CTVision System Case Studies

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Content

CTVision System Case Studies – Introduction

CTVision™ System from Siemens is a unique, fully integrated Image-Guided Radiation Therapy (IGRT) solution that provides in-room CT imaging. The system consists of a CT, linear accelerator, and treatment table.

The SOMATOM® CT family, including Sensation Open, takes advantage of the large-bore CT with advanced multi-slice CT technology. The CT performs seamlessly with all Siemens linear accelerators. The SOMATOM sliding gantry travels along parallel highprecision rails (called "CT-on-rails"), offering high quality images while the patient is on the treatment table.

After the scan, the CT gantry returns to the park position, other procedures can be performed, and radiation therapy can start immediately. CTVision System combines the strength and stability of the 550 TxT™ Treatment Table with the speed and accuracy of Siemens linear accelerators; it is designed for ready integration with new and existing PRIMUS™ and ONCOR™ Linear Accelerators and the ARTISTE™ Solution. The 550 TxT table offers excellent patient accessibility and easy accommodation of patient load capacity up to 550 lbs (250 kg).

CTVision System's advanced technology allows for fast, 3D tumor localization prior to any treatment, allowing clinicians to make last-minute adjustments. The resulting treatment plan provides a significant improvement in precision and therapeutic quality by significantly reducing extrinsic and intrinsic uncertainties associated with patient setup and organ motion.

CTVision System can be used for all disease sites, although the major interest has been for anatomical regions such as the prostate and head and neck, which require soft-tissue contrast and tumor motion management.

The following case studies document the proven success of CTVision System at several treatment centers around the world. These testimonials are positive proof that CTVision System's efficient workflow and leading-edge technology in diagnostic imaging and precision performance can help save lives and advance patient care.

Horst Alheit, MD, PhD, Senior Registrar and Private Docent
Clinic and Policlinic for Radiation Oncology and Radiotherapy
University Hospital Carl Gustav Carus
Dresden, Germany

Targeting Prostate Cancer

The University Clinic Dresden has treated numerous prostate cancer patients with CTVision since 2005. Together with an ExacTracXray6D-System (BrainLab, Heimstetten, Germany) for the primary setup of the patient according to bony structures, the clinic uses the CTVision CT-scanner for a target-adapted setup correction. The daily imaging of the prostate with diagnostic image quality enables clinicians to hit the target prostate every day with high precision on the order of 1–2 mm in all directions. Moreover, a daily check of the position and shape of normal tissues such as the bladder and rectum is possible using CTVision.

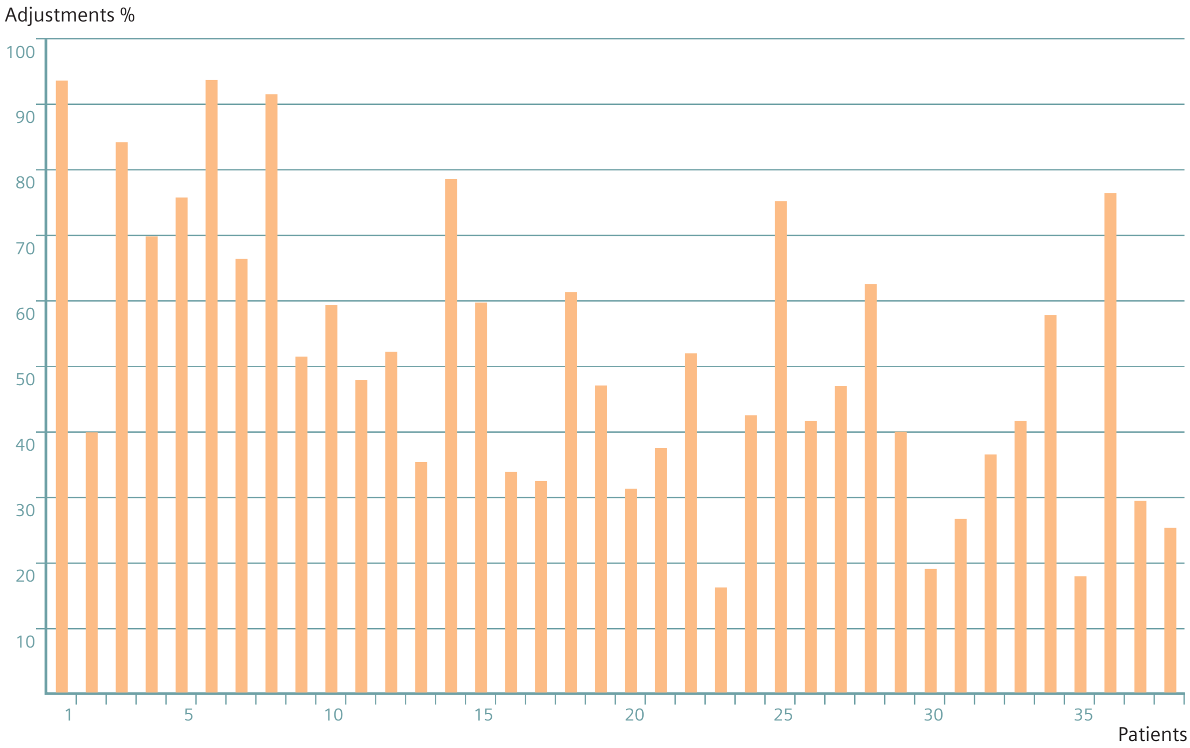


Figure 1
Number of target-adapted adjustments in 38 prostate cancer patients (intervention threshold ≥ 3 mm).

> "Our experience with CTVision has shown that imaging and diagnostic quality provide information about the position and shape of at-risk organs."
>
> Horst Alheit

Treatment Approach

After treating 38 patients, it was noted that the systematic setup error by conventional laser setup related to the prostate position was reduced from 2.2, 3.9, and 4.1 mm in lateral, longitudinal, and vertical direction respectively to almost zero (0.2, 0.2, 0.3 mm) by target-adapted setup, with an intervention threshold of more than 3 mm. The random setup errors were reduced from 2.8, 2.7, and 3.8 mm to 0.8, 0.8, and 0.9 mm, respectively. This allowed a margin reduction from CTV to PTV from about 12 mm to about 1mm to cover the PTV with the 95% isodose in 90% of the setups.

The frequency of necessary target adjustments using an intervention threshold of more than 3 mm deviation is shown in Figure 1. A large variation among patients was observed, ranging from below 20% of setups to nearly 95% of setups. Therefore, the benefit of target-adapted imageguided therapy was different for each patient. About 50% of the patients had more than 50% necessary corrections.

For most of the patients, there was no good correlation between prostate position within the pelvis and the bony anatomy. Our experience with CTVision has shown that imaging and diagnostic quality provide information about the position and shape of at-risk organs. Differences in bladder and rectum filling were easily detected, and in cases of extreme deviations from the planning situation, the patient was asked to empty the bowels and / or bladder before treatment was performed. In some cases, it was appropriate to do a re-planning. The latter also might be indicated if a substantial shrinkage of the tumor is detected.

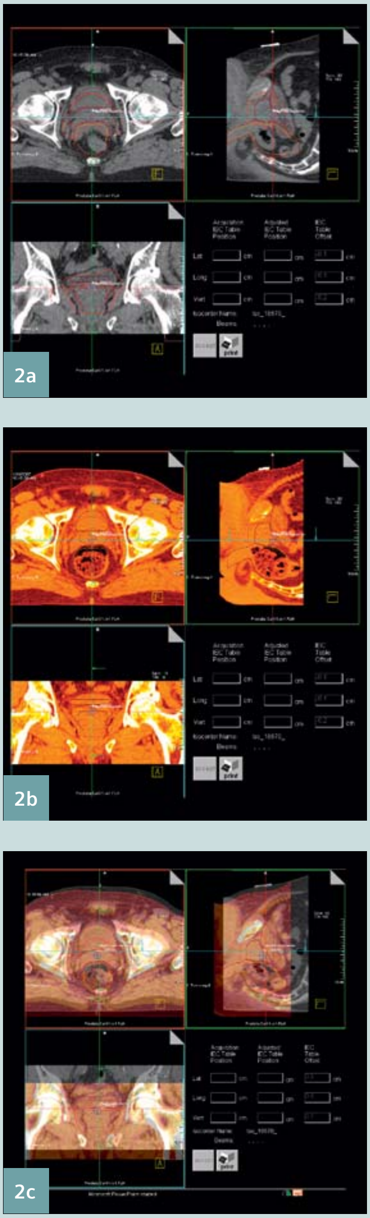
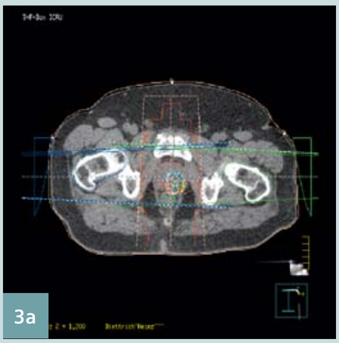
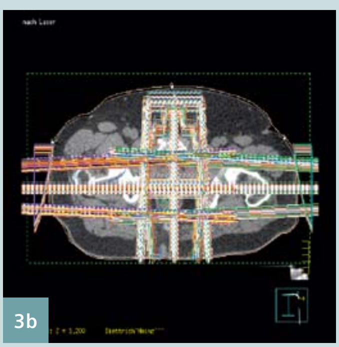


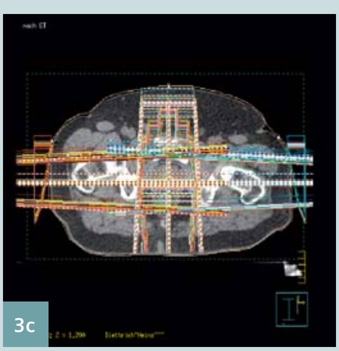
Figure 2
Example of a patient with extreme different rectum filling between planning scan (a) and treatment scan (b) and image fusion with target adaptation (c). The seminal vesicles are in an extremely different position, and a re-planning took place.



Original



Laser



ET

AT

The following example demonstrates the benefit of daily image-guided treatment for prostate cancer (Figure 3). The daily target-adapted setup deviations were recorded and the related isocenter shift was simulated with the planning system (Pinnacle). All fractions were summed up to one treatment plan. A three-field conformal technique was employed. After conventional setup with wall lasers and skin marks, a blurring of the field borders occurred. This can be substantially improved by setup correction according to bony structures (ET) and according to the prostate position with CTVision using an intervention threshold of > 5 mm. This enhanced the probability of a complication-free cure as demonstrated in Figure 4.

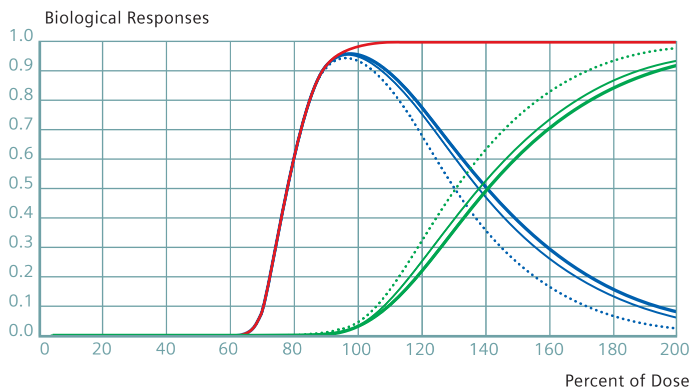
For this patient, computation of biological effects of isocenter deviations during treatment was performed (Figure 4). Due mainly to the isocenter shift to dorsal with laser setup only (upper image), a dose higher than planned was applied to the rectum, while coverage of the target (e.g., the prostate) was not significantly compromised due to a safety margin from CTV to PTV of 1 cm in all directions, but only 5 mm dorsal.

This resulted in a higher complication probability for rectal toxicity, including ulceration and bleeding, as well as decreases in the probability of complication-free cure by about 4.5% at the prescribed dose.

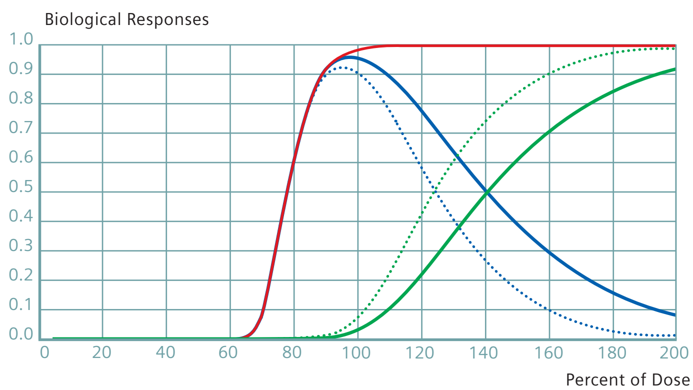
Conclusion

According to bony landmarks with ExacTra, IGRT significantly improves probability for a complication-free cure, and only target-adapted setup with CTVision brings NTCP nearly back to planned values. Therefore, target-adapted IGRT with CTVision has the potential for opening the therapeutic window by escalating the dose to the target due to less blurring at the margins, while at the same time avoiding unnecessary dose deposition to normal tissues.

Figure 3
Example of setup improvement with different methods of Image-Guided Radiation Therapy (IGRT). The most accuracy was achieved with Adaptive Targeting™ (AT) of the prostate using CTVision System (Fig. 3d). Figure 3a shows the initial treatment plan using a 3-field conformal technique. Figure 3b demonstrates the blurring of the field borders after conventional setup with skin marks and laser. The lower images show improvement of accuracy by setup correction according to bony structures (Figure 3c) and according to the prostate position with CTVision using an intervention threshold of > 5 mm (Figure 3d).



Line Type	Probability	Response Description
	0.954	P+ 3-F-Box ICRU
	0.95	P+ after AT 5mm
	0.937	P+ after ET
	0.985	Prostate(1) 3-F-Box ICRU
	0.985	Prostate(1) after AT 5mm
	0.984	Prostate(1) after ET
	0.03	Rectum HW(2) 3-F-Box ICRU
	0.035	Rectum HW(2) after AT 5mm
	0.046	Rectum HW(2) after ET



Line Type	Probability	Response Description
	0.954	P+ 3-F-Box ICRU
	0.91	P+ after Laser
	0.985	Prostate(1) 3-F-Box ICRU
	0.983	Prostate(1) after Laser
	0.03	Rectum HW(2) 3-F-Box ICRU
	0.072	Rectum HW(2) after Laser

Figure 4

Computation of biological effects caused by setup deviations and compensation with IGRT with CTVision. Both images show the original plan in solid lines, with tumor control probability (TCP; red) and normal tissue complication probability for the rectum (NTCP; green). The blue line indicates complication-free cure probability. In the upper image, dashed lines show increased NTCP for the rectum due to setup deviations after conventional setup with lasers and skin marks, resulting in a 4.4% loss of complication-free cure probability at 100% of the prescribed dose (70.4 Gy). The TCP is nearly uninvolved because of appropriate security margins of 10 mm in all directions, but only 5 mm dorsal. The lower image shows improvement by IGRT with bony landmarks (thin dashed line) and with Adaptive Targeting™ using CTVision (thin solid line) regarding NTCP for the rectum, resulting in nearly the same complication- free cure probability of 95% as the original plan.

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The German Cancer Research Center
Heidelberg, Germany

Treating a Complex Head and Neck Case

Treatment planning at the German Cancer Research Center is performed using the in-house software (Voxelplan) in combination with KonRad™ from Siemens Healthcare. Since the installation of CTVision, approximately 600 patients have been treated at the center.

CTVision allows for fast application of Intensity-Modulated Radiation Therapy (IMRT) and a CT-based image-guided positioning control with excellent image contrast. A special workflow based on CTVision for IGRT has been developed in recent years. New implementations in Voxelplan software allow for a real Adaptive Radiation Therapy (ART) approach for interfractional changes of the target volume or the patient geometry. Individual positioning devices for different organ regions are manufactured for all patients.

Treatment Approach

A 62 year-old male patient presented with laryngeal carcinoma at our outpatient clinic. ENT control revealed a T4a N2c tumor without distant metastases. In our interdisciplinary tumor board, the decision was made to treat this patient with primary combined radiochemotherapy with a platinum-based regimen (carboplatinum 70mg / m² and 5-FU 600mg / m² continuous infusion, both d1–5 and d28–32) and Intensity-Modulated Radiation Therapy (IMRT). Application of an integrated boost concept did not seem feasible due to the increased dose per fraction and the extent of the prospective boost volume (primary laryngeal carcinoma and right cervical lymph node metastasis). It was decided to treat this patient with a sequential radiation therapy regimen, applying 56 Gy in 2 Gy per fraction to the locoregional lymph nodes and subsequently boosting macroscopic tumor / lymph node metastases to a total dose of 74 Gy (2 Gy / Fx).

A radiotherapy treatment planning CT scan was carried out in 3 mm slices with the patient immobilized in an pronounced cutaneous emphysema due to fistula formation posttracheotomy was clearly visible on the planning scans.

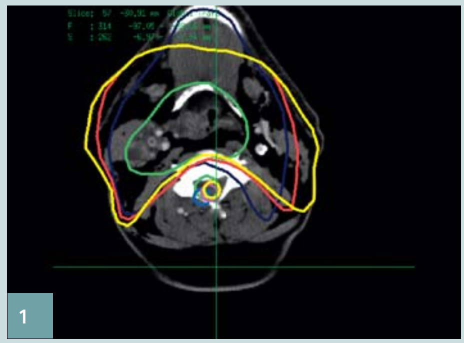
In favor of a quick treatment start, it was decided to plan IMRT radiotherapy treatment on the basis of this CT scan, bearing in mind the necessity of frequent controls in case of rapid resorption of air. This occurred quite soon and was visible on the second positioning control on Fraction 2 (F02). Hence, the need to adjust treatment volumes arose and positioning control scans of our in-room CT (CTVision System) were used to create new contours for target organs (pink) and organs at risk (OARs).

As frequently seen when treating patients with head and neck tumors, this patient also lost a substantial amount of weight despite best supportive therapy and high-caloric PEG nutrition. Due to excessive change in body outline and contour, adaptation of target volumes became mandatory again, leading to replanning on the basis of another position control CT scan on Fraction 13 (blue) with CTVision. Regular position control scans were carried out to ensure adequate inclusion of lymph node areas within our defined target volume.

> “One of the most important advantages of CTVision inroom CT is clearly the ability to use scans for both position control and as a basis for another treatment plan.”
>
> **M. W. Münter**

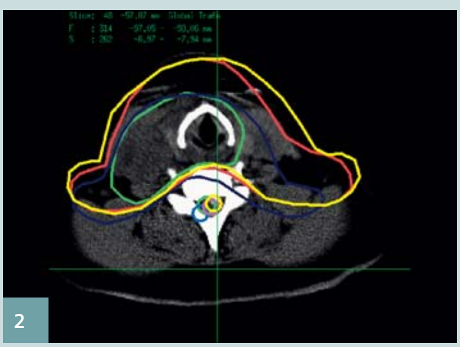
Figures 1–6
show the various target contours on the basis of the four (re)planning CTs. In order to demonstrate clearly the tissue changes and thus the changed TVs, the contours from all four planning steps have been superimposed on each of the images.

The TV and OARs from the first CT scan are outlined in yellow. The TV and OARs for fraction 02 (F02) is shown in red / pink., for F13 in blue. The scan for F24 was used to outline the tissue for a boost; TV and OARs for the boost are shown in green.



1

F0 (TV and OARs: yellow)



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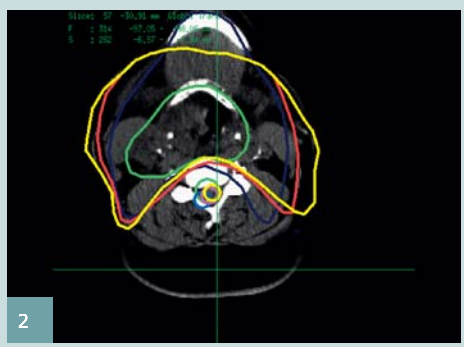
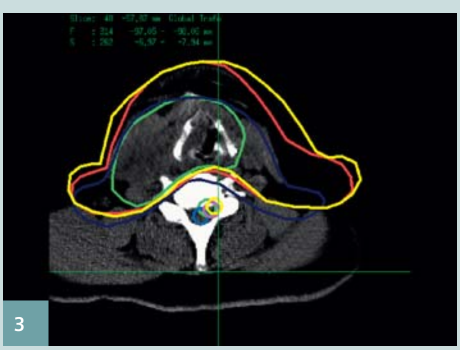
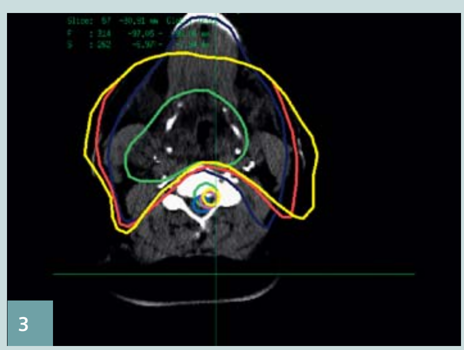


2

F02 (TV and OARs: red / pink)

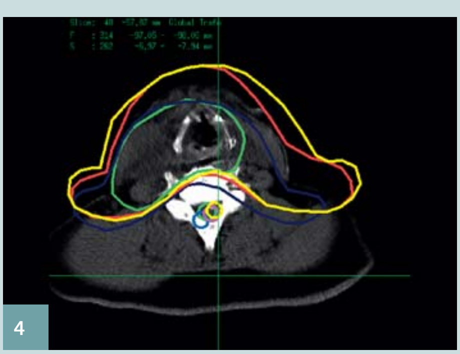


3

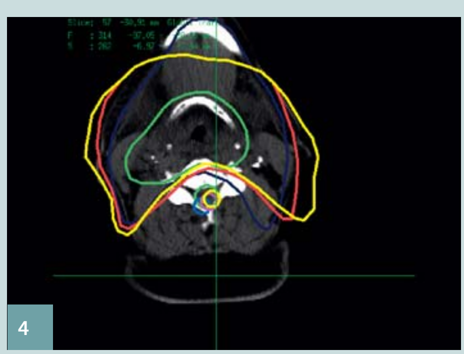


3

F13 (TV and OARs: blue)

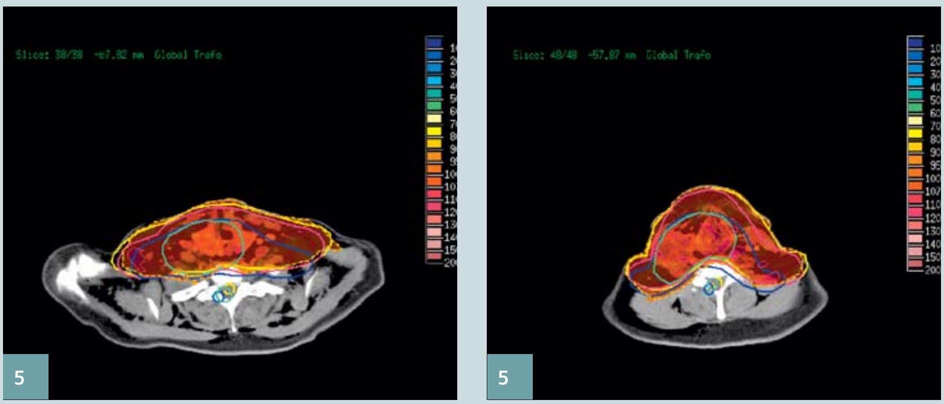


4



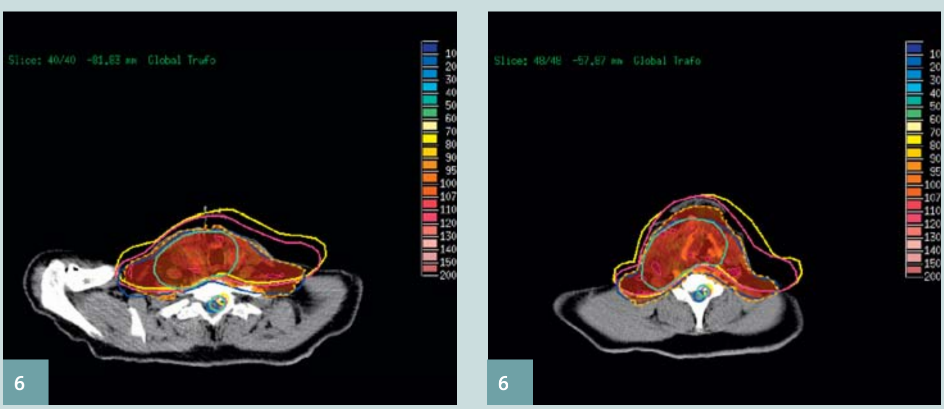
4

F24 (TV and OARs: green)



5

Original dose distribution (F0)



6

Adapted dose distribution after resorption of air and weight loss (F13)

To achieve best possible fit of boost volume outline, another positioning control scan with CTVision at Fraction 24 served as the basis for outlining boost volume and creating the subsequent boost plan. We changed the treatment plan again as planned at Fraction 28 for the last 10 Fractions (F24: green).

It is important to note that the effects of the patient's weight loss not only affect target volumes but also delineation of critical OARs including the spinal cord and parotid glands. Very frequently, patients tend to shift slightly backward due to loss of subcutaneous fat, which even accurate positioning devices such as the vacuum mattress and scotch-cast mask cannot prevent.

Conclusion

In cases of excessive weight loss (as in the described case of a combination of weight loss and resorption of cutaneous emphysema), ART and quick replanning become absolutely necessary and unavoidable to adequately treat the tumor and spare normal tissues.

In addition to the high quality of obtained scans compared to either linear accelerator-mounted kV or MV CTs, one of the most important advantages of CTVision in-room CT is clearly the ability to use scans for both position control and as a basis for another treatment plan. Especially in departments where a large number of patients are being treated with high-precision treatment techniques, ART also needs to be feasible in planning time and effort.

This case demonstrates that ART using CTVision in-room CT is fast and feasible because these scans can be used for radiation therapy planning. The advantages demonstrated by this system also increase patient comfort.

James Wong, MD, Chairman
Department of Radiation Oncology
Carol G. Simon Cancer Center
Morristown Memorial Hospital, NJ, USA

Addressing the Problem of Prostate Motion

At Morristown Memorial Hospital, clinicians use the CTVision System to reduce uncertainties caused by organ motion and setup inaccuracy. Through the large variety of patients treated at Morristown, the radiation oncology team has found CTVision offers significant implications for dose escalation and decreasing rectal complications in treating prostate cancer. We are very fortunate to have the opportunity to be involved with the design and development of CTVision. Since the clinical introduction of CTVision in the year 2000, we have been constantly amazed and surprised by the improvement in both the hardware and software involved. In the year 2000, it would take over 30 minutes to delineate the changes or shift of the isocenter because the whole process required much manual labor. Currently, this entire process is automated and takes a mere 2-3 minutes. Over the past 8 years, we have delivered over 4000 CTVision guided treatments. We found that CTVision gave unprecedented clarity in comparison to all existing image-guided radiation machines currently in the market. Moreover, with the exceptional image quality, it provides the future possibility of real time treatment corrections.

Treatment Approach

As the first center in the United States to implement IG-IMRT for prostate cancer using CTVision, the Department of Radiation Oncology at the Carol G. Simon Cancer center, Morristown Memorial Hospital has accumulated over 4000 fractions of IG-IMRT experience. In one of our studies, CT scan images were obtained from a total of 329 prostate patients who were treated from May 2000 to August 2005 just prior to radiation treatments. Of the 1870 CT scans reviewed, 44% required no setup adjustments in the AP direction (no adjustment was performed if target shift < 3 mm), 14% had shifts of 3–5 mm, 29% had shifts of 6–10 mm, and 13% had shifts >10 mm. In the SI direction, 81% had no setup adjustments, 2% had shifts of 3–5 mm, 15% had shifts of 6–10 mm, and 2% had shifts >10 mm. In the LR direction, 65% had no setup adjustment, 13% had shifts of 3–5 mm, 17% had shifts of 6-10mm, and 5% had shifts >10 mm.

The review of 1870 interfractional prostate shift data demonstrated that there was a more significant shift in the anterior-posterior direction than in the lateral and superior-inferior directions. Without correcting for the interfractional prostate movement, under-dosing of the prostate gland and overdosing of the rectum can occur. In a separate study, 117 prostate patients treated from January 2005 to April 2007 were analyzed. A total of 1465 CT scans were analyzed with respect to the patient's body weight, body mass index (BMI), and subcutaneous adipose-tissue thickness. Of the 117 patients, 26.5% were considered normal weight, 48.7% were overweight, 17.9% were mildly obese, and 6.9% were moderately to severely obese. Notably, 1.3%, 1.5%, 2.0%, and 21.2% of the respective shifts were greater than 10 mm in the lateral direction for the four patient groups, while in the anterior-posterior direction the shifts were 18.2%, 12.6%, 6.7%, and 21.0%, respectively. Strong correlation was observed between SAT, BMI, patient weight, and standard deviation of daily shift in the lateral direction ($p < 0.01$). Of the 117 patients, 26.5% were considered normal weight, 48.7% were overweight, 17.9% were mildly obese, and 6.9% were moderately to severely obese. Notably, 1.3%, 1.5%, 2.0%, and 21.2% of the respective shifts were greater than 10 mm in the lateral direction for the four patient groups, while in the anteriorposterior direction the shifts were 18.2%, 12.6%, 6.7%, and 21.0%, respectively.

> "We found the CTVision System gave unprecedented clarity in comparision to all existing image-guided radiation machines currently in the market."
>
> **James Wong**

With CTVision, the exact location of the prostate, seminal vesicles, and rectum can now be located and identified without any internal or external markers, even for bariatric patients.

Strong correlation was observed between SAT, BMI, patient weight, and standard deviation of daily shift in the lateral direction ($p < 0.01$). The strong correlation between obesity and shift indicates that without IGRT, the target volume (prostate +/- seminal vesicles) may not receive the intended dose for patients who are moderate to severely obese. This may explain the higher recurrence rate with conventional EBRT (that did not use IGRT) as observed by some recent studies.

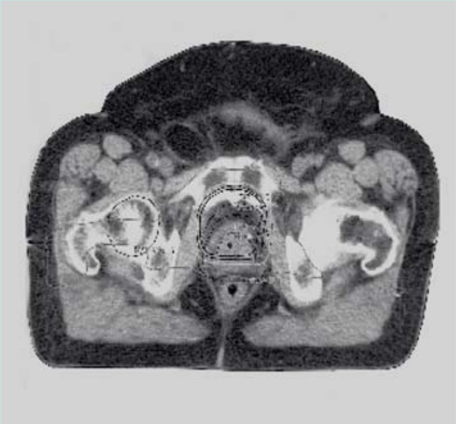
As an example, a prostate patient who weighed 450 lb (204 Kg) with BMI = 45 was recently treated at the clinic. The subcutaneous adipose-tissue thickness was 17.8 cm. The patient received daily pre-treatment CT for setup verification. The magnitude of setup error in 13 of 40 fractions was found to be more than 10 mm in the LR direction. Had this patient been treated with the conventional 3D conformal technique whereby a uniform margin of 10 mm is commonly chosen for prostate cancer, the LR shifts imply that a portion of the prostate target volume may be under-dosed up to 30%. For the other three groups, the frequency of large shift in the lateral direction was relatively small (< 2% of the entire treatment course) and may have result in approximately 2% under-dosage with the same 3D conformal technique.

Because other image guidance options suffer from limited image quality they have to rely on internal and/or external markers to locate the prostate. Precision is even worse when treating larger patients. Recent studies have demonstrated treatment results on large patients are below the normal rate of results. One explanation is the challenge of obtaining good-quality images to maintain treatment precision.

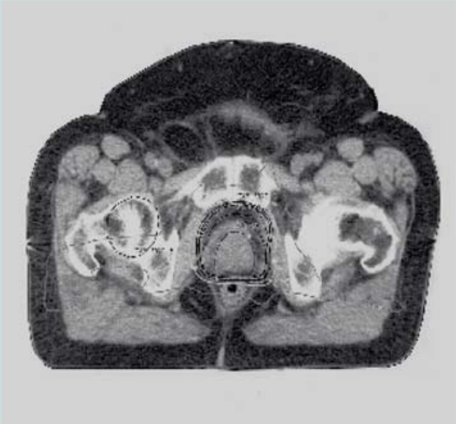
This problem can be corrected using CTVision System's CT-on-rails in the treatment room to deliver and maintain optimum image quality. With CTVision, the exact location of the prostate, seminal vesicles, and rectum can now be located and identified without any internal or external markers, even for bariatric patients. These positions are then compared with planned positions, daily movement of the prostate and rectum are subsequently corrected, and a new isocenter is derived. We can treat our patients immediately and with much more confidence using the new isocenter.

Conclusion

We found that daily intrinsic prostate movements can be easily and precisely corrected for any patient, independent of size, before each radiation therapy session. CTVision allows for extremely precise prostate cancer treatment.



Radiation treatment base on external BBs marks



Radiation treatment base on Image guided method

Case 4

Ron R. Allison, MD, Professor & Chairman
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The Brody School of Medicine
East Carolina University, Greenville, NC, USA

“CTVision System allows us to adapt therapy as needed to accurately target the changing cranial topography.”

Clinical Accuracy for Cranial Tumors

Clinicians at East Carolina University have treated patients with CTVision-based IGRT for more than three years. One surprising result to emerge from their experience has been how useful this system is for targeting cranial tumors.

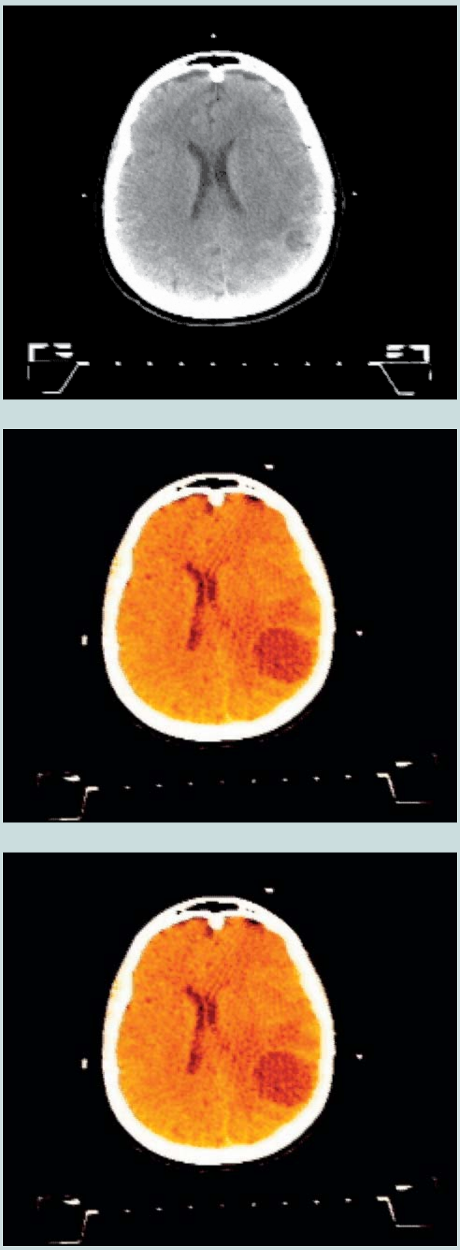

Figure 1
Sequence of images showing growth of lesions during XRT.

Treatment Approach

The daily diagnostic-quality CT images showed a large percentage of brain patients experienced soft-tissue changes during radiation therapy. The kV volumetric imaging revealed changes that other imaging modalities likely would have missed: postsurgical healing, tumor growth, tumor destruction, brain edema, hydrocephalus, and reabsorption of pneumocephalus.
In several cases, critical structures were shown to move by more than one centimeter. CTVision gives us the ability to know about these changes daily and allows us to adapt therapy as needed to accurately target the changing cranial topography.

Another critical CTVision benefit is its ability to reveal how well immobilization techniques are performing. Consistency in setting up the patient is crucial. Fortunately, any rotation or misalignment that might be hidden beneath an immobilization device is readily visible when CTVision System fuses daily images to the planning CT. Therapists know immediately when a patient setup needs to be adjusted.

Conclusion

The clinical utility of CTVision-based IGRT for our brain patients has been a nice bonus from a system already earning its keep by improving treatment accuracy throughout the body. The kV volumetric imaging revealed changes that other imaging modalities likely would have missed.

Summary

CTVision System is the first solution to integrate a "CT-on-rails" design with the linear accelerators ARTISTE, ONCOR and PRIMUS. This high-performance technology gives clinicians the ability to combine daily images with CT planning. The information can be incorporated immediately into the treatment plan, and therapy can be adapted on the spot without the patient ever having to stand or move, for a more precise patient setup and IGRT delivery.

CTVision System provides a critical improvement in therapeutic success for difficult-to-treat cancers. From superior CT images to precision treatment techniques, CTVision System from Siemens offers unparalleled solutions for cancer treatment and patient care.

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