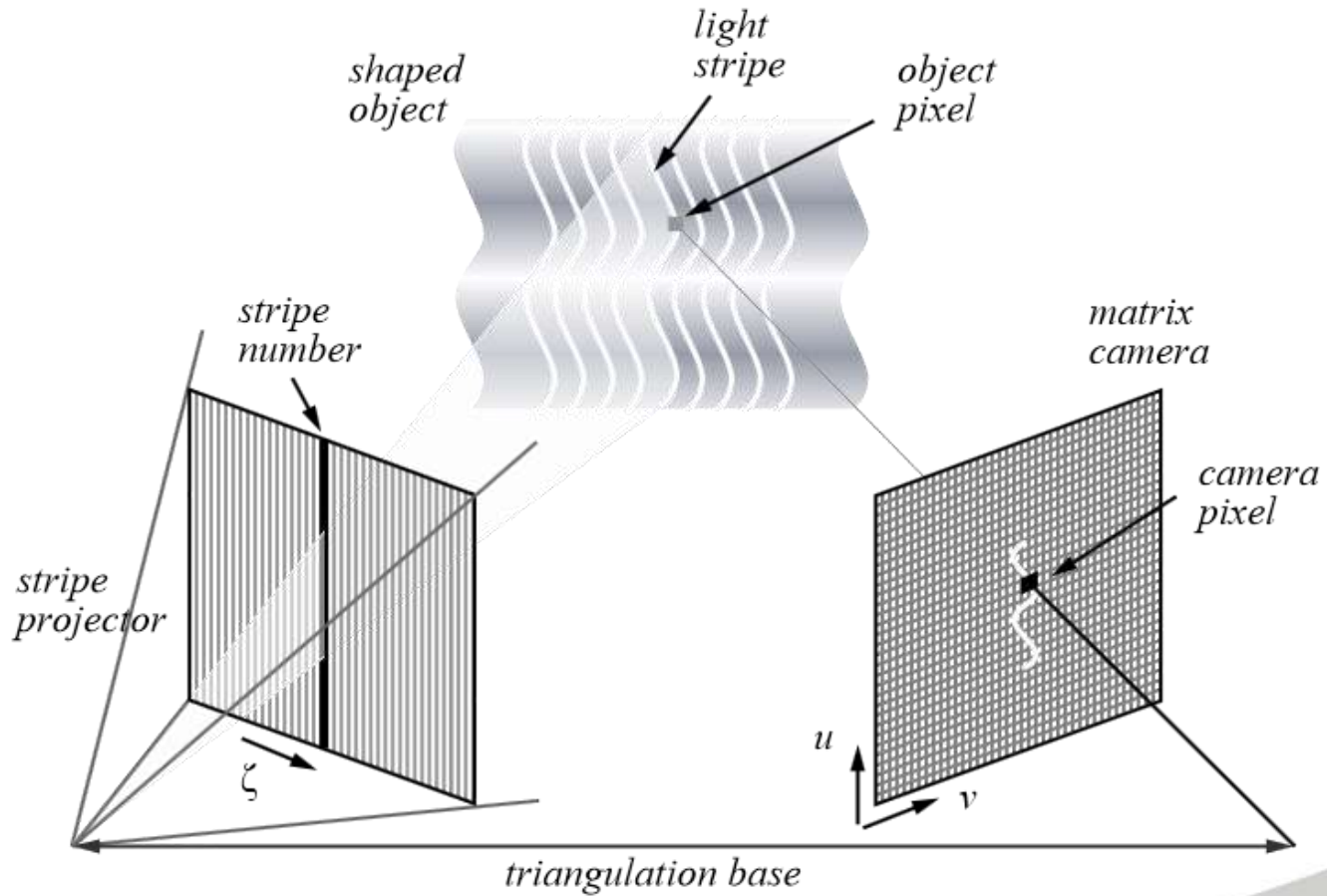


Gating at Linac

Back-projection,
Patient Vicinity & Safety

Isocenter


Catalyst Algorithm



Rückprojektion : Beispiel Torso Rotation

Muss nach **unten** (weil Rot ist)



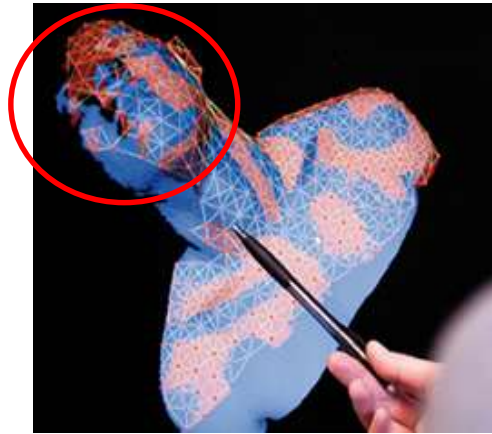
 catalyst

THE HIGH END
SOLUTION FOR
MOTION MANAGEMENT

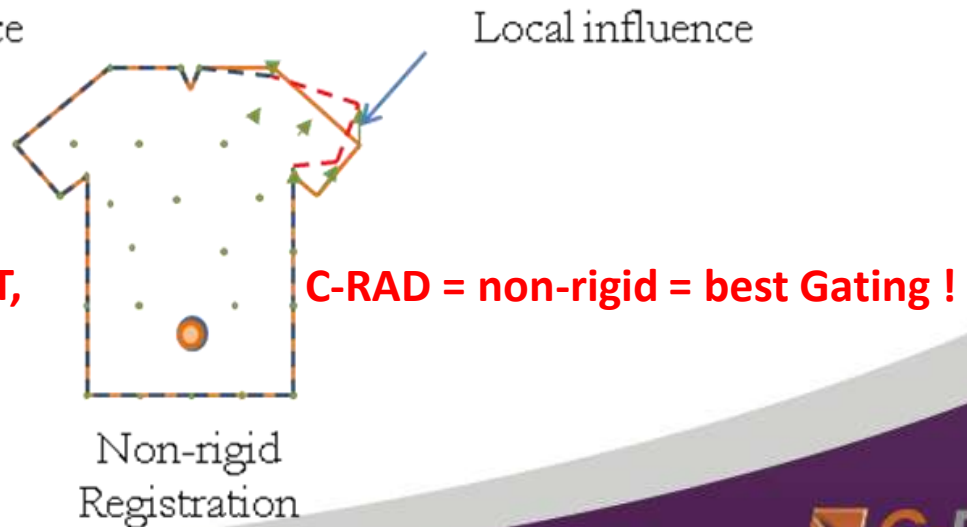
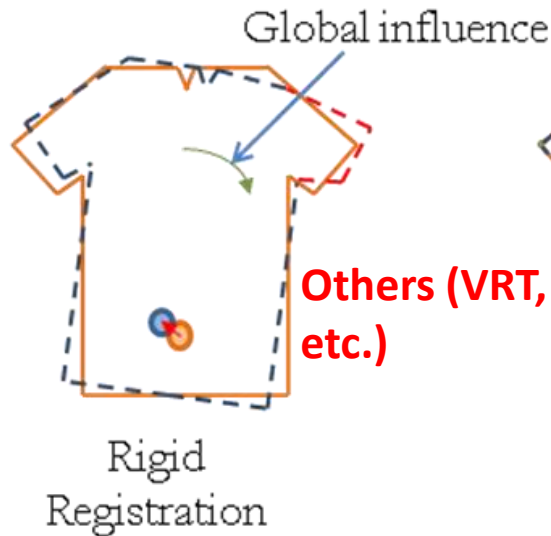
Muss nach **oben** (weil Gelb ist)

Sub-matrixes and non-rigid elastic registration

**Patient
recognition**



Linked, independent and elastic sub-matrixes on the patient's surface



Depth Sensor-Based Realtime Tumor Tracking for Accurate Radiation Therapy

Björn Nutti^{1,2} Åsa Kronander¹ Mattias Nilsing¹ Kristofer Maad¹ Cristina Svensson¹ Hao Li³

¹C-RAD Positioning AB ²AlgoritmFabriken AB ³University of Southern California

Abstract

We present an image guided radiation therapy (IGRT) system for tracking tumors in realtime based on continuous structured light imaging. While an accurate positioning of the radiation isocenter to pre-imaged cancer cells is critical to minimize the risk of damaging healthy tissues, patients undergo involuntary motions such as breathing or unpredictable gestures during treatment. Moreover, multiple sessions are typically necessary and repositioning the patient accurately can be difficult. Our approach consists of determining the tumor position by densely tracking the deformation of a stream of 3D scans using a realtime variant of a state-of-the-art non-rigid registration algorithm and an FEM simulation on the interior body. We use interactive reprojection for visual guidance to adjust the posture of the patient and couch position, depending on the tumor location. Compared to existing techniques, our method uniquely estimates tumor deviations under body deformations. Our pipeline has been successfully commercialized as part of the C-RAD AB Catalyst™ product line and is already deployed in a number of hospitals.

Guaranteed Accuracy Performances :

Long term stability:	Within 0.3 mm
Measurement reproducibility:	0.2 mm
Frame Rate:	200 frames/s
Positioning accuracy Catalyst	Within 1 mm for rigid body
Positioning accuracy CatalystHD	Within 0.5 mm for rigid body
Motion detection accuracy Catalyst	Within 1 mm for rigid body when couch is in fixed position during treatment Within 3 mm for rigid body when couch is moving during treatment (e.g. Tomotherapy)
Motion detection accuracy CatalystHD	Within 0.5 mm for rigid body when couch is in fixed position during treatment
cRespiration detection accuracy	Within 1 mm for rigid body

Modules (min. 1 must be configured) :



... always present and monitoring the ROI in real-time ...



Patient setup, Positioning and Vicinity Recognition (Module)

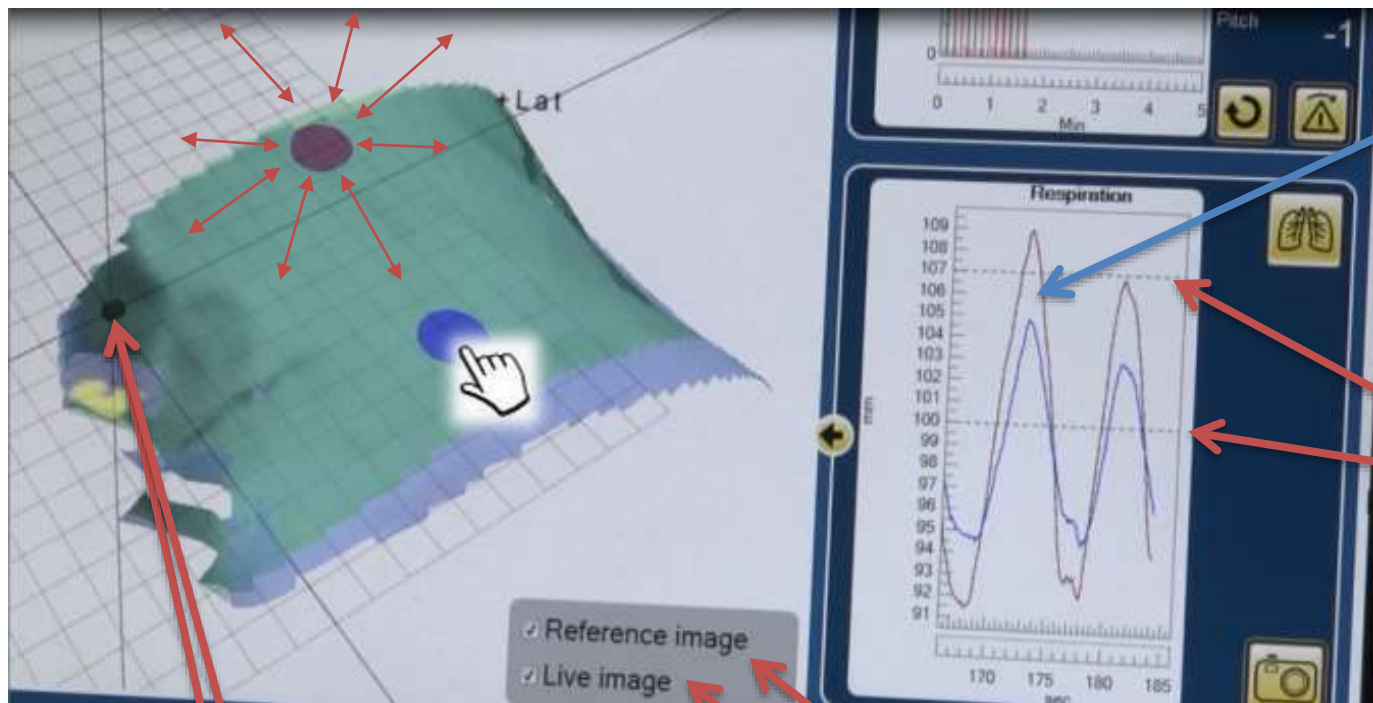


Motion detection (Module)



Respiratory gating (Module)

Respiratory Gating with the Catalyst in Linac Room (with Touch Screen Option) with non-rigid registr.



Real-time Measurements (free breathing) in Linac Room

From CT for free-breathing and DIBH

1) Tumor's Isocenter

2) Linac = Catalyst Isocenter

From Sentinel - CT

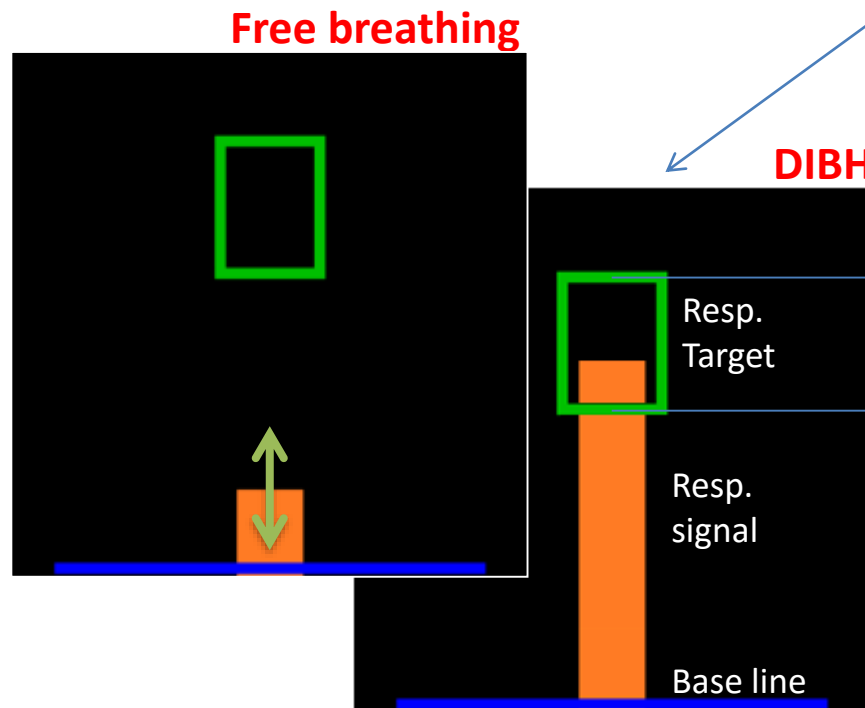
From Catalyst - Linac

Respiratory gating / coaching for "Deep Inspiration Breath Hold" (DIBH)



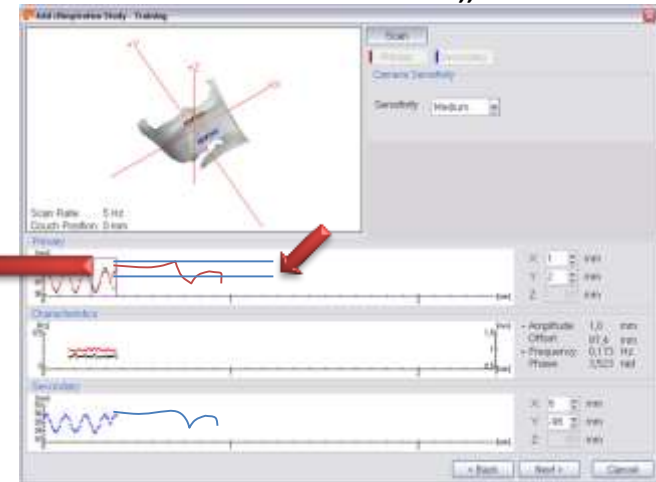
„Catalyst“
RT ← CT
„Sentinel“

Patient's Visual feedback

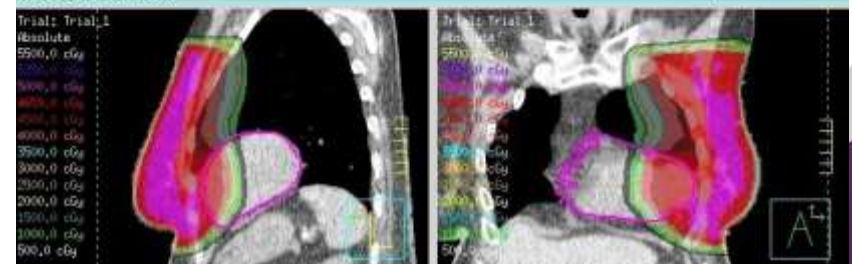
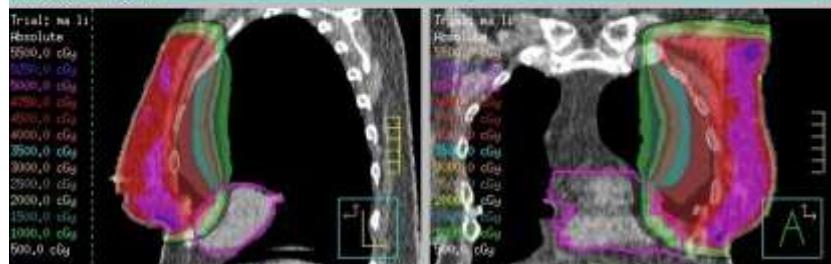


Exported via DICOM

from 4DCT „Sentinel“



Dosimetrical comparison between Plans in DIBH and free breathing via C-RAD Goggles.



1-camera vs. 3-camera Upgrade and final Installation



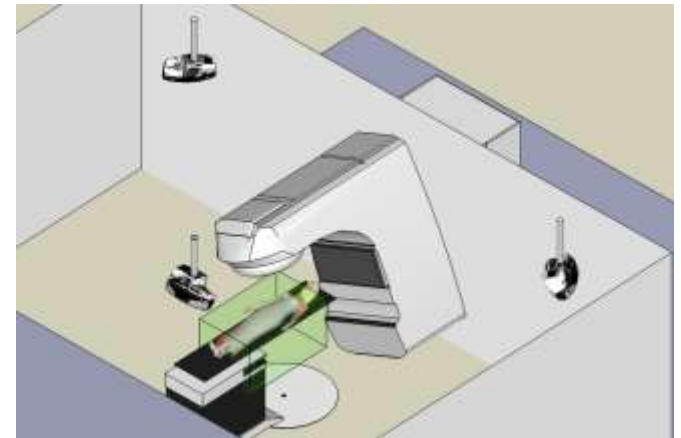
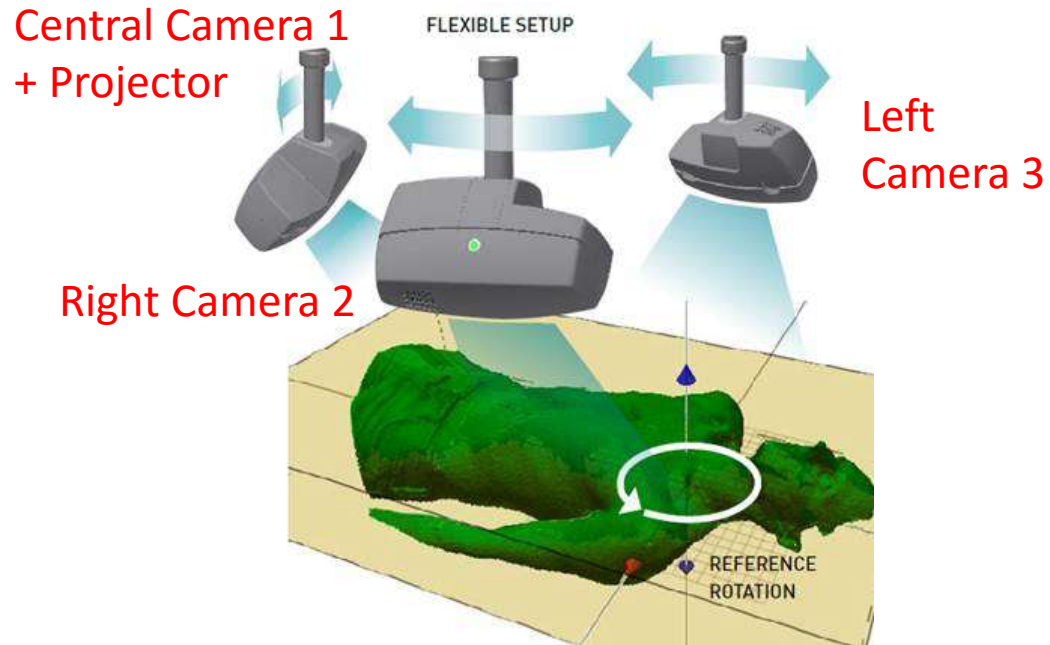
3-Camera Catalyst PT with IBA Interface



Iba

... other Vendors Interfaces
coming soon ...

3-Camera Solution

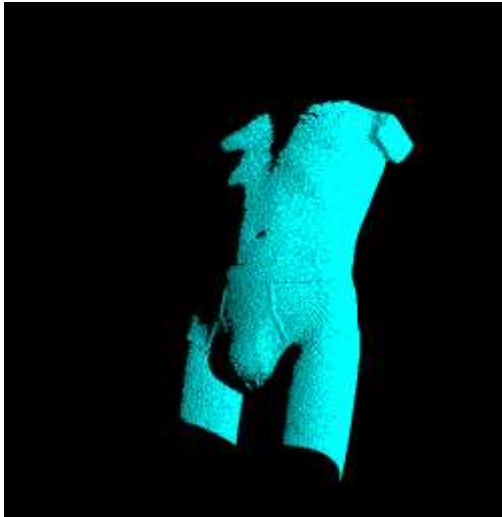


3-Camera Solution KFJ Spital – Wien –

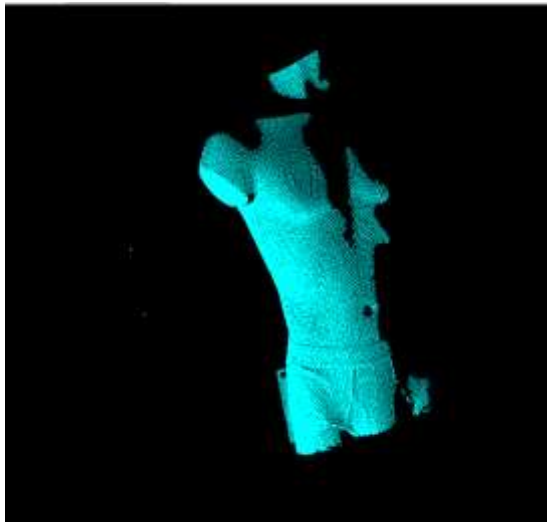


- Also for Stereotactic and PT Treatments
- Full Patient Surface coverage
- Monitoring independent from couch kicks

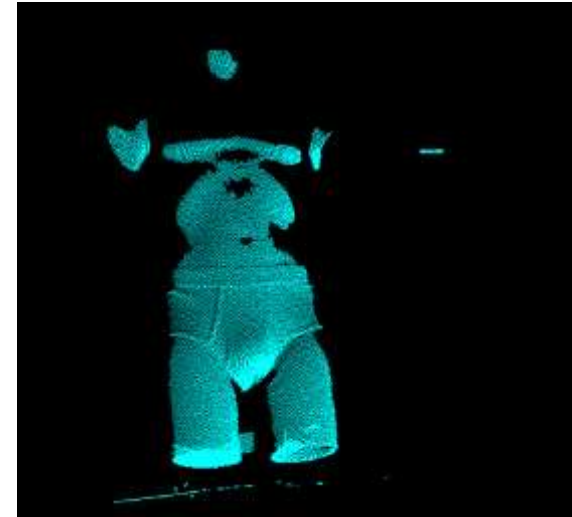
Right Camera 2



Left Camera 3

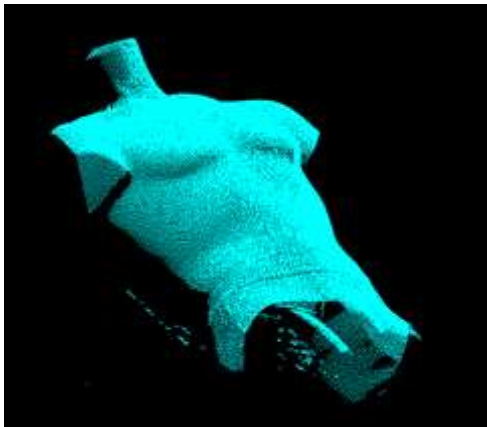


Central Camera 1

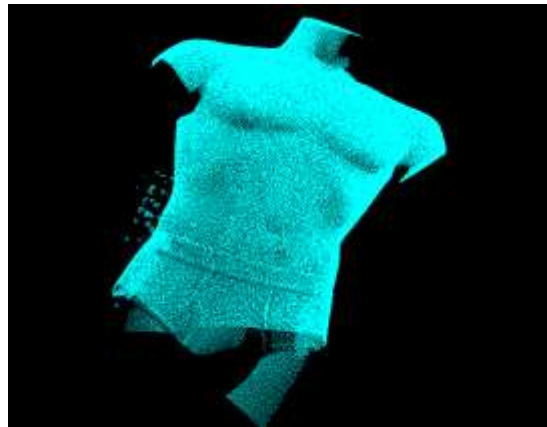


Camera
Shots

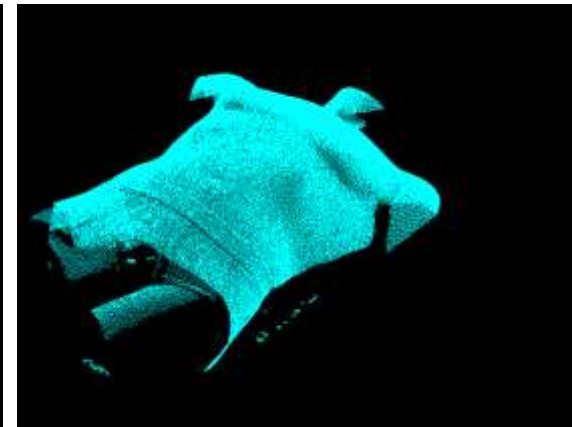
Composite
Global
Views
(**R2+L3+C1**
Camera Shots
Super-
impositions)



Right View

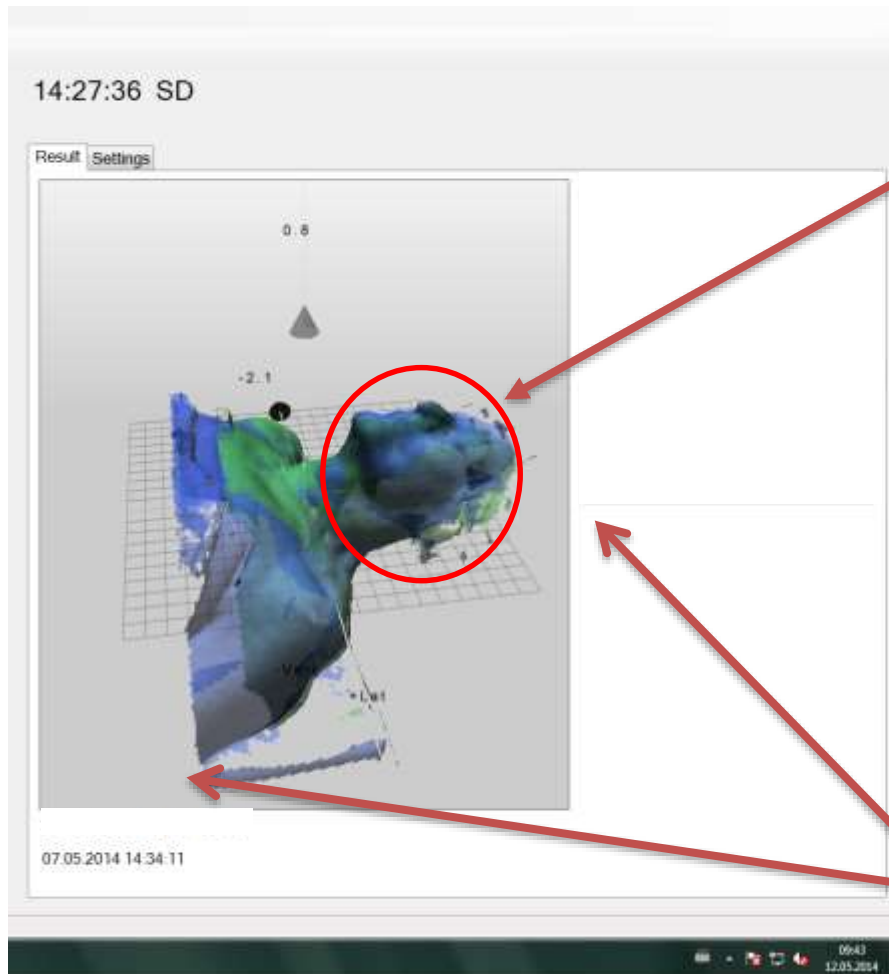


Central View



Left View

3-Camera Catalyst Stereotactic Report with Screen View



Patient Vicinity Recognition

Benefits for Stereotactic Applications :

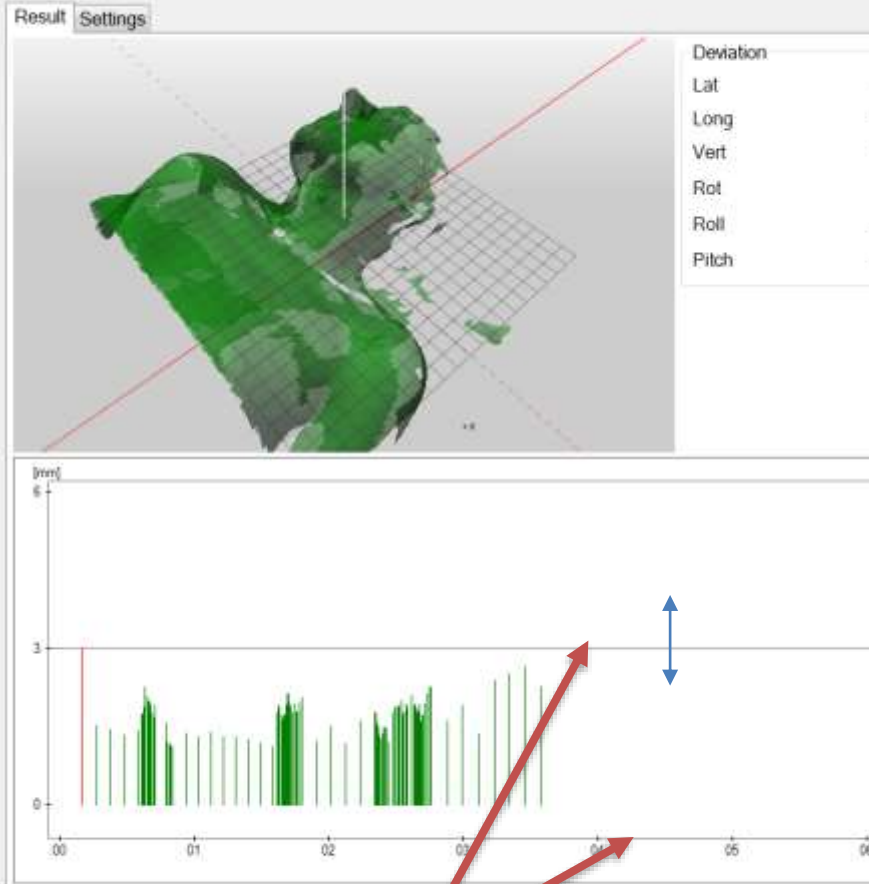
- 1) Full patient coverage indep. from couch kicks
- 2) Positioning, Patient Vicinity
- 3) Motion
- 4) Gating
- 5) Audio/Vidual (Googles)
- 6) Non-rigid Algorithm

Critical Angles / Views

→ Instant verification of postural errors (shoulder and head rotation)

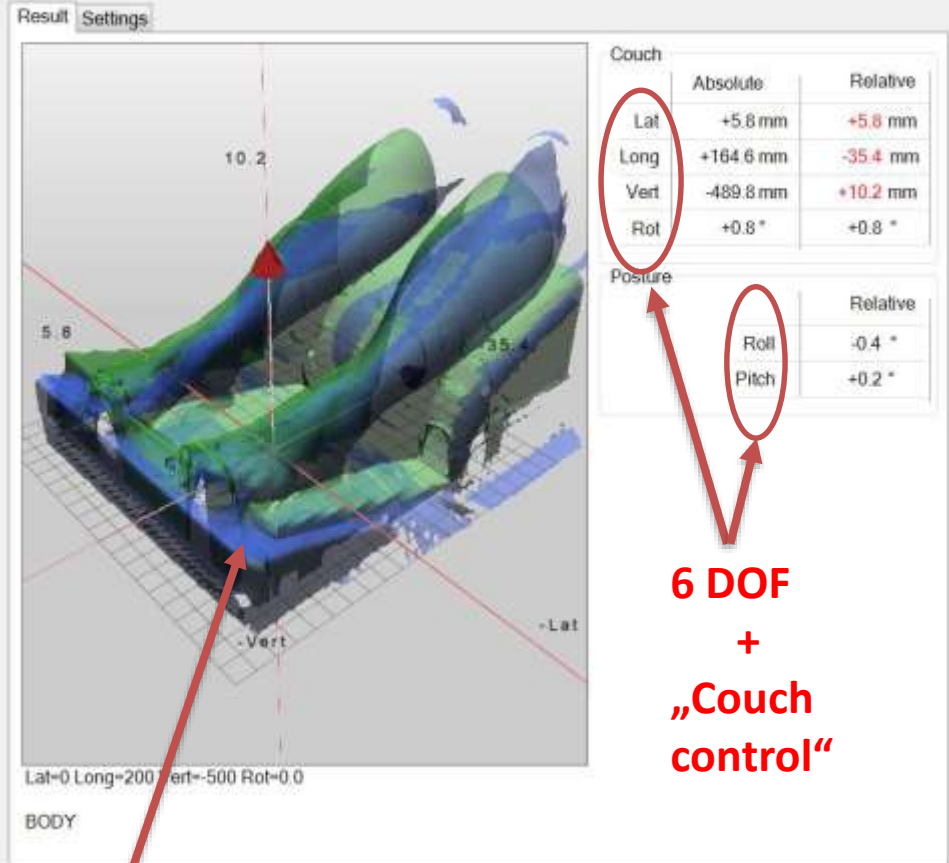
„Patient Vicinity“ und Sicherheit :

13:51:38 Hals li



Sicherheitsfenster
(konfigurierbar)

12:43:26 Fuss li 📷



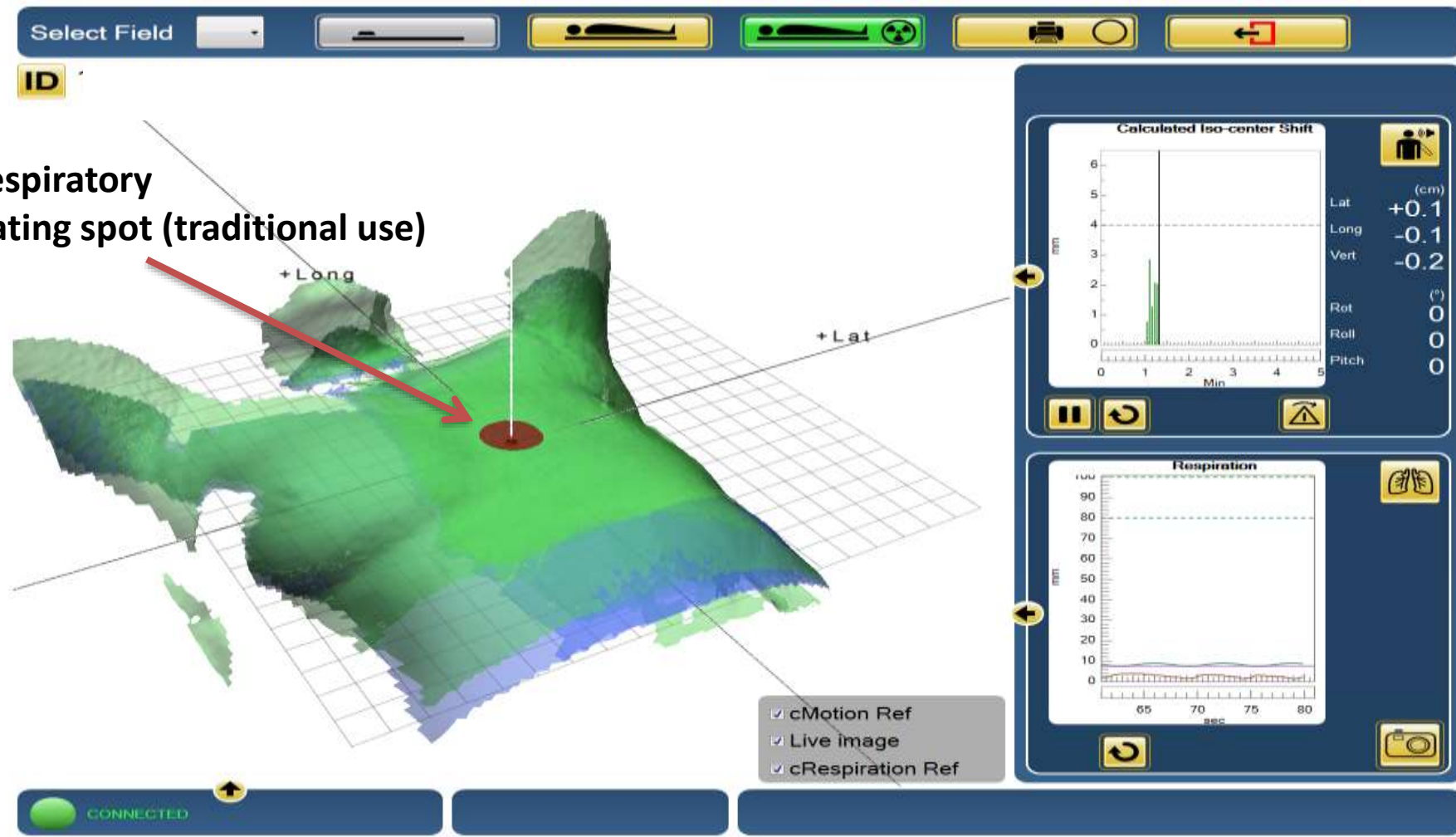
Lagerungshilfe Informationen ...

6 DOF
+
„Couch control“

Flexibilität des Systems ... mit / ohne Brille



Respiratory
Gating spot (traditional use)



Head & Neck ... ohne Masken ... (Sweden)

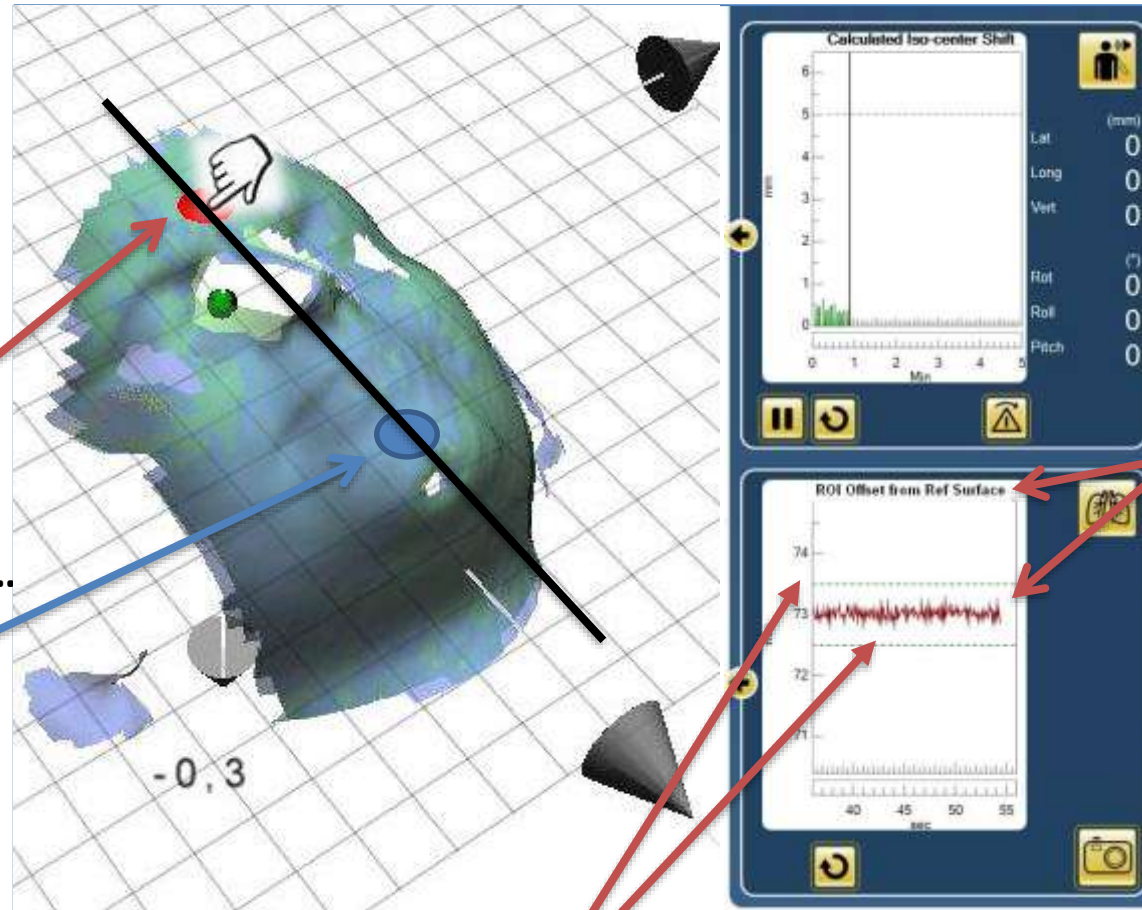
“Reduced fixation with optical monitoring for palliative whole brain radiotherapy treatment”.

Silke Engelholm at al.

Radiation Physics, Skåne University Hospital, Lund, Sweden

„Gating“ primary spot ...

Secondary spot



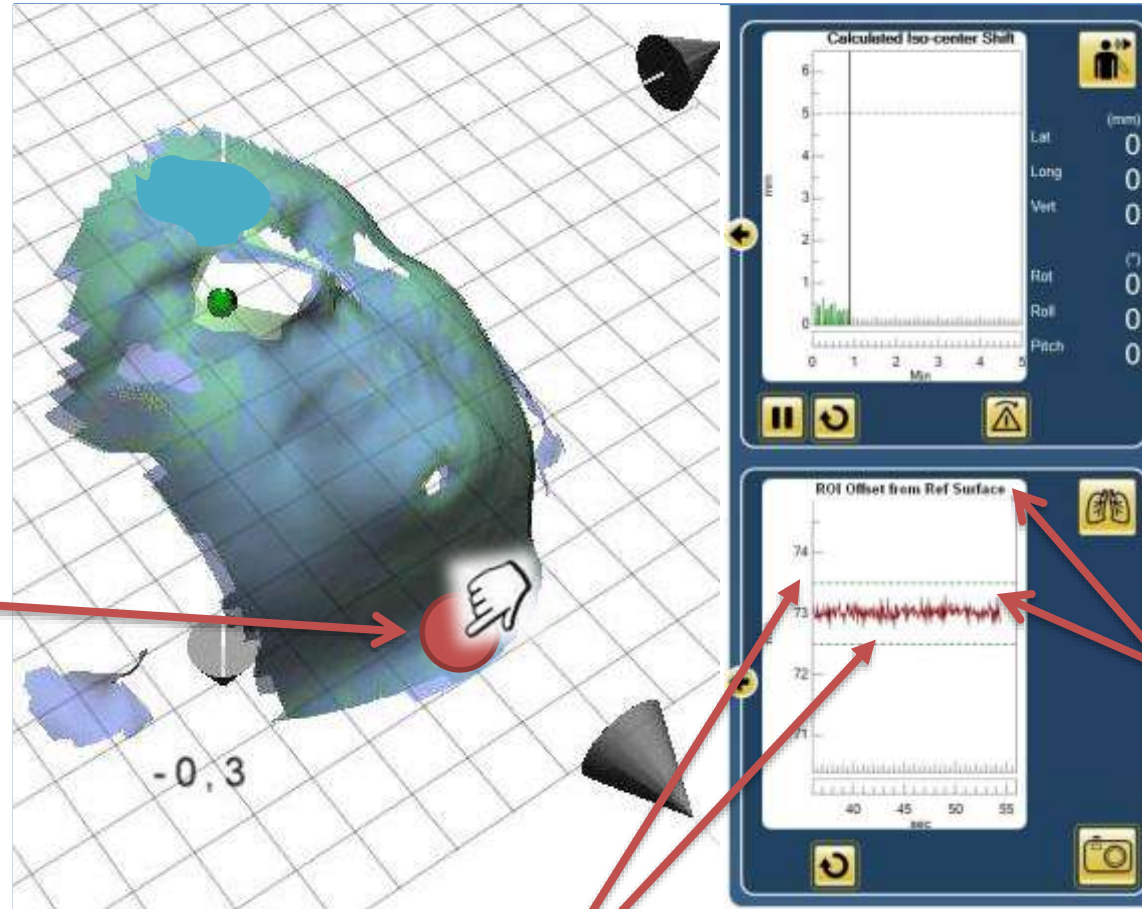
Sicherheitsfenster

Head & Neck ... ohne Masken ... (USA)

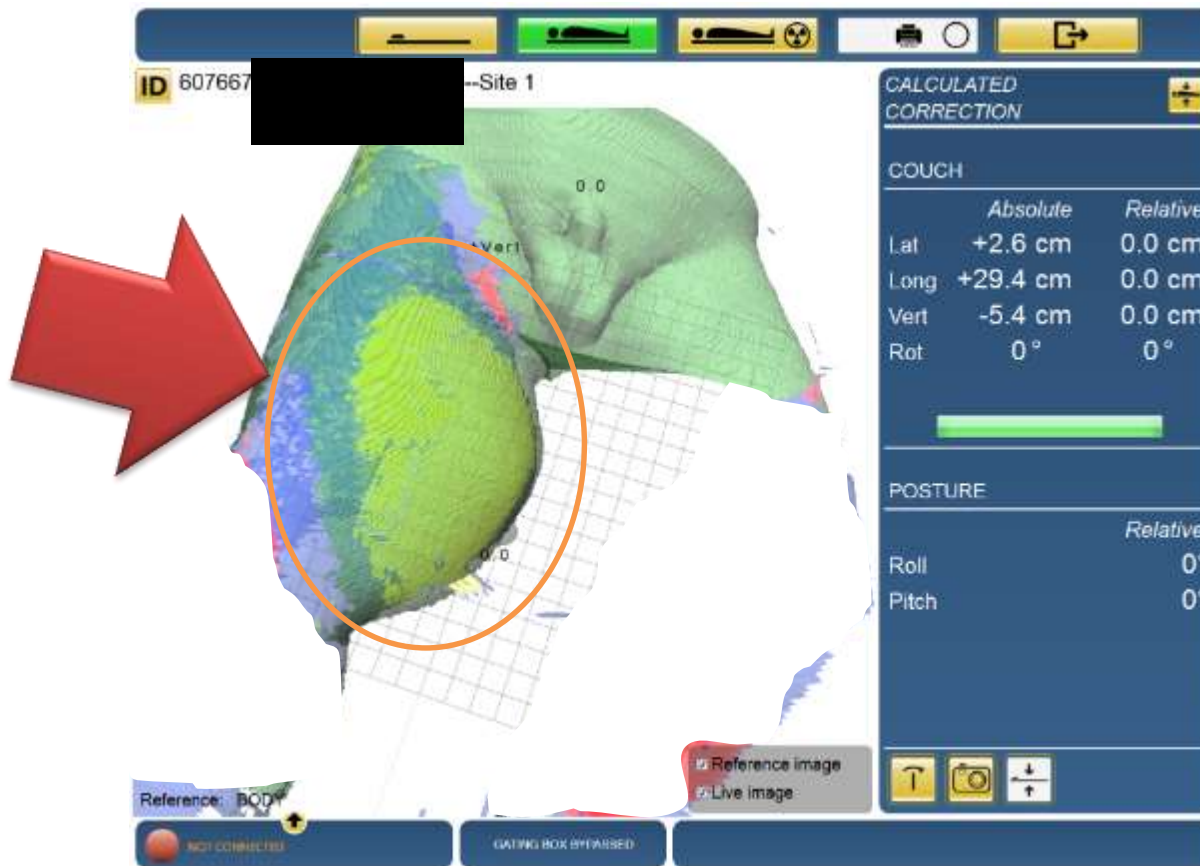
“Application of Surface Mapping in detecting Swallowing for Head & Neck Cancer”

David Shepard et al. - Swedish Hospital Seattle, USA

„Gating“ spot ...



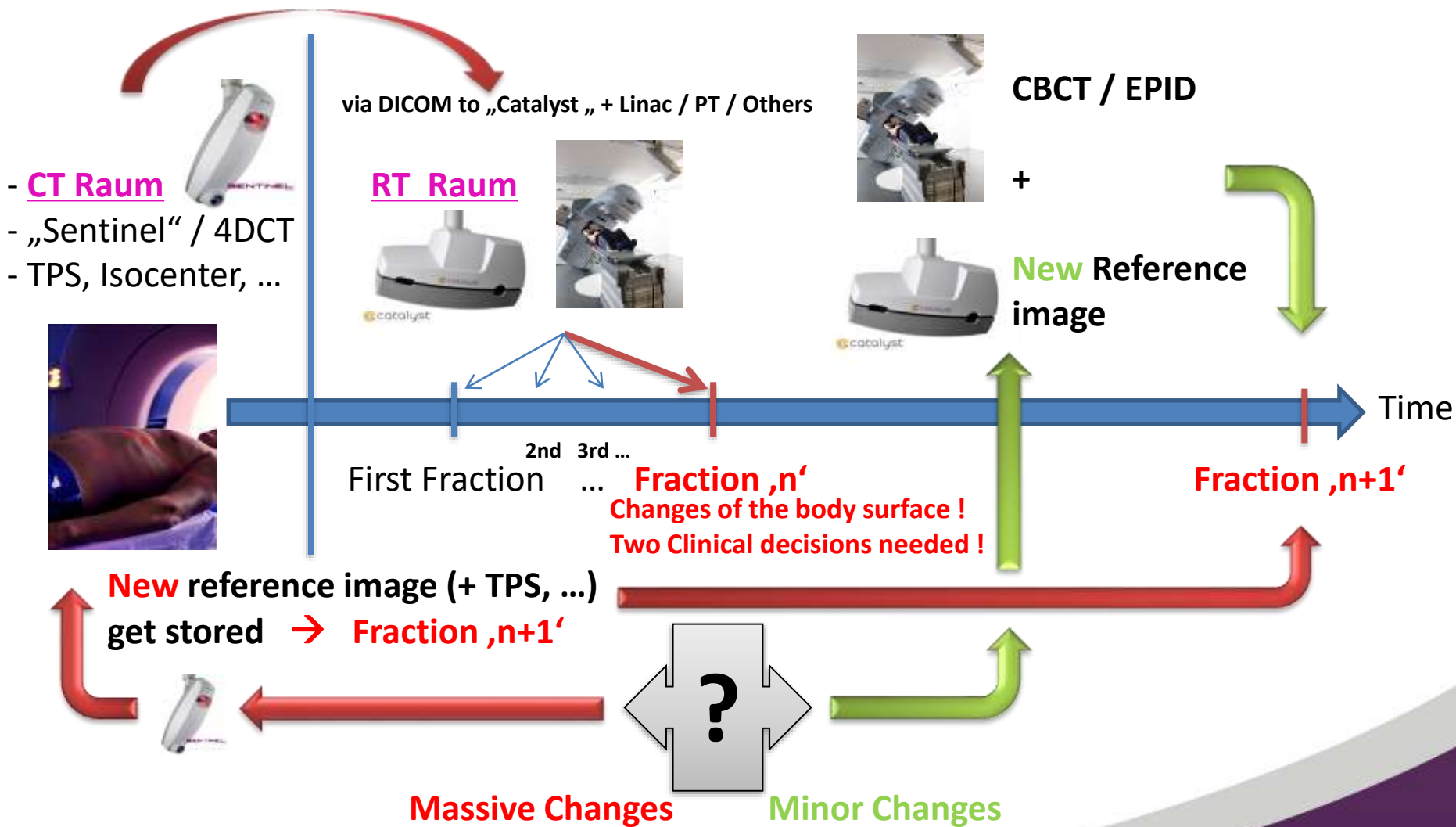
Sarcoma Positioning after / during Pharmaceutical Treatment (with “crop” function)



C-RAD Catalyst's „cPositioning“ shows fraction-by-fraction surface changes ...

Has the patient's surface **changed** after the first fractions ?

Always a safe dynamic Workflow :



Clinical Training Process

Technical Training as part of the Installation

Target group: Physicist and Lead Therapist

Performed by: C-RAD Installation Engineer

4 hours

On-Site Clinical Application Training

Target Group: Physicians, Physicists and all therapists

Performed by: C-RAD Clinical Application Specialist

3 days

Optional: C-RAD Training center

Target group: "Super user"

2 days

Follow up On-Site Clinical Application Training

Target Group: Physicians, Physicists and all therapists

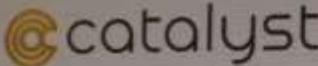
Performed by: C-RAD Clinical Application Specialist

2-3 days

Training and support on demand

Reporting

(on screen and in .pdf)

 Patient: AIRO 2014 Padova
Patient ID: 1234
Personal ID:
Room: Room 1
Scanner: Catalyst

Patient session report

Summary

Start time: 09.11.2014 14:52:45
End time: 09.11.2014 15:07:18
Comment:

cPosition Results

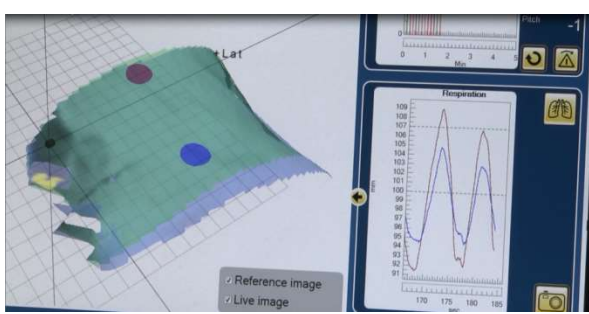
Date	Site	Reference	Lat (mm)	Long (mm)	Vert (mm)	Rot (°)	Roll (°)	Pitch (°)
09.11.2014 15:02:05	Default	09.11.2014 10:42:20	+19,7	+21,8	+1,3	-4,1	0,0	0,0
09.11.2014 15:02:30	Default	09.11.2014 10:42:20	+19,7	+21,8	+1,3	-4,2	+0,1	0,0
09.11.2014 15:03:43	Default	09.11.2014 15:02:33	+0,1	-0,1	+0,4	0,0	-0,1	+0,1
09.11.2014 15:04:04	Default	09.11.2014 15:02:33	+0,3	-0,1	+0,5	0,0	-0,1	+0,1
09.11.2014 15:05:18	Default	09.11.2014 15:02:33	-0,2	+2,2	+0,7	-0,4	0,0	0,0

cMotion Results

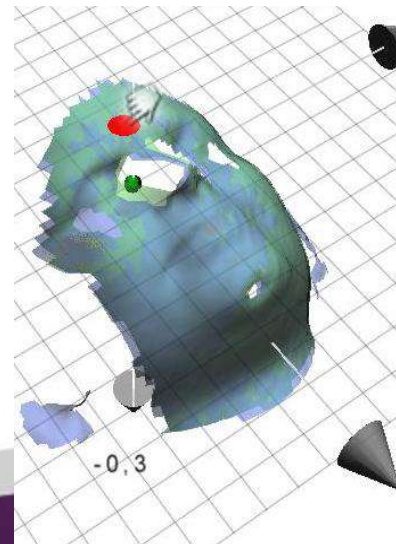
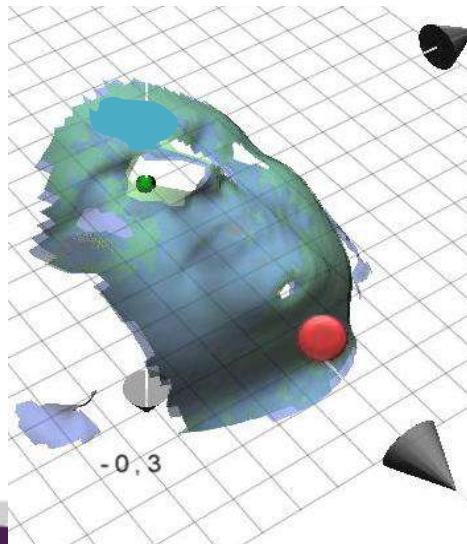
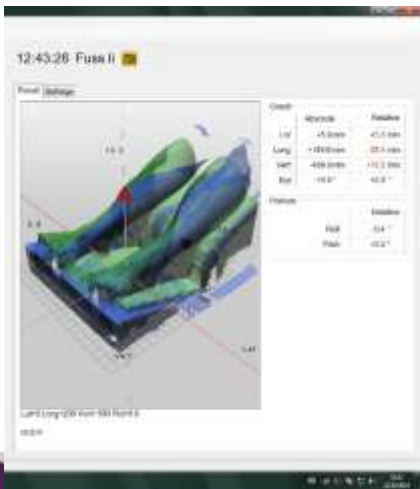
Date	Duration	Site	Max deviation (mm)	Tolerance (mm)
09.11.2014 15:05:27	00:01:51	Default	26	5,0
09.11.2014 15:04:08	00:00:02	Default	-	5,0

cRespiration Results

Date	Duration	Site	Reference
09.11.2014 15:04:08	00:00:01	Default	08.11.2014 10:47:11
09.11.2014 15:05:27	00:01:51	Default	08.11.2014 10:47:11



- 1) 1- bis 3-Kamera im Linac Raum
- 2) Immer in Real-time und kontinuierlich
- 3) Patient vicinity & recognition
- 4) Ohne Markers, Blocks, Belts, etc.
- 5) Flexibilität
- 6) Rückprojektion für Lagerung
- 7) Gating free breathing und DIBH
- 8) Bewegungsmonitoring
- 9) Nicht-rigide Registrierung
- 10) Alle CTs, Linacs, Tomo und PT ABI.



„Installed base“ C-RAD Systeme in DACH :

„Sentinel“ (CT Raum) : 15

„Catalysts“ (Behandl. Raum) : 27

(„Catalysts HD“ (Behandl. Raum) : **10 (*)**)

C-RAD „HIT“ Raum Lasers : 7

Gesamt : 47 C-RAD Systeme - Deutschsprachige Länder
(Status ende März 2016)

Publikationen : aus LMU, UMM, Uni Mainz, Gelsenkirchen, etc.

Uni Kliniken mit C-RAD : Aachen, Mainz, LMU x 2, UMM, Bonn, Köln, Essen.

(*) : 3-Kamera Version

Hepp R, Ammerpohl M, Morgenstern C, Niolinger L, Erichsen P, Abdallah A, Galalae R. Deep inspiration breath-hold (DIBH) radiotherapy in left-sided breast cancer : Dosimetrical comparison and clinical feasibility in 20 patients. *Strahlenther Onkol.* 2015 Apr 18. [Epub ahead of print]

Deep inspiration breath-hold (DIBH) Radiotherapy in left-sided breast cancer: Dosimetrical comparison and clinical feasibility in 20 patients

Bestrahlung der linken Brust in tiefer Inspiration und Atemhaltetechnik (DIBH) bei linksseitigem Brustkrebs: Dosimetrischer Vergleich und Prüfung der klinischen Durchführbarkeit in 20 Patientinnen.

Rodrigo Hepp M.D.¹,
Niolinger^{1,2} B.Eng., P.
M.D.

¹Klinik für Strahlentherapie
Evangelische Kliniken

²Hochschule Hamm-L.

³Klinik für Senologie
Evangelische Kliniken

⁴Medizinische Fakultät

Corresponding Author

Dr. med. Rodrigo Hepp
Klinik für Strahlentherapie
Evangelische Kliniken

Munckelstraße 27
45879 Gelsenkirchen

Tel: +49 209 160 3001
Fax: +49 209 160 304
e-mail: heppdelosirio

Sentinel/Catalyst surface tracking system for respiratory gating. Tests performed at Skåne University Hospital, SUS, Malmö.

Charlotte Thornberg, Mattias Jönsson, Sofie Cederberg, Malin Kugler, Fredrik Nordström

Introduction

In radiation treatment, gating can be used in different ways to minimize the absorbed dose to risk organs. A positive correlation has been observed between cardiac dose-volume and the level of excess risk of cardiac mortality from ischemic heart disease [1] as well as between the irradiated lung volume and radiation pneumonitis [2]. Respiratory gating for breast cancer patients is a simple and straightforward way to reduce the absorbed dose to the heart and lungs [3]. In Malmö, gating of left-sided breast cancer patients has been in use clinically since 2007 (Varian Real-time Position Management (RPM) system). A Sentinel system was installed in 2009 for evaluation and development of gating functionalities. In 2011, the Sentinel system in the treatment room was moved to the CT room and replaced by a Catalyst system.

This report describes some of the initial tests performed in the implementation of the gating functionality, as well as comparisons with the RPM system.

Material and methods

Catalyst

The Catalyst system is installed in connection with two treatment machines (Varian X 2100 Clinac), and there is also a system in a training room for gating evaluation. Measurement in the Catalyst system is based on the principle of optical triangulation. A rapid and near-invisible sequence of patterns is projected onto the surface of the object to be measured. At the same time, images are captured by a camera, which is mounted at an angle from the projector. By analyzing the recorded image sequence, a high-resolution 3D surface model can immediately be reconstructed. A complete surface can be captured in fractions of a second, with an accuracy of a few tenths of a millimeter – measured at a distance of several meters away.



Fig. 3. The Catalyst system

Application of Surface Mapping in Detecting Swallowing for Head-&-Neck Cancer

Daliang Cao, Xin Xie, Vivek Mehta, David M. Shepard
Swedish Cancer Institute, Seattle, WA

Introduction	Methods & Materials	Results	Conclusions
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Swallowing (either voluntary or involuntary) during radiotherapy may introduce errors in actual tissue motion that is not accounted for in standard radiation treatment plans. VMAT and IMRT plans may be more prone to suboptimal treatment results if swallowing motion is significant. Future evidence suggests that long-term swallowing recovery after head and neck radiotherapy may be improved if the dose to the swallowing structures can be limited. Head-&-Neck cancer radiotherapy typically uses a mask to immobilize the patient. The mask does not restrict either voluntary or involuntary swallowing. In some respects, the mask may limit the observation/measurement of this event. CBCT in portal film cannot effectively monitor such a target motion. While fluoroscopy images may detect the swallowing motion, it introduces extra radiation dose. Surface mapping techniques provide an opportunity for continuous high-resolution motion monitoring without using ionizing radiation. We therefore carried out the study of using C-RAD Catalyst surface mapping system to test the feasibility of measuring patient swallowing during treatment. We also evaluated the accuracy of the method.

The C-RAD Catalyst system and track volometer being installed in the pre-Catalyst system to create any invasive shifts. The Catalyst system is very close to it made the video more accurate to show in Figure placed on the posterior side. The dependence of mapping table placement, we investigate, can be other one is possible.

The actual patient was not in use the system in motion.



Figure 1: The Catalyst system and the video on the floor in the CT room in the motion.

Image-guided radiotherapy (IGRT) reduces setup errors and thus minimizes the margin between clinical target volume (CTV) and planning target volume (PTV). Two-dimensional (2D) image guidance with the therapy beam enables matching/positioning relative to bony structures only [1]. Cone-beam computed tomography (CBCT) has been widely adopted and provides the most accurate patient positioning with a relatively low cost imaging dose to the patient [1, 2]. A re-positioning strategy based on target motion during dose delivery in the treatment of lung and liver metastases. Multiple strategies have been developed to compensate for the manufacturing tolerances [3].

An alternative positioning strategy is based on surface tracking. The patient surface scan is compared to the reference surface (based on planning CT) and a shift vector is calculated [4, 5, 6, 7]. These systems may reduce the number of CBCT scans and thus limit the imaging dose to patients. The system described in this study uses a new scanning method with a non-visible light projector and a charge-coupled device (CCD) camera. It projects the calculated regional patient shift directly onto the patient's surface in order to simplify the patient positioning process. It also permits a non-visible function to detect patient movement or breathing during treatment (introduction movement): a functional mobility that can also be used to drive the gating interface of a linear accelerator.

The surveillance function, the new scanning approach and gating may further improve the accuracy of liver and lung treatments [4], provided that the inherent accuracy of the system is sufficient. As a first step, we investigated the basic performance and accuracy of the new scanning method of the Catalyst (C-RAD, Uppsala, Sweden) system in a non-gated environment. These issues were addressed in both phantom experiments mimicking different clinical situations and in a prospective clinical study covering three anatomical regions.

Materials and methods

Phantom and clinical studies were performed on an Elekta Synergy (Elekta AB, Stockholm, Sweden) accelerator with CBCT. The Catalyst optical system is mounted to the ceiling above the top end of the treatment table (Fig. 1). Instead of using laser light to scan the surface,

F. Steiner, T. Wenz, M. Shi, F. Lohr
Department of Radiation Oncology, University Medical Center
Mannheim, University of Heidelberg, Mannheim

A novel surface imaging system for patient positioning and surveillance during radiotherapy

A phantom study and clinical evaluation

Original article

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Catalyst employs three high-power LEDs to project light with wavelengths of 460 (blue), 538 (green) and 634 nm (red) onto the object. The blue component in the measuring light (the object scanning and is detected by a monochrome CCD camera with an acquisition speed of 200 frames per second. The green and red light project surface structures (actual vs. reference) onto the area where the measurement is directed to aid patient positioning. Two custom settings, gate and integration time (IT), made the Catalyst software can influence scan quality. The gate is the quantity of captured electrons required on a pixel of the CCD camera to convert light into electronic charge and a digital readout. IT defines the time of light absorption. The maximal scan volume is 60 cm wide, 20 cm long and 70 cm high. An individual region of interest relative to the paradigm can be defined. The phantom part of the study analyzed scanning quality, reproducibility



Fig. 1. A optical system Catalyst left and set up to linear accelerator room right

Publications :

Increased patient throughput for treatment with helical tomotherapy

K. Petersson,¹ C. Ceberg,¹ T Knöds,^{1,2} and M. Enmark²

¹Medical Radiation Physics, Lund University, Lund, Sweden ²Radiation Physics, Skåne University Hospital, Lund, Sweden

1. Purpose

Treatment with helical tomotherapy is beneficial for many patients compared to treatment with a conventional C-arm beam. To be able to treat more patients with tomotherapy the total treatment time per fraction for every patient has to be shortened.

One way of doing this is to replace the time-consuming use of MVCT imaging for positioning of the patient with a faster laser scanning positioning system, for most fractions in a treatment. The Sentinel system (C-Rad AB, Uppsala, Sweden) is such a system and it has been used for a year for patients receiving treatment with helical tomotherapy at our hospital. A time study has been performed to quantify how much time the system can save per fraction and subsequently how much the patient throughput can increase.

2. Conclusions

This study shows that significant amount of time can be saved if using the Sentinel system as an alternative method to MVCT imaging for positioning the patient, when treating with helical tomotherapy. The time saved can be used for a substantial increase in the number of patients treated with this technique.

Another benefit with limiting the number of MVCT scans is the reduction of the scattered dose from MVCT scans received by the patients. The disadvantage with Sentinel system is that it scans and positions the surface of the patient but we almost always treat internal structures. This means that the surface positioning must correlate with the correct positioning of the treated internal structures for the system to be useful. The diagnostic consequences of not using the MVCT for the positioning of the patients needs to be investigated in future studies.



Figure 2. The Sentinel system hardware consisting of a laser and a camera in a single unit.

3. Methods

The Sentinel system was used for the positioning of the patients when the MVCT imaging system was not utilized. The study was performed for 20 patients (2-3 fractions). In the study, the time when the patient entered the treatment room was registered as well as the time when the patient left. The time it took to MVCT scan the patient and the time it took to match the MVCT scan to the planning MVCT scan was registered.

The total treatment time (patient entering treatment room until patient leaving) was compared for fractions when the laser scanning positioning system was used vs. fractions when the MVCT imaging system was used. The increased patient throughput was calculated based on an imaging protocol that stipulates that the MVCT imaging system is used for positioning of the patients for the first three

4. Results

The positioning of the patient with the Sentinel system took on average 15 minutes to perform in average 20 minutes (with a stand when the MVCT system was utilized and standard deviation of 4 minutes) when it was used. A time plot of total treatment time (Planned MVCT scans according to the plan) is an increased patient throughput of this

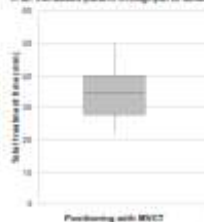


Figure 3. Box and whisker plot showing the total time of the treatment room until they in MVCT system as well as the Sentinel system. It is noteworthy that the time for the MVCT scan and the time for the Sentinel scan are similar.

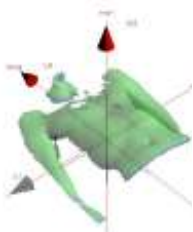


Figure 3. Prepared positioning tomotherapy 1 after a laser surface scan is prepared for the treatment system.



Klinische Erfahrungen mit dem Einsatz des Catalyst™-Systems zur Beurteilung der Lagerungsgenauigkeit bei Patientinnen mit Mammakarzinom

F. Walter, S. Schönecker, Dipl.-Ing. P. Fretschner, Dr. E. Nikiel, Dipl. Phys. A. Triller, Dr. rer. nat. M. Söhn, Prof. Dr. C. Belka

Hintergrund

Die Positionierung von Patientinnen mit Mammakarzinom erfolgt in der Strahlentherapie mittels orthogonaler Röntgenaufnahmen, anhand deren kreisförmige Strukturen des Thorax bzw. der Lungenkontur beurteilt werden können. Das Catalyst™ System (RAD AB, Schweden) bietet die Möglichkeit die Oberfläche des Patienten zu scannen und die Patientenpositionierung zu beurteilen.



Abb. 1. Catalyst™-System (RAD AB, Schweden).

Methoden

Die Lagerung der Mammakarzinompatienten erfolgte standardmäßig anhand der Röntgenaufnahmen und wurde anschließend mittels Catalyst™ dokumentiert. Die korrekte Patientenlagerung wurde mittels orthogonaler Röntgenaufnahmen verifiziert und ggf. korrigiert. Bei allen Patientinnen erfolgte die subkroische Beurteilung der Lagerung mittels Catalyst™ und EPD (ViewCT™, Elekta AB, Schweden) mindestens fünfmal im Verlauf der Bestrahlungstage.



Abb. 2. Abweichung der Lagerung nach Kollimatorung und nach Catalyst™. Abweichung verglichen mit EPD-Aufnahmen, aufgetragen pro Patientin.

Ergebnisse

Für die Lagerung nach Kollimatorung zeigte die Kontrolle mit ViewCT™ eine mittlere Abweichung in lateraler Richtung von $-0,1 \pm 1,4$ mm, longitudinal $0,7 \pm 1,2$ mm und vertikal $1,0 \pm 1,6$ mm. Die Abweichung der Catalyst™-Messung von den aus den Kollimatorungen ermittelten Verschiebewerten nach ViewCT™ ergab eine Abweichung von $1,5 \pm 1,5$ mm in lateraler, $0,9 \pm 2,5$ mm in longitudinaler und $1,2 \pm 2,4$ mm in vertikaler Richtung. Die Mittelwerte wurden mit dem Wilcoxon-Signifikanz-Test verglichen und ergaben keine signifikante Abweichung (laterale $p=0,55$, longitudinal $p=0,7$, vertikal $p=0,1$).

Abw.	mm	Stärke	Abw. bei	Stärke	Stärke	Stärke
0-10	12	100	12	100	100	100
10-20	11	100	10	100	100	100
20-30	10	100	10	100	100	100
30-40	10	100	10	100	100	100
40-50	10	100	10	100	100	100
50-60	10	100	10	100	100	100
60-70	10	100	10	100	100	100
70-80	10	100	10	100	100	100
80-90	10	100	10	100	100	100
90-100	10	100	10	100	100	100

Diskussion

In der Einzelbildbeurteilung zeigt sich, dass lokale Abweichungen der Lagerung insbesondere der Arme und des Kopfes einen deutlichen Einfluss auf die von der definierten Registrierung des Catalyst™ errechneten Verschiebewerte hat. Diese lokalen Abweichungen lassen sich mit der aus Standard angebotenen Bildgebung mittels EPD nicht beurteilen. Es handelt sich bei der vorliegenden Auswertung um eine retrospektive Beobachtung der Werte in einer Klinik erhebenen Daten zur Lagerungsgenauigkeit mittels Catalyst™. Die Präzision der lokalen Abweichungen ist daher bei der Systembeurteilung nicht weiter systematisch beurteilt werden. Trotzdem zeigt sich ein signifikanter Unterschied im Vergleich der Mittelwerte.



Abb. 3. Catalyst™-System (RAD AB, Schweden).

A pilot study of breast cancer patient positioning using optical surface scanning and reprojection

Mattias Jonsson¹, Sofie Ceberg¹, Charlotte Thurnberg¹, Sven Bäck²
¹Medical Radiation Physics, Department of Clinical Sciences, Malmö, Lund University
²Radiation Physics, Skåne University Hospital, Malmö, Sweden

Aim
 The aim of this pilot study was to evaluate the optical scanning system for patient positioning in breast radiotherapy.

As a complement to a ray tracing reconstruction of the treatment room, the patient position due to skin such as the postural muscles, tension is located, would not be



Figure 1. Mispositioned arm highlighted in red by the projector.



Figure 2. 3D reconstruction of the patient's arm and torso.

Materials and Methods
 A Catalyst™ system was installed in the waiting room in the treatment room. The Catalyst™ consists of a LED projector projecting a mesh pattern onto the patient. A CCD-camera registers the projected pattern and reconstructs a surface 3D-model. Using the LED-projector, deviations between the body contour and the contour reconstructed from the CT-scan will be coloured giving the therapy personal instant feedback during the patient positioning (Figure 1).

A total of 12 treatment sessions (four patients) were analysed in this study. After patient setup and position correction based on planar kV-imaging of the thorax wall and spine, the thorax region was scanned and registered using the Catalyst™ system. At each treatment session a new surface image was acquired after patient positioning (Figure 2).

Interfractional changes in arm position were observed by measuring the angle of the upper arm (humerus) in the sagittal and coronal plane. To find misplacements, each measured arm position was compared to the median value of all treatment sessions of the same patient.

mis within 12 degrees from the sagittal and within 15 degrees maximum observed deviation from the sagittal plane. An optical scanning of the patient correct with a direct patient positioned in the patient a helpful tool during patient setup with the potential of increasing work efficiency and patient safety.

Conclusions
 After patient setup using planar kV-imaging, interfractional changes in the patient's arm position were observed using optical scanning. The misplacements were not detected using planar kV-imaging of the thorax region. An optical scanning of the patient correct with a direct patient positioned in the patient a helpful tool during patient setup with the potential of increasing work efficiency and patient safety.

trial id: 2013-11, 9-13 May 2012, Barcelona, Spain *corresponding author: mattias.jonsson@med.lu.se



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