XVI Protocols: Netherlands Cancer Institute The Netherlands

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Note to the reader.

In this document you will find the current IGRT protocols that are used at the Netherlands Cancer Institute/Antoni van Leeuwenhoek. The protocols describe XVI settings, such as clipboxes and scanning parameters. The protocols in this issue are limited to those protocols that can be performed with XVI 5. In no way are they meant as the gold standard. They have been derived from our own clinical practice and are a result of collaboration between RTT's, physicians, and physicists. This document can be used as guidance, when designing your own protocols.

The screen shots and information boxes used in this document are copied from our instruction manual. The manual is created as a guide for our RTT's when using the XVI system on the treatment machines.

For our lung and head and neck patients in our clinic a multi clipbox registration is used. These protocols are not in this document, because they are not available in XVI 5

New in this document are the examples of our "take action" protocol. We recommend a guideline for RTTs, how to respond on anatomical changes seen on the CBCT. For many years we used a traffic light protocol, which was a basic guideline "green" no action, "yellow/orange" inform the radiation oncologist (RO), "red" do not irradiate call RO first. The traffic light protocol has been upgraded to an action protocol, where the RTTs do not only have a role in detecting the anatomical changes, but also decide on the appropriate action and follow up, resulting in a significant shift in responsibility.

At the end of this document you find references to publications that can provide some additional information on our IGRT strategies.

If you have any questions, you can address them to our imaging RTT's at **imagingrt@nki.nl**.

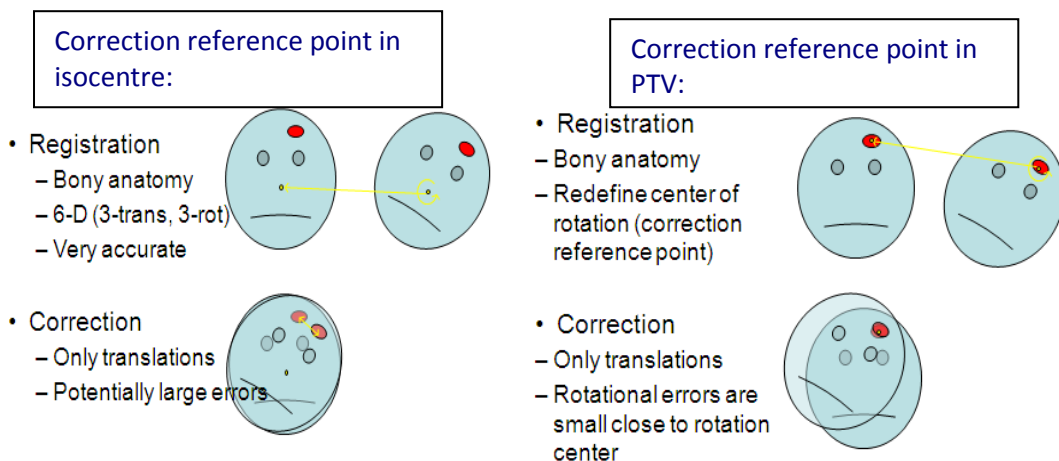Sincerely,

Imaging group

Contents

Introduction

For each imaging protocol there will be an overview of match & scan parameters (as shown below). Print screens will show an example of how we use the match parameters in our clinic.

MATCH PARAMETERS		SCAN PARAMETERS	
Structures	*GTV and PTV*	**Preset selection**	*Bladder Bow Tie*
Correction ref point	*PTV*	**Gantry rotation**	*-180°→ 180°*
Registration	*Clipbox*	**Gantry speed**	*0.5 rpm*
Method	*Bone (T + R)*	**Detector position**	*M*
Restriction rotations	*5°*	**Filter**	*F1*
Restriction Translation	10 mm	**Collimation**	*M20*

MATCH PARAMETERS:

- **Structures:** There is an option within the XVI system to display structures in the viewers. The structures are sent from the treatment planning system and can be selected in Volume Reference. By default GTV and PTV are displayed. These structures are helpful to evaluate target coverage in the presence of changes and/or rotations during registration.

- **Correction ref point:** Two images can be accurately registered with 6 degrees of freedom (3 translations and 3 rotations). A table shift however can only correct the translations (and a robotic couch can only correct up to 3° of the rotations). For this the strategy 'smart ignoring of rotations' is used: the correction reference point. When using a correction reference point, the point of rotation is redefined (default of the XVI software is at the isocentre, default in NKI/AvL is at the centre of gravity. Therefore the residual errors due to ignoring the rotations will be zero in the correction reference point. It is important to choose this point wisely, when the correction reference point is too far away from the PTV, the PTV could move away from the target area. See figure below.

Correction reference point in isocentre:

- Registration
  - Bony anatomy
  - 6-D (3-trans, 3-rot)
  - Very accurate

- Correction
  - Only translations
  - Potentially large errors

Correction reference point in PTV:

- Registration
  - Bony anatomy
  - Redefine center of rotation (correction reference point)

- Correction
  - Only translations
  - Rotational errors are small close to rotation center

Registration: There are different registration options: clipbox, mask, and first clipbox then mask (dual registration). All options are designed to register only a part of the CBCT scan, to be able to register (and correct) what is representative for a treatment. The dual registration (first clipbox then mask) is designed to compare the outcome of the two registrations and can be used for a critical structure avoidance strategy.

Clipbox:
A clipbox is a rectangular shaped region of interest which is placed around anatomy representative for the target area. Usually it is placed on bony structures, but it can also be applied on soft tissue. Choosing the anatomy within the clipbox should be done carefully in respect to the target area, preferable around rigid bony anatomy, to obtain fast and accurate registration results.

Mask:
A mask is a region of interest that can be designed in all shapes and sizes, but is usually generated from a (GTV-) structure and is usually used to perform soft tissue registrations. The mask is created from CTV or GTV with or without a margin, and without removing air or high densities. Check for high densities inside the mask that should not be included, e.g. bony anatomy. Structures within the list sent from the treatment planning system can be used to create a mask from, for example: **GTVpros+vs** (prostate+seminal vesicles).
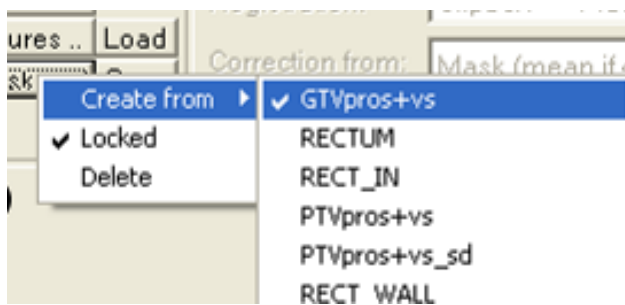
XVI gives a standard margin of 0,5 cm, which can be altered if required.
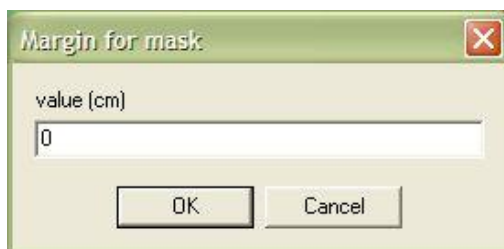

- **Method:** Method of registration, meaning the algorithm used for registration. Basically there are two methods of registration in the software: The chamfer registration and the grey value registration. The chamfer registration method ('bone' and 'seed') segments high densities in the reference scan and CBCT scan inside the region of interest and compares them. The second method uses all the grey value information inside the regions of interest. The first method is very quick and therefore the first choice for registering bony anatomy, but sometimes it fails when it is difficult to segment the bony anatomy in either one of the two scans. For example old patients with low bone density or heavy patients where the contrast in the scan is low. In these cases the grey value algorithm can be used to obtain accurate registration results. The grey value algorithm is the standard registration method to perform soft tissue registrations.

- **Restriction:** Bony anatomy rotations are by default restricted to 0° and for translations to 0 mm. The restrictions, that we use in the NKI/AvL, can be found for each area in the protocol overview. If these limits are exceeded we consider re-aligning the patient. In general these restrictions are used to flag differences in set-up that are not expected to happen and can have an impact on dose distribution. If the rotations are a result of anatomical variation and cannot be optimized by re-aligning the patient it is important to check after 'convert to correction' whether this has any negative impact on target volume coverage. If this is the case and there is a systematical change in position, rescanning and re-planning should be considered.

SCAN PARAMETERS:

- **Preset selection**: The name of the preset is chosen to be intuitive for the RTT's. For example: "Pelvis M10 or Pelvis M20".

- **Gantry rotation**: The start and ending gantry position of the arc of the CBCT scan (only clockwise). (it is possible to have the gantry rotate CC, but for this u have to calibrate and perform the geo-check also in CC direction)

- **Gantry speed**: The speed of the arc of the CBCT scan is adjustable in XVI. Within our department 3 default scan speeds are used: 0.125/0.5/1.0 rpm. Only 4D scans require a slow 0.125 rpm: It is used so that sufficient breathing cycles are required for a 4D reconstruction. The default gantry speed is 0.5 rpm. For scans in which only the bony anatomy is of interest a 1.0 rpm is used. For example brain, with a registration of the skull and no soft tissues as interest.

- **kV en mAs settings:** The kV and mAs settings can be adapted to optimise the image quality for the specific area for the different treatment sites. For example for head and neck when interested in bony anatomy and for prostate when interested in soft tissue.

- **Detector position**: Only S (small) or M (medium) is used in NKI/AvL. The position of the detector has to correlate with software presets and collimation filter. The reconstructed Field of View (FOV) depends on this. When using a medium FOV you must acquire a 360° rotation.

Small

Medium

Large

Medium offset panel position

360° rotation with medium FOV
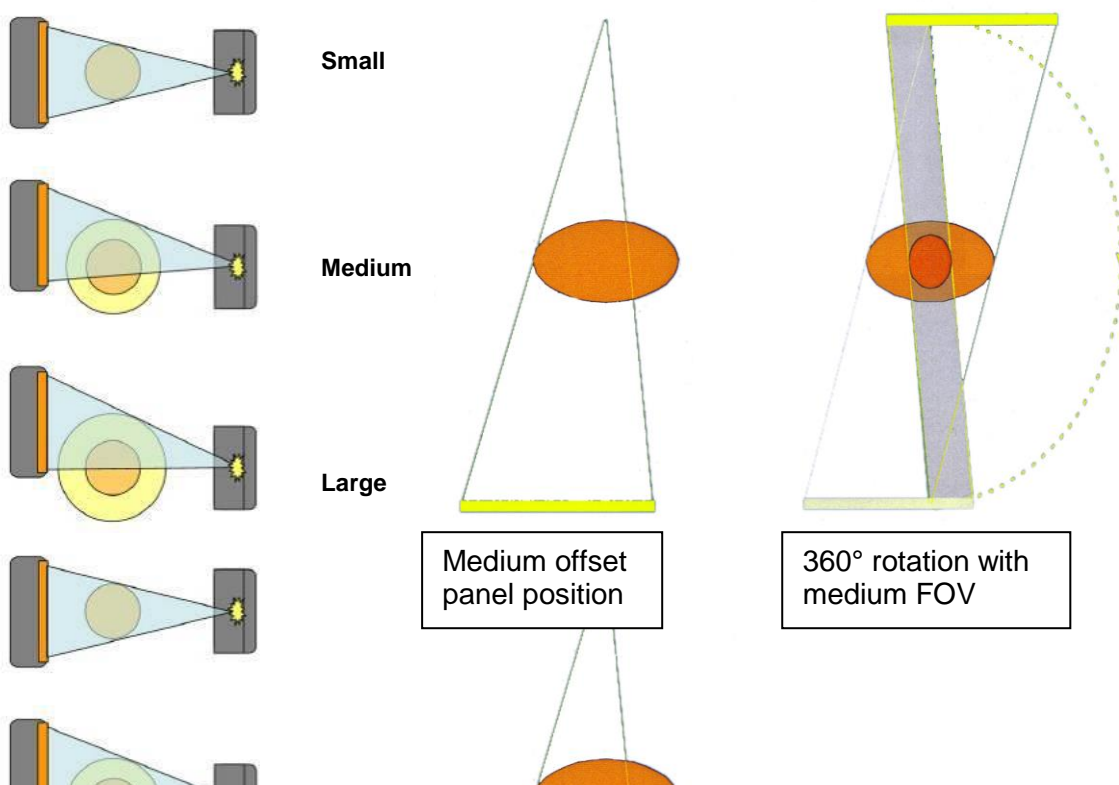
- **Collimation CC:** The collimator choice determines the FOV in cranial caudal direction and the position of the beam relative to the patient, correlating to the chosen detector position (central or in offset, depending of S or M detector postion). Scans are collimated as much as possible to improve image quality as the reduction of the field of view reduces scatter irradiation. Dependent of the size of the PTV a small as possible collimator opening is therefore preferable, considering that the scan contains all crucial anatomical information of the target area.

- **Filter:** The bowtie shaped F1 filter is used for all treatment sites. It improves image quality for the FOV by reducing the scatter and it decreases skin dose for all FOV's. (The F0 is an empty insert.)
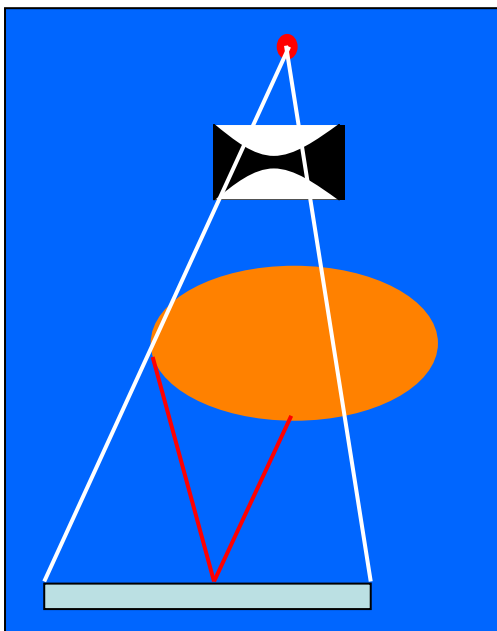
Common practice for registration:

Preparing registration:
Registration is prepared in XVI in the volume view reference. In the NKI for the first treatment one RTT does the preparation and signs off, then a second RTT checks this and co-signs. Match parameters from our protocols are used to prepare the XVI for a particular patient.

Registration:
The chamfer match algorithm is our first choice when registering bony anatomy because it is fast and robust. Grey value registration is mainly used for soft tissue registrations, but it can also be applied in case a bony anatomy registration fails on visual inspection, for example if a patient has bone decalcification. Seed registration algorithm is used for high density fiducials, commonly used in prostate patients as a surrogate for the location of the prostate. Manual registration is only used, if the automatic registrations have failed. It will sometimes help the bone or grey value match to manually match the two scans and then try one of the automatic registration algorithm. If even this fails, we use the manual registration. This is best visualised in the green-purple display mode and by using the arrows next to the translation. To evaluate the registration we first check the green-purple display for gross errors before using the other display options like cut-view.
After the evaluation of the registration we check to see whether the target volume is within the PTV structure (See Chapter Traffic light protocol).

We also check for changes in the patient's anatomy that may influence the dose distribution or target coverage, such as:

- contour changes (for example breast treatment)
- atelectasis appearing or resolving (lung treatment)
- rectum/bladder filling (for example prostate treatment)
- tongue depressors (H&N treatment)
- displacement of tumours (for example the position of the uterus with cervix treatment)

Evaluation of correction:

Very important: After evaluation of the registration we also check the correction, which is the registration after **convert to correction**. Rotations of the registration are recalculated to translations as the rotations cannot be corrected by a table displacement, see Correction Reference Point. We focus on target coverage: is the GTV still within PTV. After **convert to correction** XVI will give a warning if the restrictions are exceeded. These may be accepted if the match is correct or patients can be realigned (an imaging RTT or physicians will be consulted in these cases).

For further background information about CBCT, see literature reference [1]

Bladder

MATCH PARAMETERS		SCAN PARAMETERS	
Structures	GTV or CTV and PTV	**Preset selection**	Bladder Bow Tie
Correction ref point	PTV	**Gantry rotation**	-180°→ 180°
Registration	Clipbox	**Gantry speed**	0.5 rpm
Method	Bone (T + R)	**Detector position**	M
Restriction rotations	5°	**Filter**	F1
Restriction translation	10 mm	**Collimation**	M10 / M15 or M20 Depend on full/empty bladder protocol. Measure (alt+mouse) on the pCT.

Example clipbox:
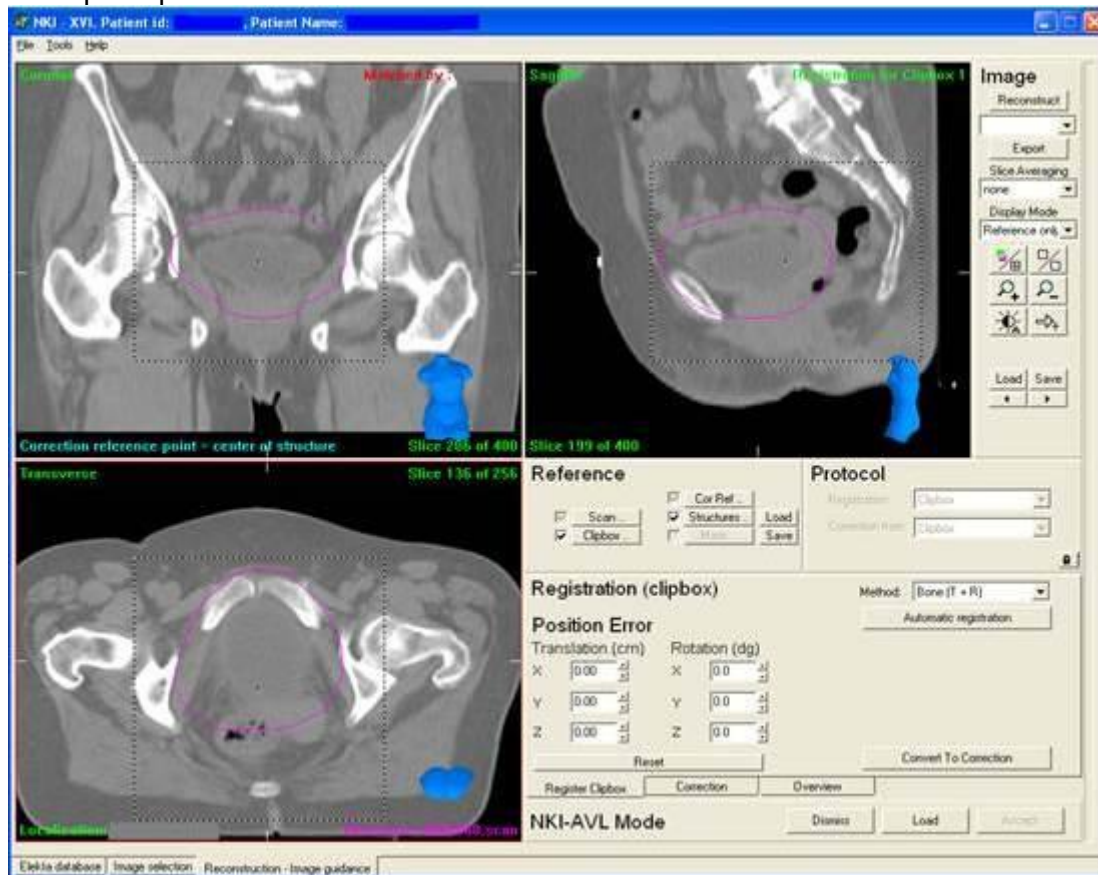
- Clipbox is placed around the rigid bony anatomy of the the pelvic region. (exclude the femoral head and trochanter minor as much as possible)

Bladder: Partial bladder treatment using Lipiodol

Lipiodol is a fatty substance that is injected around the tumour by the urologist during cystoscopy. This lipiodol will serve as a surrogate for the tumour and can be used for registration. It is typically used when treating only part of the bladder or a boost, with a full bladder drinking protocol.

The two step registration is used to flag large differences (over 2 cm) between the clipbox registration and the lipiodol registration.

MATCH PARAMETERS		SCAN PARAMETERS	
Structures	GTV or CTV and PTV	**Preset selection**	Bladder Bow Tie
Correction ref point	PTV	**Gantry rotation**	-180°→ 180°
Registration	Dual Registration	**Gantry speed**	0.5 rpm
Method	Clipbox : Bone (T + R) Mask : Grey value (T + R)	**Detector position**	M
Restriction translations	Clipbox < 2 cm Mask < 0.5 cm	**Filter**	F1
Restriction Rotations	Clipbox < 5° Mask < 10°	**Collimation**	M20 (full bladder)

Example clipbox:
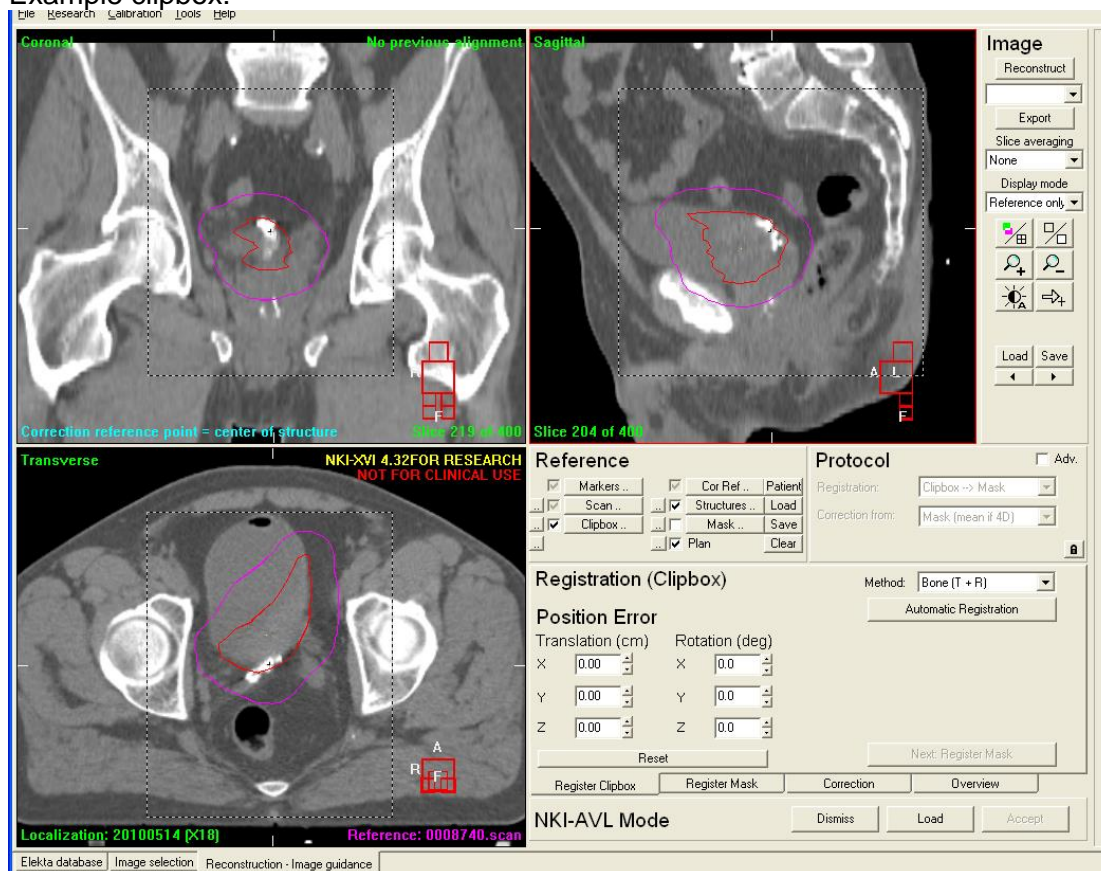
- Clipbox is placed around the rigid bony anatomy of the pelvic region. (exclude the femoral head and trochanter minor as much as possible)

Because the lipiodol deforms from day to day (with different bladder fillings) the visual inspection of the registration is not always straight forward and may require extra training. After automatic registration and visual inspection manual adaptation of the registration can be applied to optimise the registration.

Example of mask: for partial bladder treatment with lipiodol:
Make sure there is no bony anatomy inside the mask.

For further background information about lipiodol and the rationale of our IGRT protocol, see literature reference [2]

Brain

MATCH PARAMETERS		SCAN PARAMETERS	
Structures	GTV or CTV and PTV	**Preset selection**	Skull
Correction ref point	PTV	**Gantry rotation**	-180° → 25°
Registration	Clipbox	**Gantry speed**	1.0 rpm
Method	Bone (T + R)	**Detector position**	S
Restriction Rotation	3°	**Filter**	F1
Restriction Translation	10 mm	**Collimation**	S20

Example clipbox:
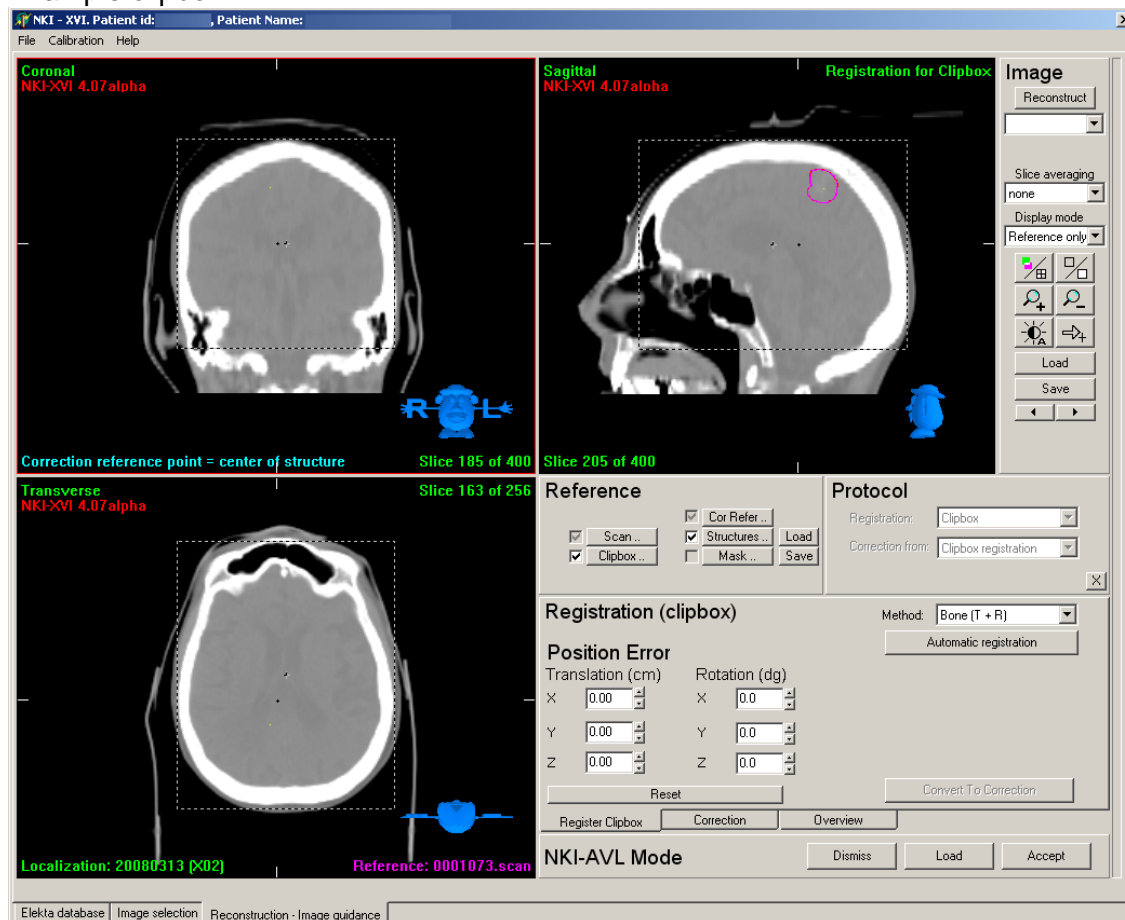
- When defining the clipbox make sure that only rigid bony anatomy is inside the clipbox. Mobile bony anatomy, like for instance the jaw, will affect the registration and lead to inaccuracy.

Breast

MATCH PARAMETERS		SCAN PARAMETERS	
Structures	TV_IMRT	Preset selection	Breast left/right
Correction ref point	TV_IMRT	Gantry rotation	Breast right: -180° → 25° Breast left: 330° → 180°
Registration	Clipbox	Gantry speed	0.5 rpm
Method	Bone (T + R)	Detector position	S
Restriction Rotation	5°	Filter	F1
Restriction Translation	10 mm	Collimation	S20

Example clipbox:

For setting the clipbox:
- Include as much breast tissue as possible in the clipbox and also include part of the sternum.
- Do not include (any) vertebrae.

Breast including integrated boost: the correction ref point is placed in the PTV of the boost area. If the boost area is asymmetrically located within the breast tissue, consider placing the correction reference point on the edge of the boost area more towards the centre of the breast PTV. This can be done by placing a marker in this position and putting the correction reference point on the marker.

For further background information and in addition specifically on breathhold see literature reference [3,4]

Breast using a single-isocentre technique for axilla

MATCH PARAMETERS		SCAN PARAMETERS	
Structures	TV_IMRT	**Preset selection**	Breast left/right
Correction ref point	Isocentre **(!)**	**Gantry rotation**	Breast right: -180° → 25° Breast left: 330° → 180°
Registration	Clipbox	**Gantry speed**	0.5 rpm
Method	Bone (T + R)	**Detector position**	S
Restriction Rotation	5°	**Filter**	F1
Restriction Translation	10 mm	**Collimation**	S20

Example clipbox:

For setting the clipbox:
- Include all of the breast tissue in the clipbox and part of the sternum.
- Try to minimize the amount of humerus and scapula in the clipbox.
- Do not include (any) vertebrae.

Breast with axilla and concomitant boost: the correction ref point is placed in the PTV of the boost area. If the boost area is asymmetrically located within the breast tissue, consider placing the correction reference point on the edge of the boost area more towards the centre of the breast PTV. This can be done by placing a marker in this position and putting the correction reference point on the marker. Also do not allow rotation of > 3°, because of connecting fields. The setup correction from the breast fields are used to correct for both the breast with axilla and the boost treatment.

Breast using a VMAT technique

MATCH PARAMETERS		SCAN PARAMETERS	
Structures	CTVtot (breast, axilla, parasternal) PTVtot	**Preset selection**	Breast left/right
Correction ref point	PTVtot, PTVsdtot	**Gantry rotation**	Breast right: -180° → 25° Breast left: 330° → 180°
Registration	Clipbox	**Gantry speed**	0.5 rpm
Method	Bone (T + R)	**Detector position**	S
Restriction Rotation	3°	**Filter**	F1
Restriction Translation	10 mm	**Collimation**	S20

Example clipbox:

For setting the clipbox:
- Include all of the breast tissue in the clipbox and part of the sternum.
- Try to minimize the amount of humerus and scapula in the clipbox.
- Do not include (any) vertebrae.

Breast: Partial breast treatment using a marker

Partial breast treatment is a treatment technique where not the whole breast, but only the tumour / or tumourarea (pre or postoperative) are irradiated, using small margins.

To accomplice accurate IGRT, surgical markers or specific PBI markers are placed around the tumour(area), these markers and contrast in surrounding breast tissue are used for matching the daily CBCTs on the pCT scan.

After the radiation a post CBCT is required to determine intrafraction motion. If the registration results are $\geq$ 0.5cm, an extra CBCT could be acquired in between arcs for the following fractions to reduce the intrafraction motion.
NB: In this case the CTV-PTV margins is 5 mm. Restriction values should be determined in every individual department, hence it depends on your departments treatment plans and margins.

MATCH PARAMETERS		SCAN PARAMETERS	
Structures	GTV(sd), CTV PTV (_opti)	**Preset selection**	Breast (left/right)
Correction ref point	GTV(sd)	**Gantry rotation**	Breast right: -180° → 25° Breast left: 330° → 180°
Registration	Dual Registration	**Gantry speed**	0.5 rpm
Method clipbox mask	Bone (T + R) Grey value (T + R)	**Detector position**	S
Restriction Rotation	Clipbox < 5° Mask < 20°	**Filter**	F1
Restriction Translation	Clipbox < 1.0 cm Mask < 1.0 cm	**Collimation**	S20
Mask	GTV(sd) margin 0.75 -1.0cm	**CBCT post RT**	Yes + match

Example clipbox:

Registration for this protocol is a two-step process. When markers are inserted choose dual registration protocol with a Grey value(T+R) registration for the mask. Performing a bony anatomy registration prior to marker registration provides a good starting position for marker registration. Having restrictions for the clipbox registration will also flag large discrepancies between the two registrations.

A mask is created from the GTV delineation with a 0.75-1.0 cm margin. Make sure that any ~~unwanted~~ air or bony anatomy inside the mask (for example ribs) is erased by editing the mask, and therefore will not influence the registration.

The visual inspection of the registration is not always straight forward so an additional training of the RTT is required. Changing the match algorithm or preforming a manual match is sometimes necessary to accomplice an accurate match.
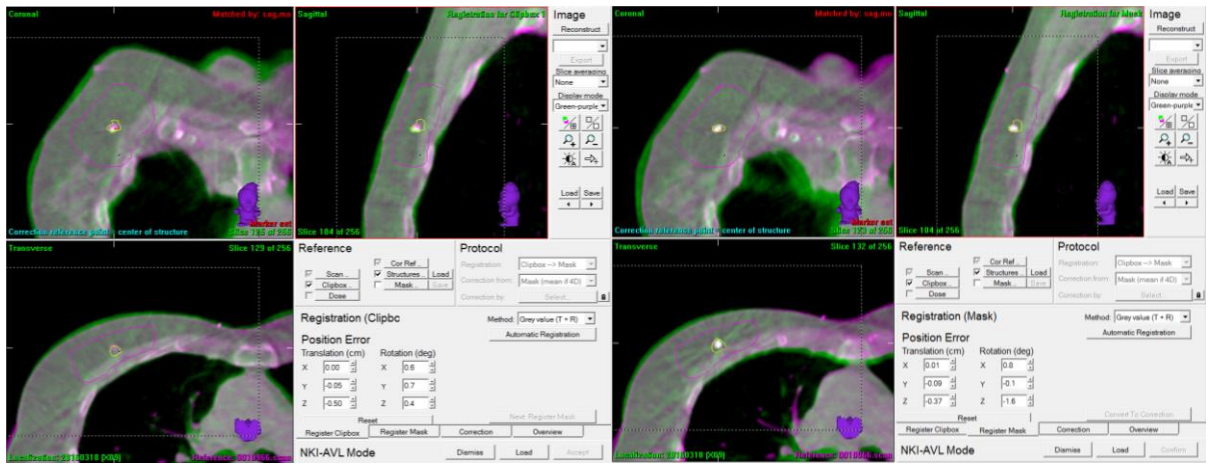
bony anatomy registration   *marker registration*

Pay attention to:
-   Glandular tissue around the markers
-   Contour
-   Rotations. For this protocol a match rotation of ≤ 20° will be accepted, provided that after convert to correction, the match result is still acceptable.
-   If the difference between the clipbox match and tumour match is more than 1 cm, XVI will warn you by giving a pop-up.

Head and Neck

In H&N we describe 3 target areas:

1. H&N tumours including neck and caudal part of the larynx or lower
   (for example: naso-, hypo-, oropharynx ,larynx ,base of tongue and oral cavity)

2. H&N tumours only in the skull
   (sinus tumours)

3. H&N tumours including neck and hyoid
   (for example: parotid glands, small tonsil tumours)

Anatomy of the head & neck area:
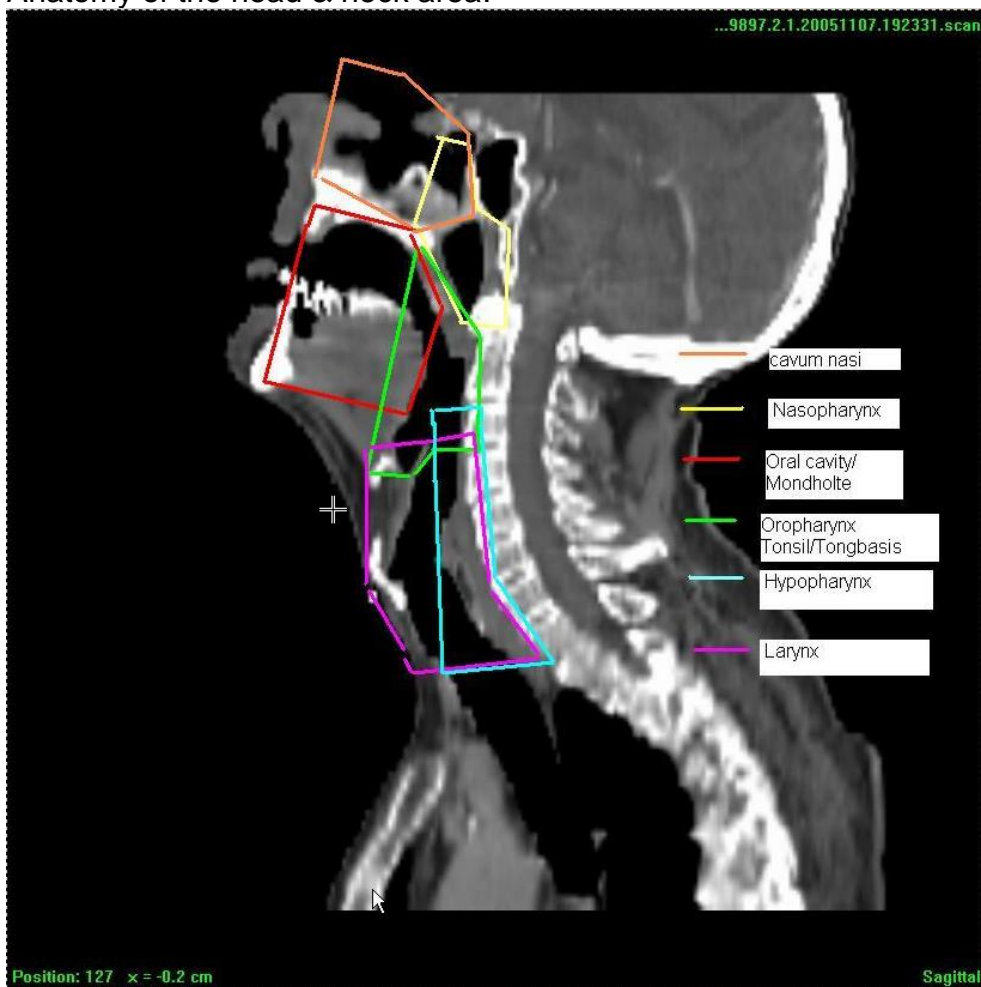
For all H&N sites, check:
- Position of bite-block and any dental prosthesis are the same.
- Position of tissue equivalent material.
- Increase or decrease of tissue and/or tumour.
- Deformations and/or rotations and their influence on structures around PTV.

1. H&N tumours including neck and caudal part of the larynx or lower

(for example: naso-, hypo-, oropharynx ,larynx ,base of tongue and oral cavity)

MATCH PARAMETERS		SCAN PARAMETERS	
Structures	GTV or CTV and PTV	**Preset selection**	Head and Neck MFOV
Correction ref point	PTV	**Gantry rotation**	-180° → 180°
Registration	Clipbox	**Gantry speed**	1.0 rpm
Method	Bone (T + R)	**Detector position**	M
Restriction Rotation	5°	**Filter**	F1
		Collimation	M20

A   Elective fields

- *Clipbox:*
- Contains the whole PTVtot_opti, (which includes all the lymph nodes PTVs)
- Vertebrae, incl. the spinous processus
- Os occipital
- Both mastoids
- Jugular notch
- If necessary: lower jaw (this depends on the position of the PTV)

- *Correction reference point:* centre of the PTVtot_opti

Example clipbox:
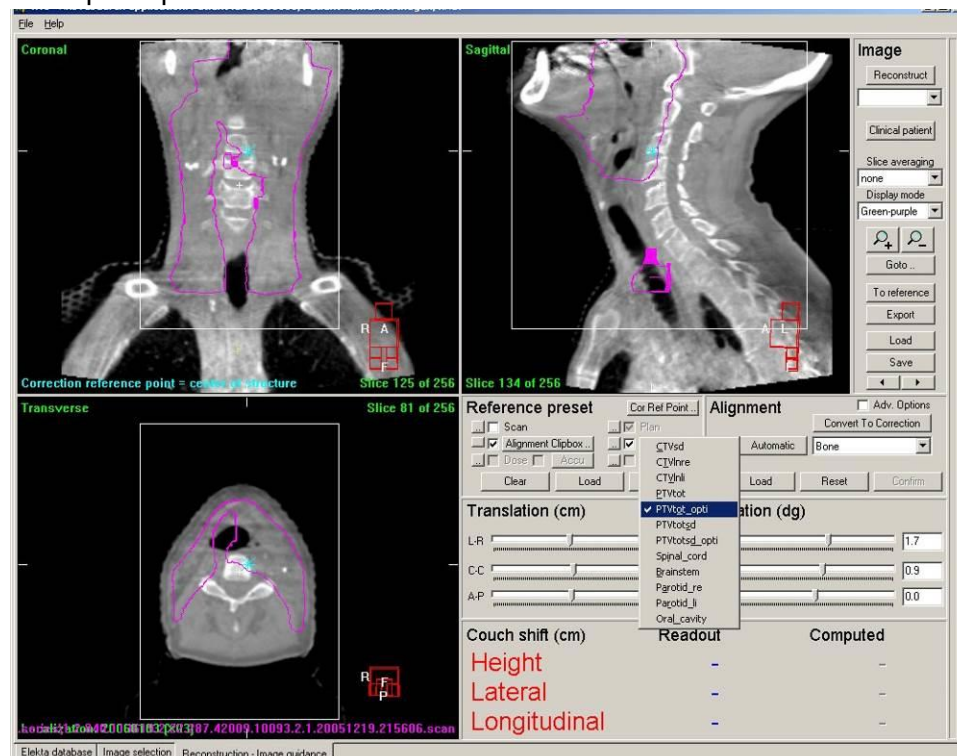
B Boost fields

- *Clipbox:*

- Contains the whole PTVtotsd_opti, the boost area (which includes all the lymph node PTVs)
- Vertebrae within the range of the PTVtotsd_opti
- If necessary: lower jaw (depending on the position of the PTV)

- *Correction reference point:* centre of the PTVtotsd_opti

Example of a boost clipbox:
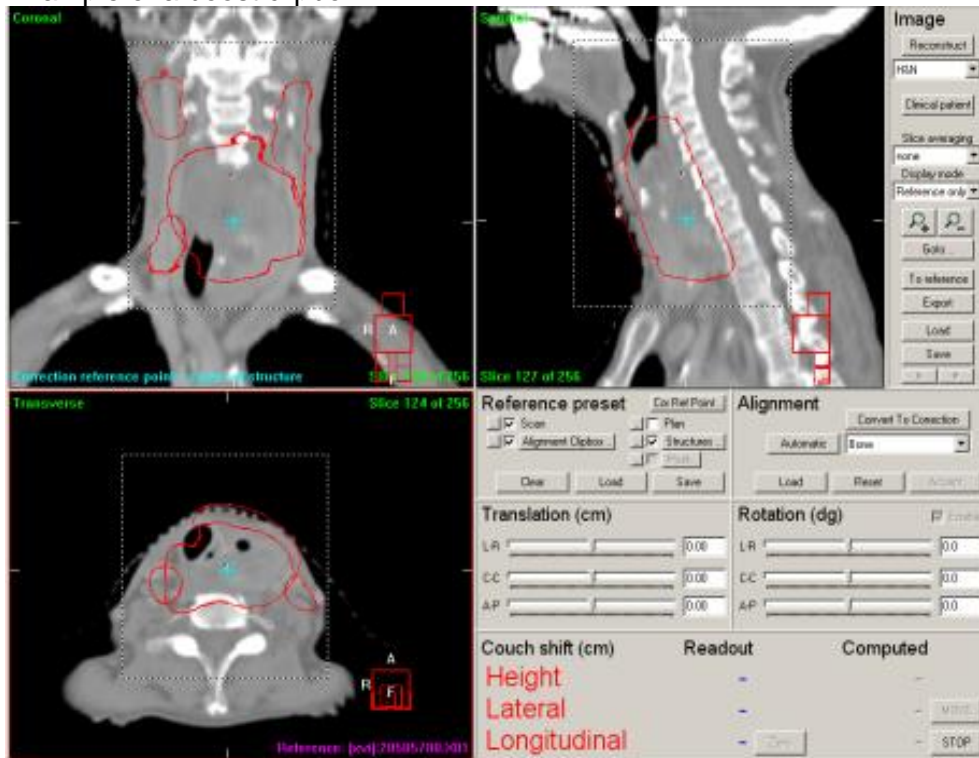
Match Instructions: When registering these large clipboxes, a critical organ avoidance strategy is applied for visual validation. The registration is mainly done on the vertebrae.

2. H&N tumours only in the skull
  (sinus tumours)

Use same **Match parameters** as for H&N tumours including neck and caudal part of the larynx or lower.

A Elective fields

   - *Clipbox:*
      - Contains the whole PTV
      - Width of the skull
      - Exclude the lower jaw
   - *Correction reference point:* centre of the PTV

B Boost fields

   - *Clipbox:*
      - Contains the whole PTVsd
      - Width of the skull
      - Exclude the lower jaw
   - *Correction reference point:* centre of the PTVsd

Example of a sinus clipbox:
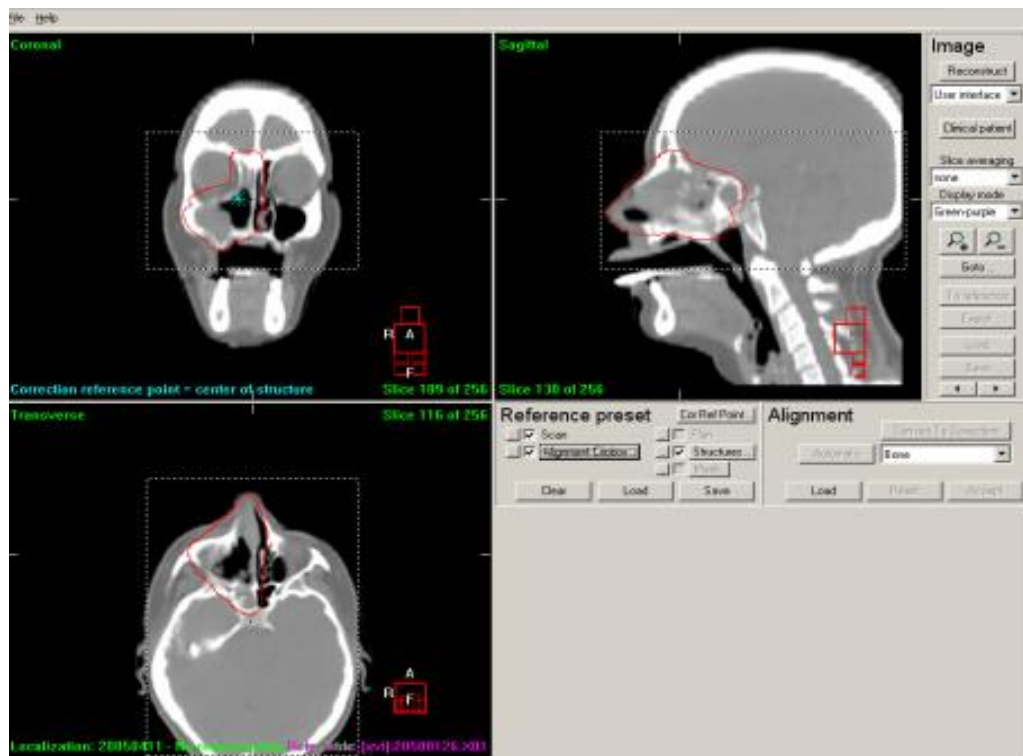
3. H&N tumours including neck and hyoid
   (for example: parotid glands, small tonsil tumours)

Use same **Match parameters** as for H&N tumours including neck and caudal part of the larynx or lower.

A Elective fields

- ***Clipbox:***
  - Contains the whole PTVtot_opti, (which includes all the lymph node PTVs)
  - Width of the skull
- ***Correction reference point:*** centre of the PTVtot_opti

B Boost fields

- ***Clipbox:***
  - Containing the whole PTVtotsd_opti, (which includes all the lymph node PTVs)
  - Width of the skull
- ***Correction reference point:*** centre of the PTVtotsd_opti

Example of a parotid gland clipbox:
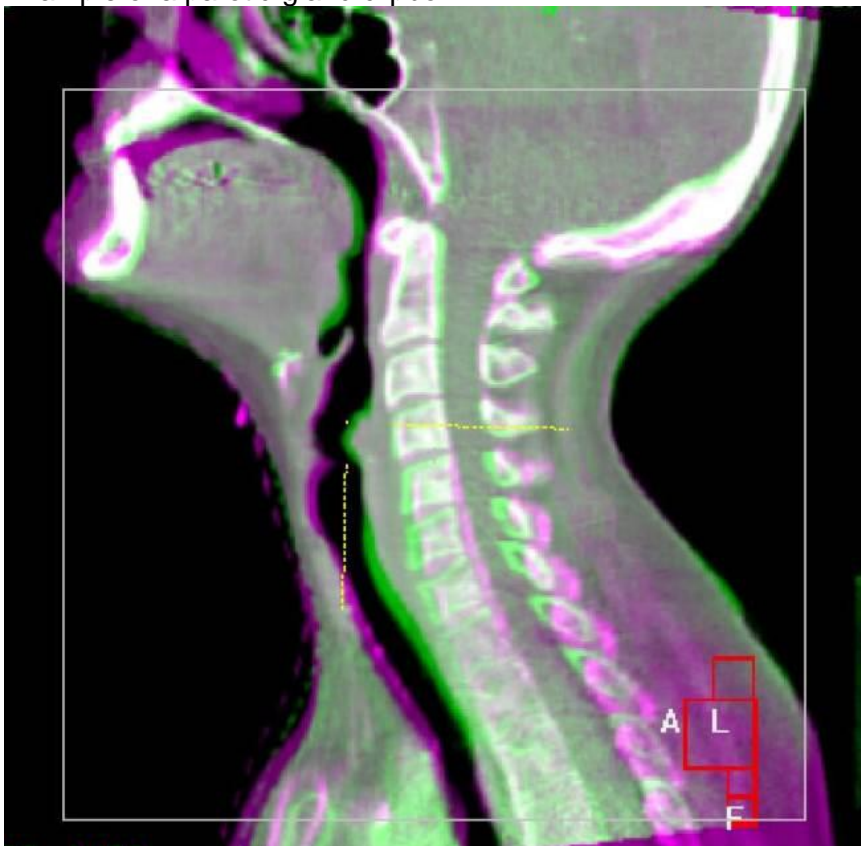
For further details about head and neck registration and in addition information about multi registration methods used in our clinic, see literature reference [5]

Larynx

MATCH PARAMETERS		SCAN PARAMETERS	
Structures	GTV or CTV and PTV.	Preset selection	Larynx MFOV
Correction ref point	PTV	Gantry rotation	-180° → 180°
Registration	Clipbox	Gantry speed	1.0 rpm
Method	Bone (T + R)	Detector position	M
Restriction Rotation	10°	Filter	F1
Restriction Translation	10 mm	Collimation	M10

Example clipbox:
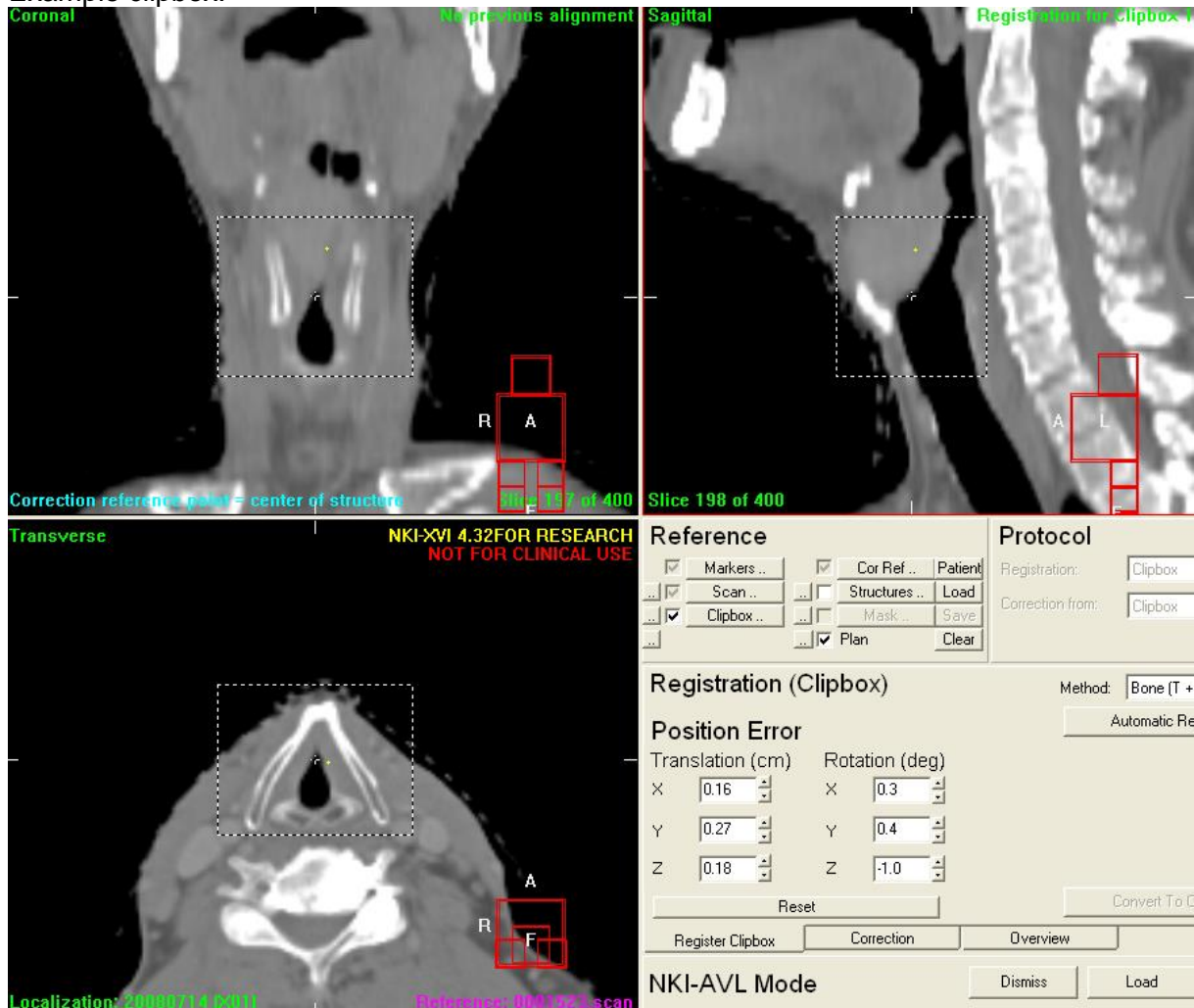
- No Hyoid and vertebrae in clipbox
- If the bony details are too small the registration method seed match (T+R) could be usefull.

Lung

Patients are scanned on a CT scanner according to in-house 4D CT protocol and the amplitude of the tumour is assessed. Depending on the amplitude of the tumour a 3D or 4D acquisition and registration can be used [8].

In our clinic we compensate for breathing motion using a priori motion model of the patient respiratory cycle which is estimated from the 4D planning CT [9]. The estimated motion, a personalized deformation vector field, is applied in an optimized reconstruction algorithm for CBCT. The motion model is checked on the first day of treatment.

1. Lung basic protocol (e.g. palliative treatment)

MATCH PARAMETERS		SCAN PARAMETERS	
Structures	GTV and PTV	Preset selection	Lung left/right
Correction ref point	PTV	Gantry rotation	Lung right: -180° → 25° Lung left: 330° → 180°
Registration	Clipbox	Gantry speed	ampl. ≥ 0.8 cm:0.125 rpm* ampl.< 0.8 cm: 0.5 rpm*
Method	Bone (T + R)	Detector position	S
Restriction Rotation	5°	Filter	F1
Restriction Translation	10 mm	Collimation	S20
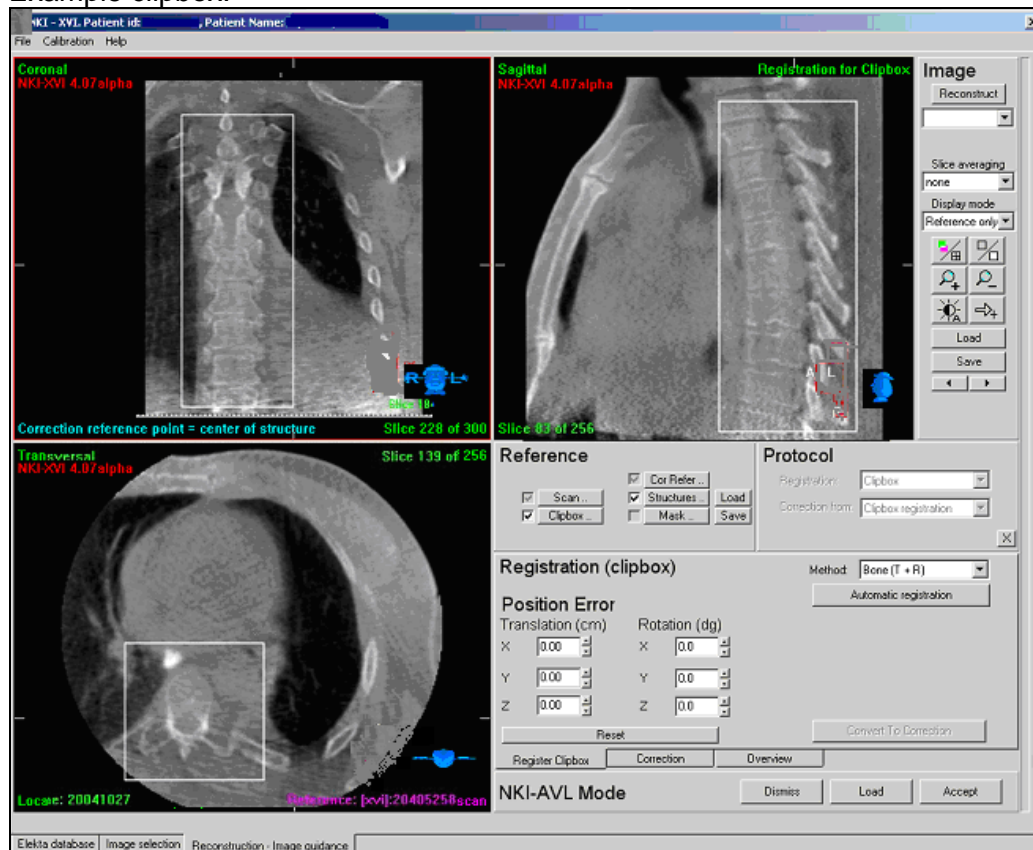
Example clipbox:

- Clipbox around the vertebrae.

- If the tumour is located ventrally then include the sternum in the clipbox (*),
- If the tumour is located laterally then include the ribs.
- Do not include (too much) of the scapula and/or the humerus head.

Example clipbox *:

Point of interest:

When registering the thoracic region using a clipbox around the vertebrae it is important to firstly review the images in green-purple. The automatic registration is sometimes one vertebra off in the longitudinal direction. If this is the case you could do a grey value registration or do a manual registration and then perform the automatic registration again.
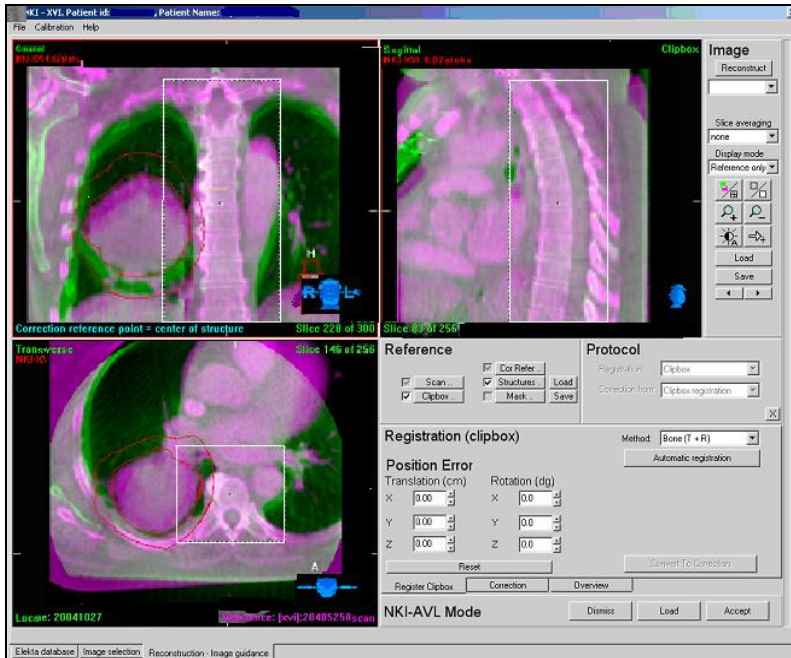
(a)

Registration review of the vertebrae seems alright at first review, but if you look outside the clipbox you see substantial differences in the registered anatomy that indicate that the registration is 1 vertebra off.
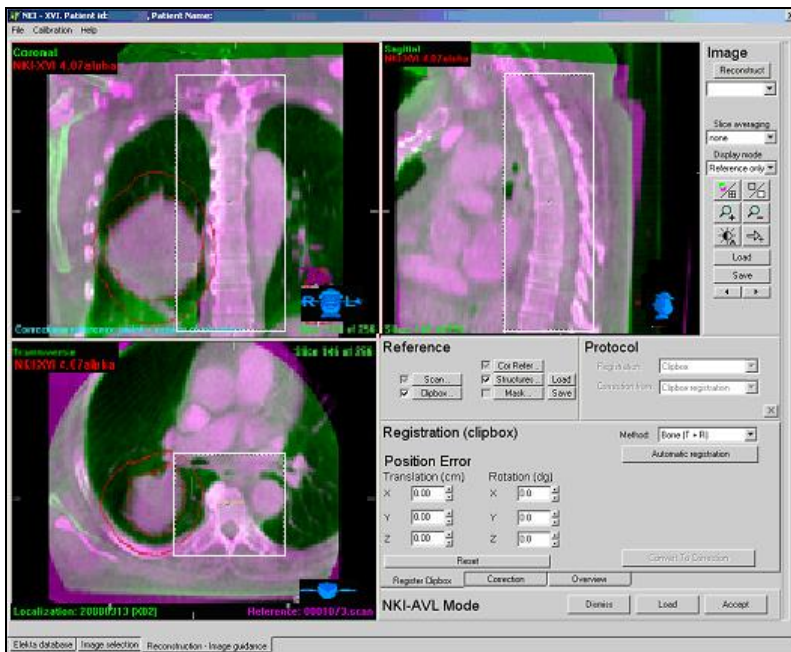
(b)

Second registration (b) uses the same clipbox and same starting position, but using the grey value registration instead of the bony anatomy registration.
Or a manual repositioning can be done and then perform a bone anatomy or grey value registration.

2. Lung primary tumour only

Dual registration can be considered in patients treated with only a primary tumour and no lymph node involvement, using a clipbox&mask method. Registration on the vertebrae with bony anatomy match followed by a mask registration on het GTV using (4D) Grey Value translations only algorithm.

Having restrictions for the clipbox registration will flag large discrepancies between the two registrations and alarms you that these changes could influence the dose distribution on OARs. In case of high dose contribution close to the critical dose of the spinal cord, small translation restrictions are necessary or the basic lung protocol should be standard.

MATCH PARAMETERS		SCAN PARAMETERS	
Structures	GTV PTV	**Preset selection**	4D/3D Lung left/right
Correction ref point	PTV tot	**Gantry rotation**	Lung right: -180° → 25° Lung left: 330° → 180°
Registration	Clipbox & Mask	**Gantry speed**	ampl. ≥ 0.8 cm: 0.125 rpm* ampl. < 0.8 cm: 0.5 rpm*
Method clipbox mask	Bone (T + R) Grey value 4D T	**Detector position**	S
Restriction Rotation	Clipbox < 5° Mask < 5°	**Filter**	F1
Restriction Translation	Clipbox < 1.0 cm Mask < 1.0 cm	**Collimation**	S20

A mask is created from the GTV delineation with a 0.5 cm margin, without removing the air of surrounding lung tissue. Make sure that any unwanted bony anatomy inside the mask (for example ribs) is erased by editing the mask, and therefore will not influence the registration. Anatomical changes could also influence the registration; consider changing the additional mask if registration problems occur.

The mask registration of the GTV is not always straight forward, due to anatomical changes of the GTV during treatment, automatic registrations will not always be correct. Interpreting these anatomical changes and the influence on the treatment can be challenging in lung cases. Additional training of the RTT is required.

3. Lung Carina

The carina protocol is for patients, irradiated on a primary tumour in the lung and lymph nodes in the mediastinum with a dose of ≥ 44 Gy.

To determine the position of the tumour, glands and vertebrae, 2 matches should be done. A bony anatomy registration on the vertebrae is done prior to carina registration, using a mask made of the carina as a surrogate for the lymph nodes. Automatic registration of the carina has a greater chance of success than a registration on the glands itself; especially at the end of treatment when anatomical changes influence the registration. The result of the carina match is used for the online set-up correction. The primary tumour is visually checked by the RTTs.

Note that this protocol can only be used if the spinal cord dose is not critical, translation restrictions could be considered or, more savely, change your registration method to clipbox, where the setup-correction will be based on the vertebrae.

MATCH PARAMETERS		SCAN PARAMETERS	
Structures	GTV (tumour and glands)/ CTV and PTV(tot(opti))	**Preset selection**	4D Lung left/right or 3D Lung left/right
Correction ref point	PTV tot(/tot_opti)	**Gantry rotation**	Lung right: -180° → 25° Lung left: 330° → 180°
Registration	Clipbox & Mask	**Gantry speed**	ampl. ≥ 0.8 cm: 0.125 rpm* ampl. < 0.8 cm: 0.5 rpm*
Method clipbox mask	Bone (T + R) Grey value 4D T	**Detector position**	S
Restriction Rotation	Clipbox < 5° Mask < 5°	**Filter**	F1
Restriction Translation	Clipbox<1.0 cm Mask <1.0 cm	**Collimation**	S20

Example clipbox:

- clipbox around the vertebrae.

There are two options to create a mask of the carina:
- Manually
- Automatically; only possible if carina structure is available.

Make sure that any unwanted bony anatomy inside the mask (e.g. vertebrae) is erased by editing the mask, and therefore will not influence the registration.

When you're satisfied with the bony anatomy match and the mask match, the tumour is checked visually, make sure the tumour moves within the PTV. Additional training of the RTT is required.

For further background information about lung IGRT and the rationale, see literature reference [6,7,8,9,10,11,12,13,19]

Prostate region (nodal involvement/post-op)

| MATCH PARAMETERS		SCAN PARAMETERS	
Structures	GTV or CTV and PTV	**Preset selection**	Prostate Bow Tie
Correction ref point	PTV	**Gantry rotation**	-180°→ 180°
Registration	Clipbox	**Gantry speed**	0.5 rpm
Method	Bone (T + R)	**Detector position**	M
Restriction rotation clipbox	3°	**Filter**	F1
Restriction Translation	10 mm	**Collimation**	M10 M20 (in case of nodal involvement)

Example clipbox:
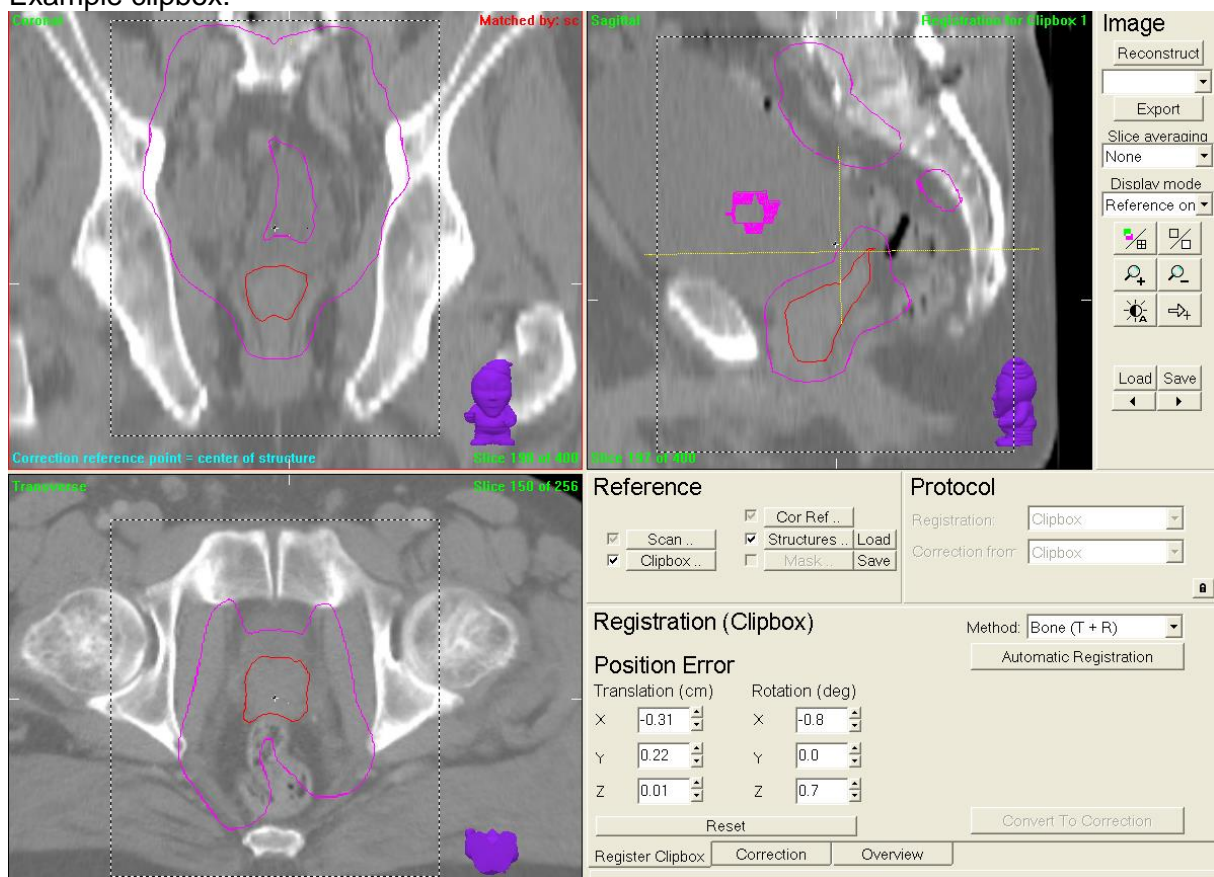
- Clipbox is placed around the rigid bony anatomy of the pelvic region (exclude the femoral head and trochanter minor as much as possible)
- Check bladder and rectum volumes. If different from planning CT check if target volume coverage is not compromised.

Prostate with markers

Registration for this prostate protocol is a two-step process. Performing a bony anatomy registration prior to prostate registration (using markers as a surrogate for the prostate) provides a good starting position for the prostate registration. Having restrictions for the clipbox registration will also flag large discrepancies between the two registrations.

MATCH PARAMETERS		SCAN PARAMETERS	
Structures	CTV and PTV incl. Seminal vesiculea	Preset selection	Prostate Bow tie
Correction ref point	PTV incl. Seminal vesiculea	Gantry rotation	-180°→ 180°
Registration	Dual registration	Gantry speed	0.5 rpm
Method	Clipbox : Bone (T + R) Mask : Seed (T + R)	Detector position	M
Restriction translation	Clipbox: 1.5cm Mask: 1.0cm	Filter	F1
Restriction rotation	Clipbox: 5° Mask: 20°	Collimation	M10

A mask is created from the CTV delineation (prostate and vesiculae) with a 0 cm margin, and without removing air or high densities. Markers and calcifications will then be included. If markers are inserted choose dual registration protocol with a seed registration for the mask. The seeds inside the mask will be segmented for registration (chamfer match). Make sure that any unwanted bony anatomy inside the mask (for example pubic bone) is erased by editing the mask, and therefore will not influence the registration. Use a 0.5 cm margin when a patient has no marker and perform a grey value match, but be alert on misregistrations due to minimal tissue contrast and deformed anatomy cause by rectalgas/fill and bladderfilling within the mask.

Left: Patient without markers   Right: Patient with markers
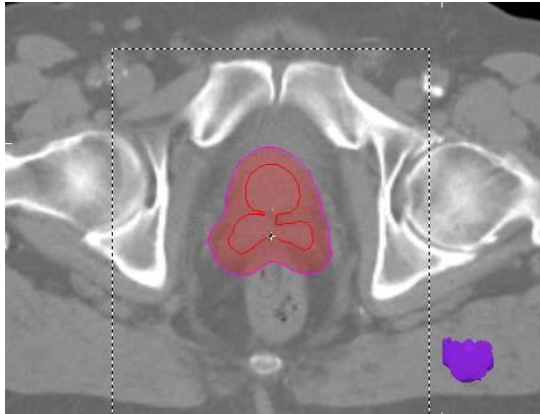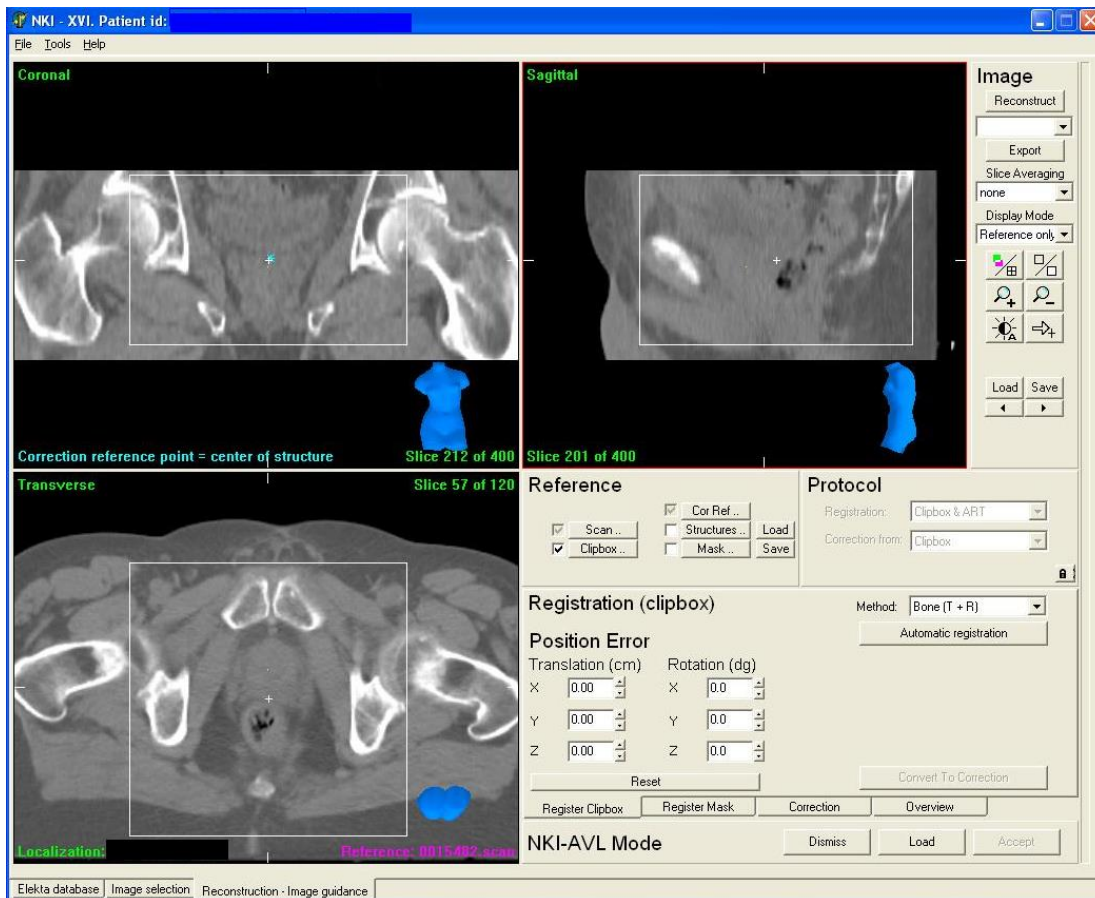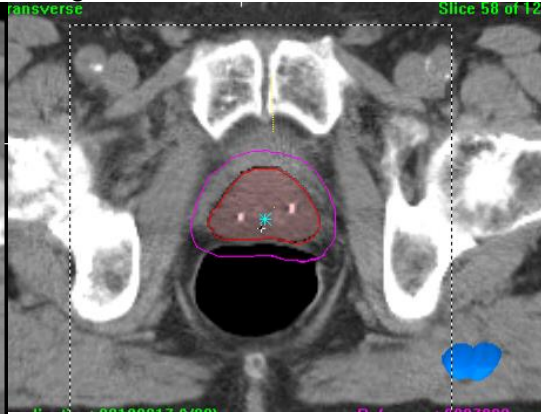
- Clipbox is placed around the rigid bony anatomy of the pelvic region (exclude the femoral head and trochanter minor as much as possible)
- Check bladder and rectum volumes. If different from planning CT check if target volume coverage is not compromised. Seminal vesicles can move differently to the prostate.

For further background information about prostate IGRT and the rationale, see literature reference [14,15,16,17]

Rectum supine, Anus/Vulva with nodes, Cervix

MATCH PARAMETERS		SCAN PARAMETERS	
Structures	GTV or CTV and PTV	**Preset selection**	Rectum Bow Tie
Correction ref point	PTV	**Gantry rotation**	-180°→ 180°
Registration	Clipbox	**Gantry speed**	0.5 rpm
Method	Bone (T + R)	**Detector position**	M
Restriction rotation clipbox	5° 3° when lymph nodes are involved	**Filter**	F1
Restriction Translation	10 mm	**Collimation**	Rectum M15 Anus, cervix M20

Example clipbox :
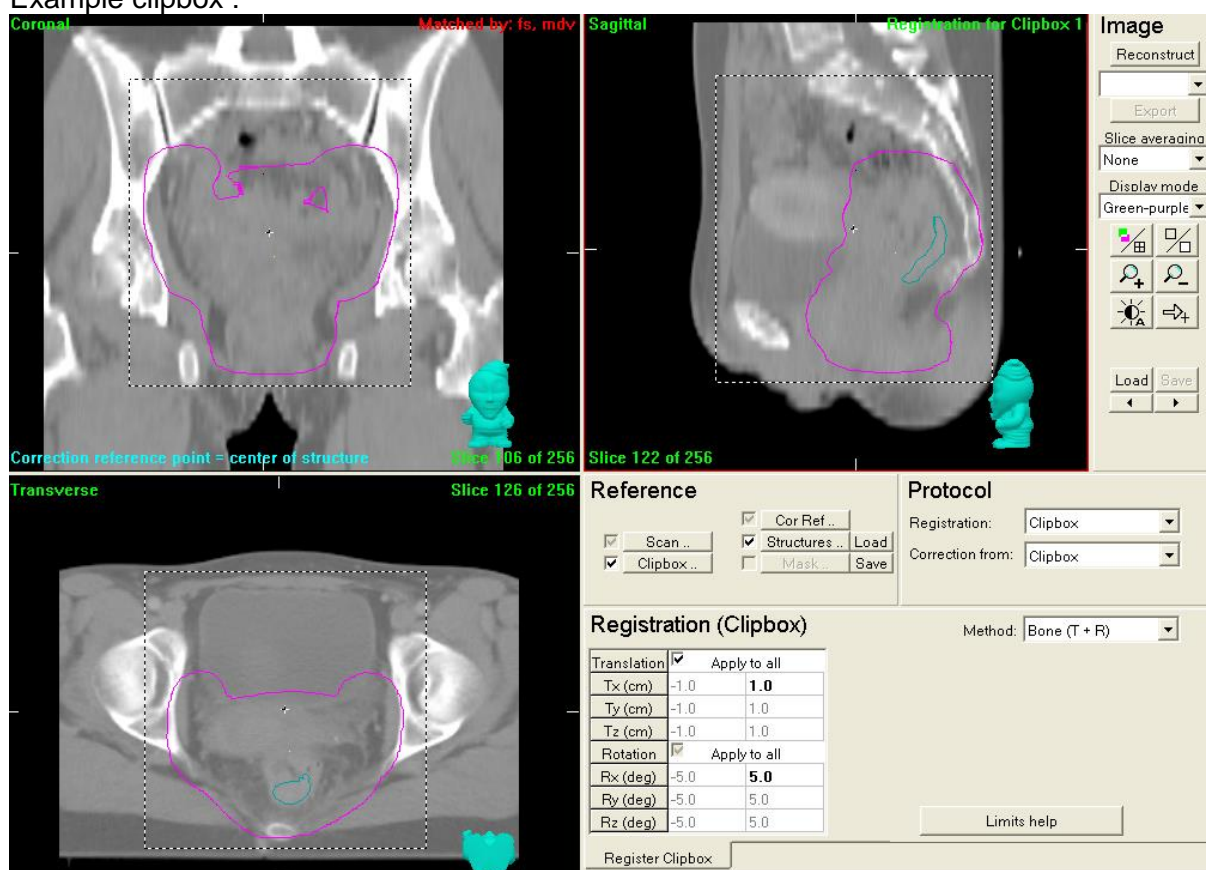
- Clipbox is placed around the rigid bony anatomy of the pelvic region (exclude the femoral head and trochanter minor as much as possible)
- Check bladder and rectum volumes. If different from planning CT check if target volume coverage is not compromised.

Sarcoma

MATCH PARAMETERS		SCAN PARAMETERS	
Structures	GTV or CTV and PTV	**Preset selection**	Sarcoma Bow Tie
Correction ref point	PTV	**Gantry rotation**	-180°→ 25° 330° → 180° Depends on localization target volume
Registration	Clipbox	**Gantry speed**	0.5 rpm
Method	Bone (T + R)	**Detector position**	S
Restriction rotation clipbox	5° if target is <10 cm 3° if target is >10 cm	**Filter**	F1
Restriction translation	10 mm	**Collimation**	S20

Definition of the clipbox depends on the localization of the tumour and the presence of bony anatomy in the area to be treated. Optimally a part of the joint should be included in the clipbox but that is not always possible in extremities.

Example clipbox:
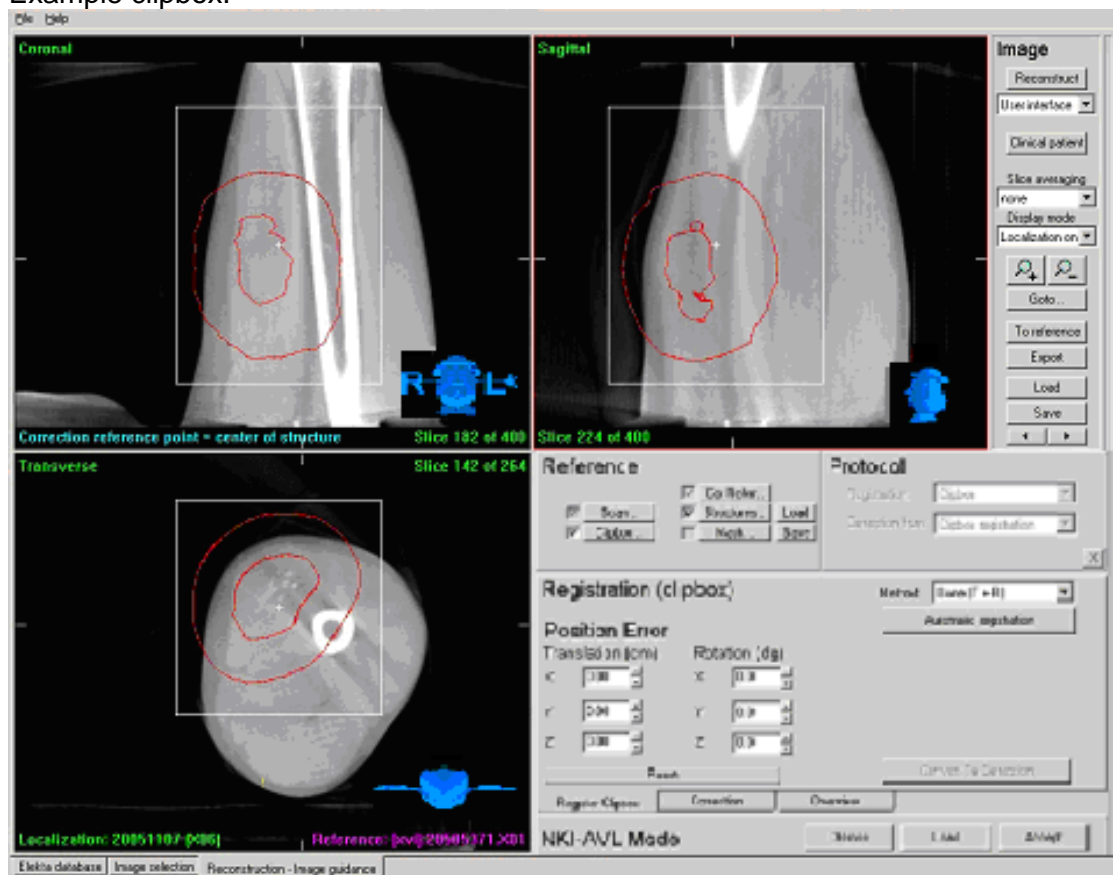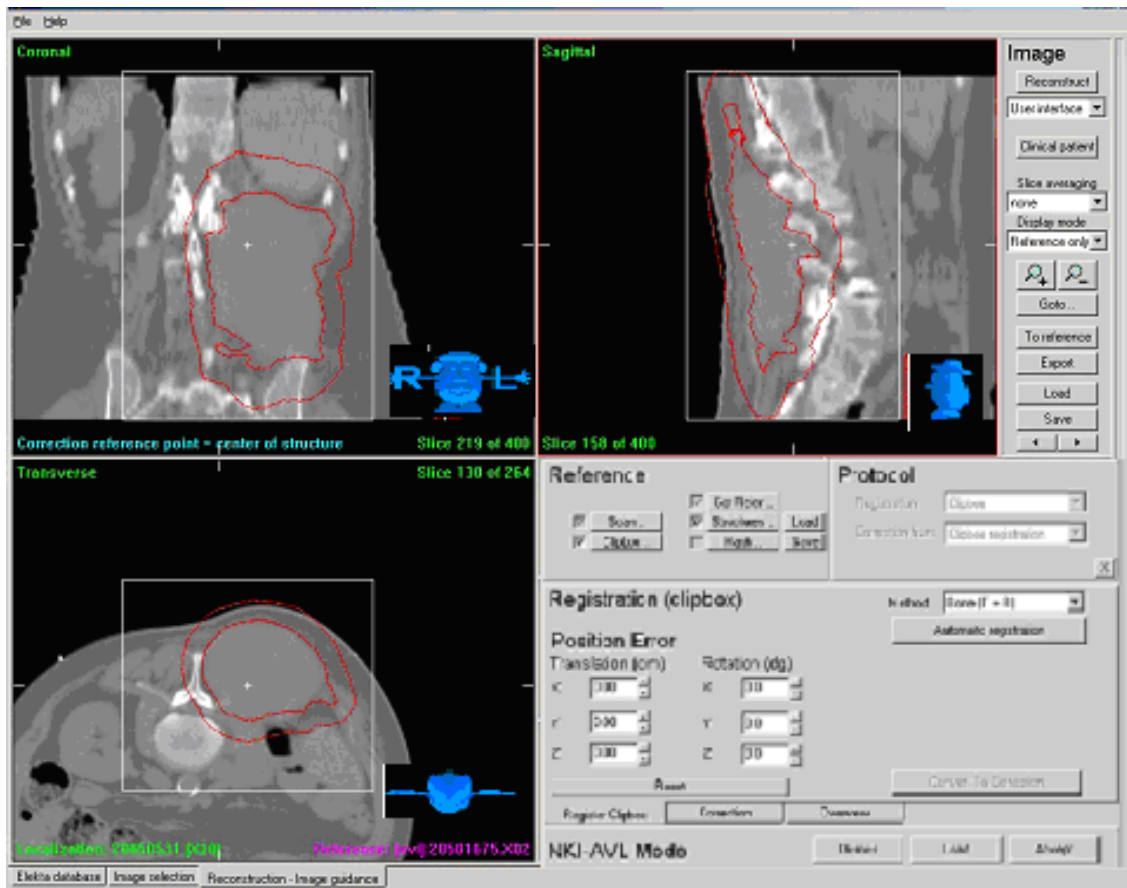
- Be aware of: Shape changes, position of target area within PTV and rotations.

For further background information about sarcoma and in addition specifically about anatomical changes seen on CBCT, see literature reference [18]

Seminoma Testis

MATCH PARAMETERS		SCAN PARAMETERS	
Structures	GTV surdo, CTV electief tot. and PTV(tot)	**Preset selection**	Pelvis Bow tie
Correction ref point	PTV (tot)	**Gantry rotation**	-180°→ 180°
Registration	Clipbox	**Gantry speed**	0.5 rpm
Method	Bone (T + R)	**Detector position**	M
Restriction rotation clipbox	3°	**Filter**	F1
		Collimation	M20

Example clipbox:

- Create the clipbox as long as the PTV, but still within the field-of-view.
- Pay attention if the target area is in the PTV, especially when there are large rotations to the cranial and caudal side.

Stomach/Oesophagus

MATCH PARAMETERS		SCAN PARAMETERS	
Structures	GTV and PTV	**Preset selection**	Lung left/right
Correction ref point	PTV	**Gantry rotation**	Lung right: -180° → 20° Lung left: 335° → 180°
Registration	Clipbox	**Gantry speed**	0.5 rpm
Method	Bone (T + R)	**Detector position**	S
Restriction rotation clipbox	5°	**Filter**	F1
Restriction Translation	10 mm	**Collimation**	S20

Example clipbox stomach*:*
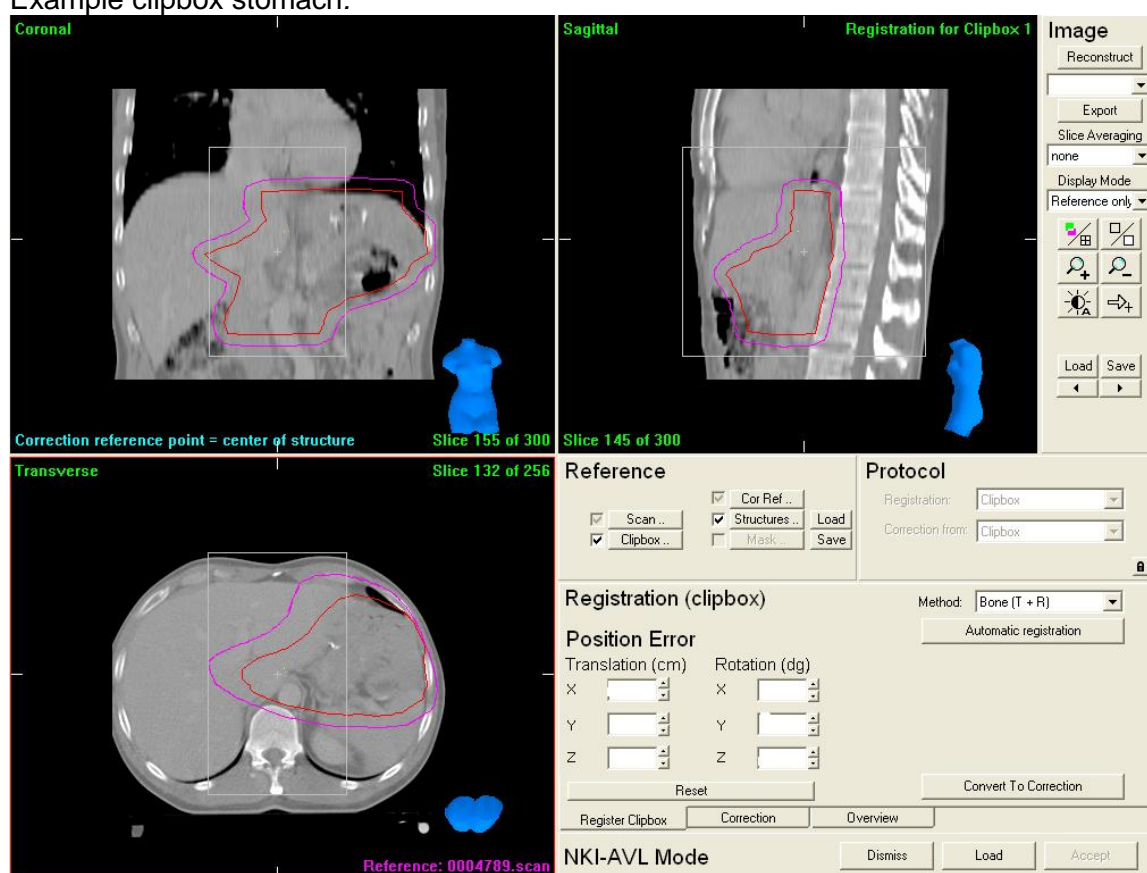
- Include vertebrae.
- If target volume is laterally or ventrally located include ribs and/or xiphoid processus respectively.
- Be aware: after the automatic registration the match could be 1 vertebra off in the longitudinal direction, so always do a visual check using nearby anatomical landmarks.

Example clipbox oesophagus:
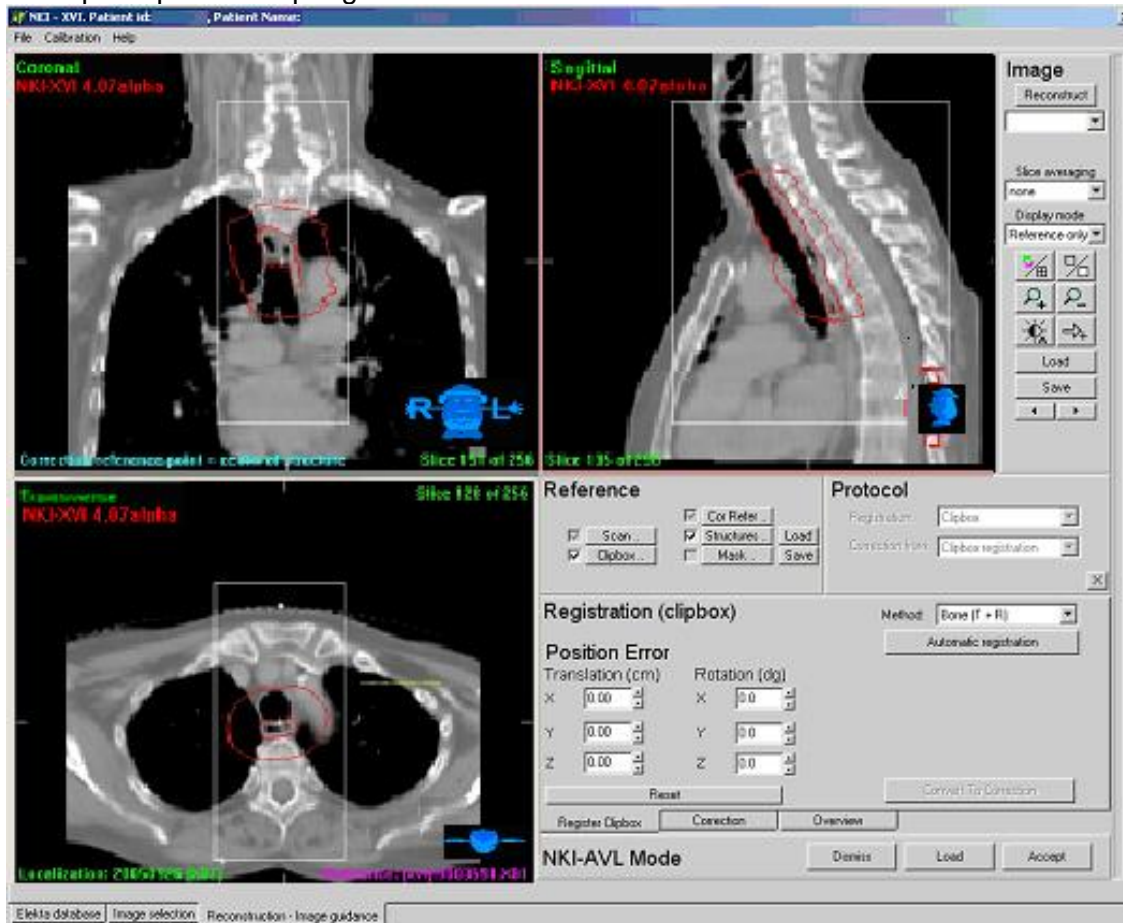
- Include vertebrae.
- Include part of the sternum only for superior thoracic tumours.
- In case superior thoracic tumours an individual head base + cast is often used to immobilize the patient. A head and neck protocol can then be used for these treatment sites.

Protocol for SBRT

A summary of the protocol for SBRT treatment in AvL:

Patients are positioned in the treatment room and a CBCT is acquired. A match is performed according to the specific target area protocol. After **convert to correction** a visual check is done, to check if the target area is within the PTV. Then an automatic table correction is performed. Because of the hypo-fractionated treatment schedule a second pre-treatment scan is acquired to validate the couch shift. If this second CBCT is correct, according to the specific requirements of the treatment site specific protocol then the treatment can start. If the tumour is still misaligned (for example change in baseline shift) the registration is repeated and the protocol is followed again from the beginning. After treatment a CBCT is acquired to assess intra fraction motion. If possible, CBCT concurrent with VMAT is also made for this purpose.

Some treatment sites require only a bony anatomy registration. If this is the case you can place the clipbox around the rigid bony anatomy and choose for registration protocol: clipbox. The other option is to use dual registration, using a bony anatomy match around the vertebrae and a mask match for the tumour. The dual registration (first clipbox then mask) is designed to compare the outcome of the two registrations and can be used for a critical structure avoidance strategy.

For Lung, Liver and Adrenal:

Patients are scanned on a CT scanner according to in-house 4D CT protocol and the amplitude of the tumour is assessed. Depending on the amplitude of the tumour we decide between 3D or 4D dual registration. The mask defined in the planning CT registers the tumour automatically in each phase of the 4D-CBCT scan. The different tumour registrations are recalculated to the (time weighted) average position of the tumour. After registration the rotations are recalculated in the predefined correction reference point (centre of PTV), because in our department the rotations cannot physically be corrected. The correction is validated against a threshold determined during treatment planning. This validation will ensure that the dose constraints for the organs at risk are not compromised. For example if the tumour is located near the spinal cord, a baseline shift towards the organ at risk could compromise the dose to the spinal cord.

Tumour registration is performed 4D, if the breathing amplitude of the tumour is more than 8 mm (assessed at the pre-treatment or planning 4D CT scan). If the amplitude is less than 8 mm a 3D CBCT is acquired and reconstructed. 3D registration will provide the same accuracy and is easier to perform than 4D. Therefore 3D registration is preferable in case of small breathing amplitudes.

In our clinic we compensate for breathing motion using a priori motion model of the patient respiratory cycle which is estimated from the 4D planning CT. The estimated motion, a personalized deformation vector field, is applied in an optimized reconstruction algorithm for CBCT. The motion model is check on the first day of treatment. [9]

Dual registration is performed and is a two-step procedure: first the bony anatomy is registered using a chamfer match method with a clipbox around the rigid bony anatomy allowing translations and rotations, for these treatment sites this is usually the vertebrae. Second a tumour registration is performed using a mask (shaped region of interest derived from the GTV delineation) allowing only translations. The grey value (T) is used. We only

allow translations because of the usual round shape of the small tumours that are most eligible for hypo fractionation. After covert to correction the table correction based on the tumour registration will be calculated, and the residual displacement of the vertebrae. To check safe displacement of the high dose regions to the spinal cord (measured with the clipbox), limits of the allowed residual vertebrae displacement are prescribed in the reference settings. This is determined when making the treatment plan. When these limits are crossed, a warning is given the time of registration. The table correction will then adjusted until the safety the position of the vertebrae meets the prescribed safe limitations.

SBRT for Adrenal, Liver and Lung

MATCH PARAMETERS		SCAN PARAMETERS	
Structures	GTV or CTV and PTV	**Preset selection**	Lung medium left/right: ampl. < 0.8 cm, 4D Lung left/right: ampl. ≥ 0.8 cm
Correction ref point	PTV	**Gantry rotation**	-180° → 20° (right) 335°→ 180° (left)
Registration	Dual registration	**Gantry speed**	0.5 rpm: ampl. < 0.8 cm 0.125 rpm: ampl. ≥ 0.8 cm
Method	Clipbox: Bone (T + R) Mask: Grey value 4D (T)	**Detector position**	S
Restriction translations	Clipbox: to be determined at treatment planning, max 1 cm. Mask: 0.3 cm.	**Filter**	F1
Restriction rotations	Clipbox: 5° Mask: 5°	**Collimation**	S20

The clipbox is placed around a representative part of the rigid bony anatomy (maximum amount of vertebrae inside Field Of View). If the tumour is located near the ribs or sternum we also include these structures in the clipbox. The mask is created from the GTV structure with a margin of 0.5 cm, high densities are erased. Any bony anatomy that might influence the tumour registration is erased by editing the mask. For the liver and adrenal tumour it might help to include the diaphragm inside the mask.

Adrenal: Example clipbox, mask and safety limitations for spinal cord:

Lung: Example clipbox and mask Lung

SBRT for Bone metastases, Brain

MATCH PARAMETERS		SCAN PARAMETERS	
Structures	GTV or CTV and PTV	**Preset selection**	
Correction ref point	PTV	**Gantry rotation**	-180° →180°
Registration	Clipbox	**Gantry speed**	0.5 rpm
Method	Bone (T + R)	**Detector position**	M
Restriction Rotation	3°	**Filter**	F1
Restriction Translation	10 mm	**Collimation**	M20

NB. For brain we use the skull preset F1 S20 -180° → 25°.

Example clipbox:
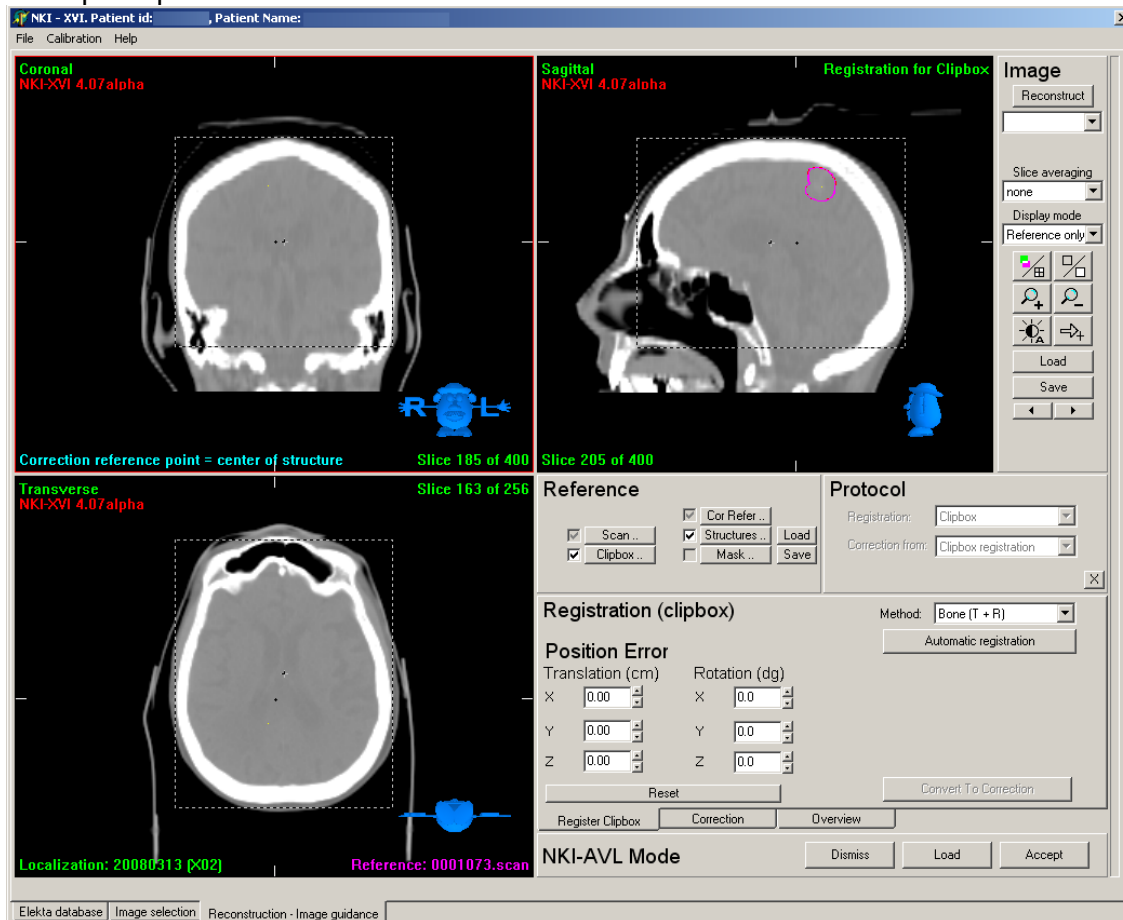
When defining the clipbox make sure that only rigid bony anatomy is inside the clipbox.
Mobile bony anatomy, like for instance the lower jaw, will affect the registration and lead to
inaccuracy.

SBRT for Spinal vertebra

MATCH PARAMETERS		SCAN PARAMETERS	
Structures	GTV or CTV and PTV	**Preset selection**	Spine MFOV
Correction ref point	OAR: Spinal cord	**Gantry rotation**	-180° →180°
Registration	Clipbox	**Gantry speed**	0.5 rpm
Method	Bone (T + R)	**Detector position**	M
Restriction Rotation	1 vertebra 3° 2 vertebrea 2° 3 vertebrea –> contact physicist	**Filter**	F1
Restriction Translation	10 mm	**Collimation**	M20

Example of clipbox: for spinal vertebrae:
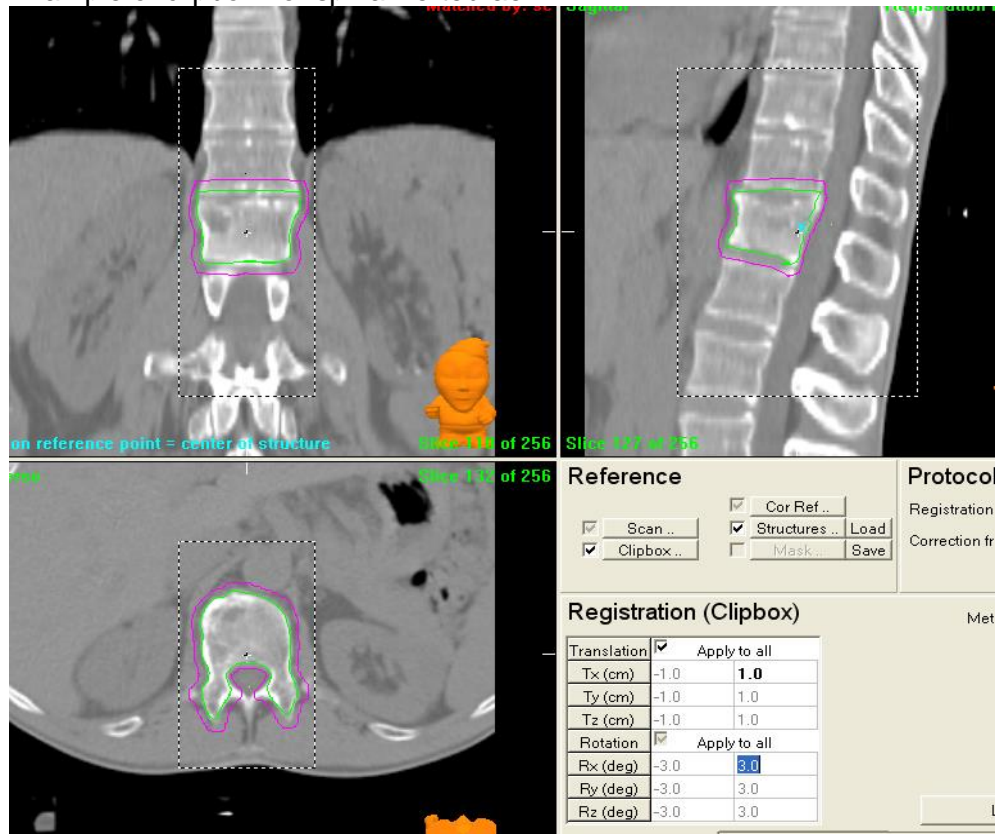
To avoid a mismatch of the vertebrae in CC direction, make sure you include enough anatomy within the clipbox. During registration be aware of rotation accuracy, make sure the clipbox is representative of your target area and adjust if necessary.

Decision support system for anatomical changes

Traffic light protocol

Introduction

In the Netherlands, CBCT's are typically analyzed by 2 radiation therapy technologists (RTTs) and the radiation oncologist is only informed when a change is observed. In our institute, we developed an action level protocol (traffic light protocol) as a decision support system to guide the RTT in prioritizing these changes.

In this part of the document you will find the traffic light protocols which was used until 2019 at the Netherlands Cancer Institute (see action protocol for current practice). Both protocols are in no way meant as a gold standard. They have been derived from our own clinical experience and are a result of collaboration between RTT's, physicians, and physicists. This document can be used as a guideline, when designing your own protocol.

Level green, no action needed.

Level yellow, the radiation oncologist is notified by email, but no response is required to continue treatment.

Level orange, the treating radiation oncologist (or back-up colleague) is informed by email and a response is required before the next fraction.

Level red changes, the radiation oncologist must be consulted immediately before the treatment fraction is allowed to be delivered.

Head& Neck

Contour changes
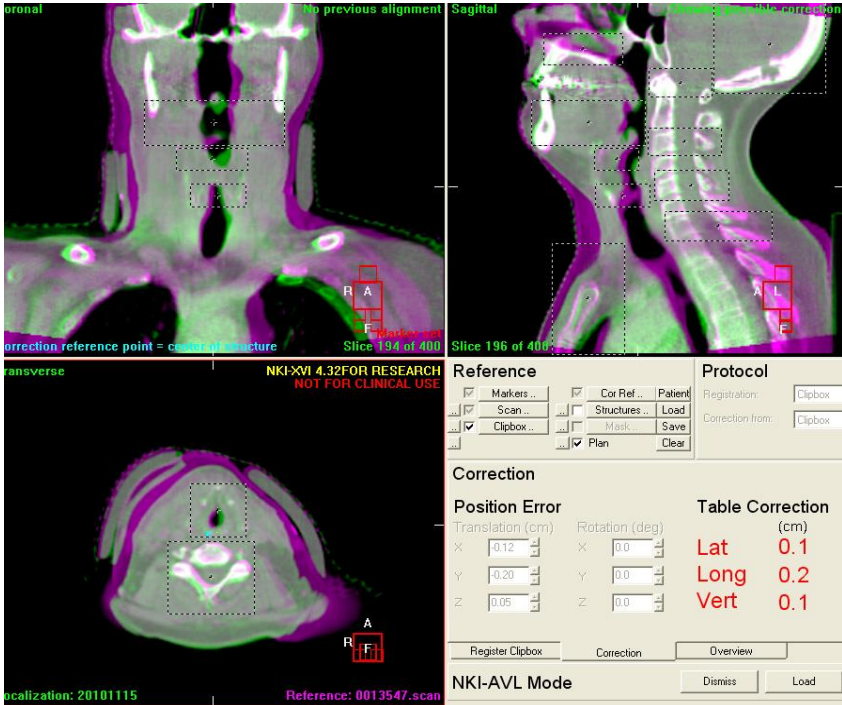
This patient has lost a lot of weight, resulting in a contour change. There is now a lot of air between the bolus and the skin.

Contour change:	Distance between skin and bolus:
≥ 2.0 cm 🟧	0.5 – 1.0 cm 🟩
	1.0 - 1.5 cm 🟨
	1.5 - 2.0 cm 🟧
	> 2.0 cm 🟥

Tumour progression or swelling of normal tissues
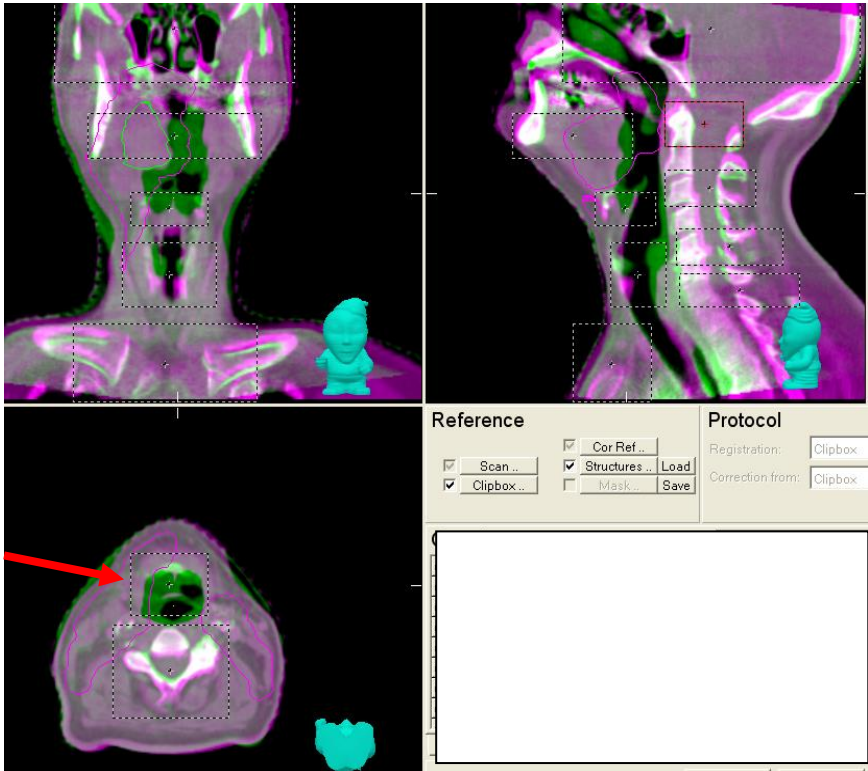
This example shows oedema.

Inside the PTV:	🟩
Only just inside the PTV:	🟨
Outside the PTV:	🟧

The patient has oedema which causes dyspnea

Patient has no physical symptoms:	🟡
Patient has physical symptoms:	🟧
Patient has severe physical symptoms:	🟥
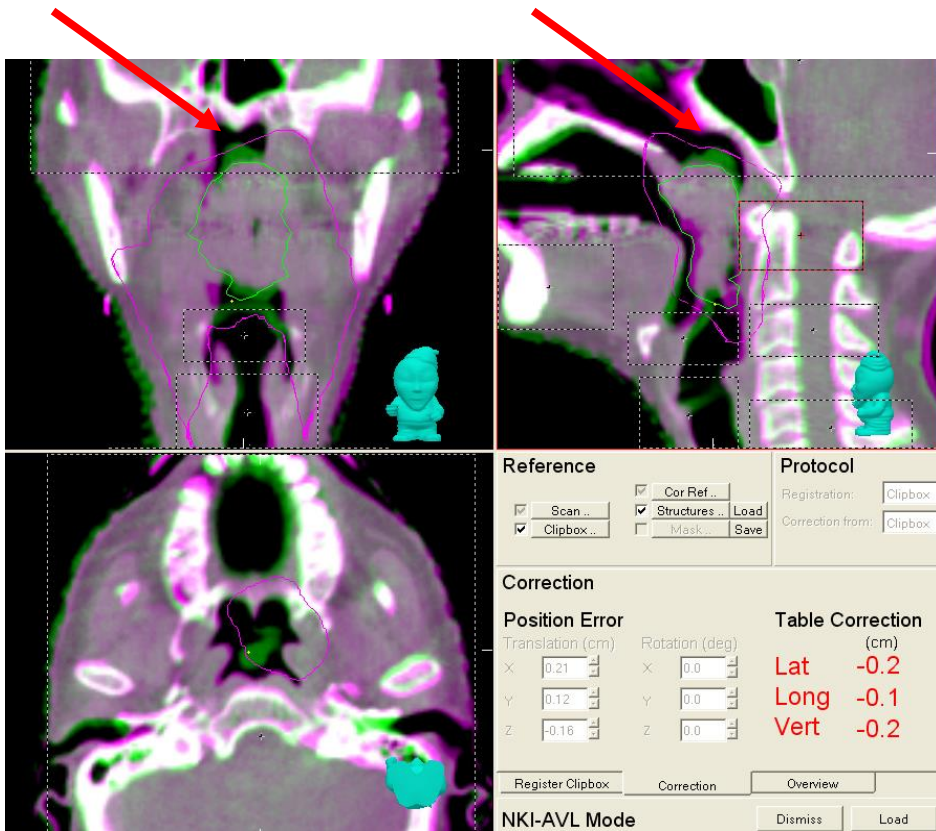
Tumour progression

Progression inside the PTV:

Progression only just inside the PTV:

Progression outside the PTV:

Changes in the PTV
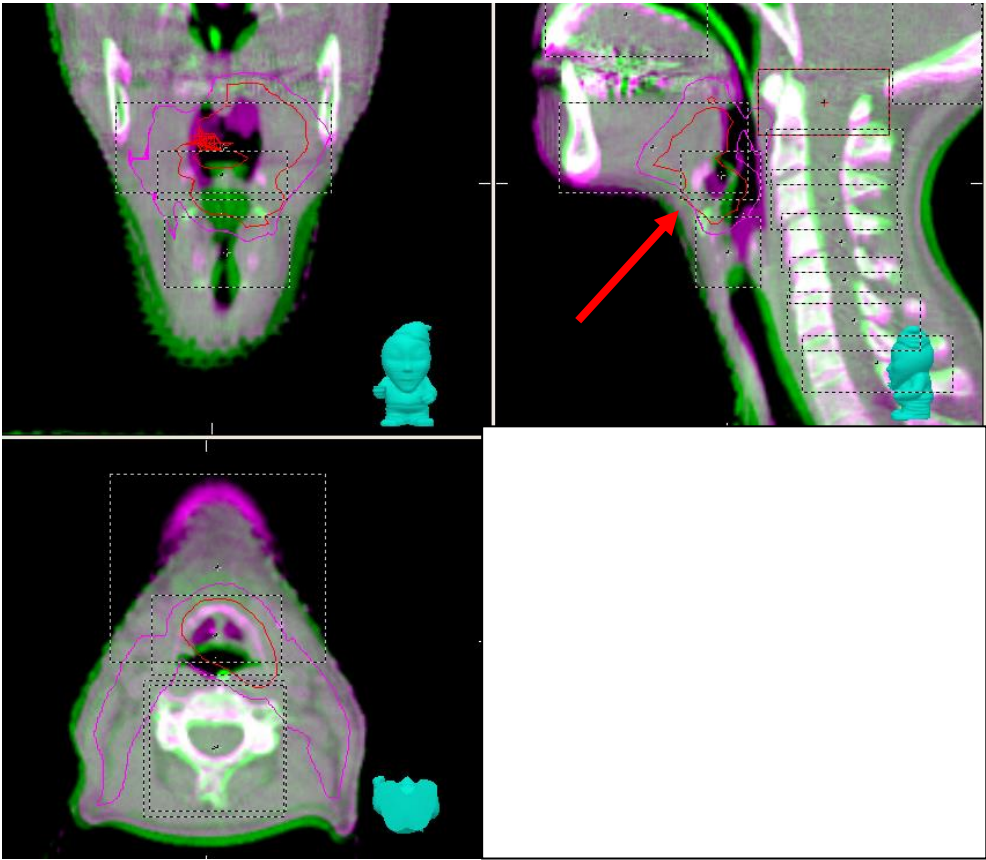
The hyoid shifts caudally outside the PTV. The hyoid is part of the CTV and therefore must be inside the PTV.

Only just inside PTV:	🟨
1st fraction outside PTV:	🟧

Tumour regression
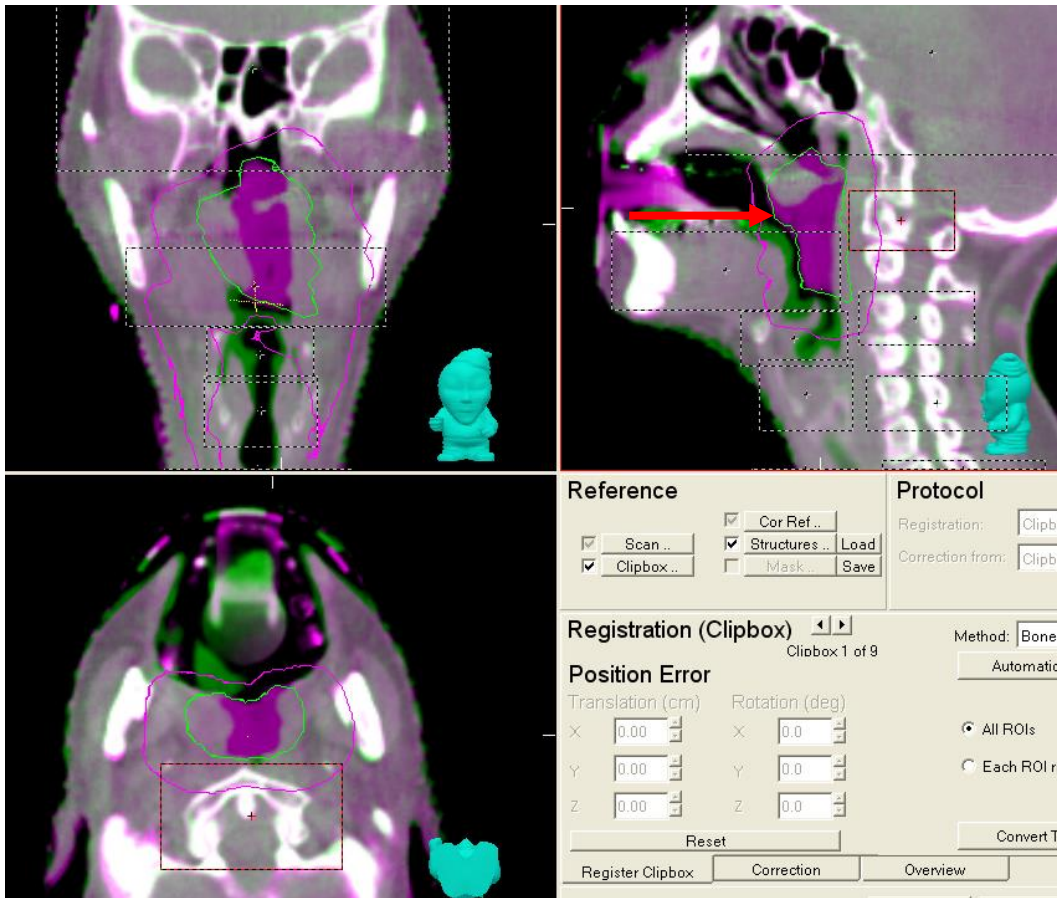
Tumour regression

Contour change:

≥ 2.0 cm

In case critical OAR:

≥ 1.5 cm

Other changes
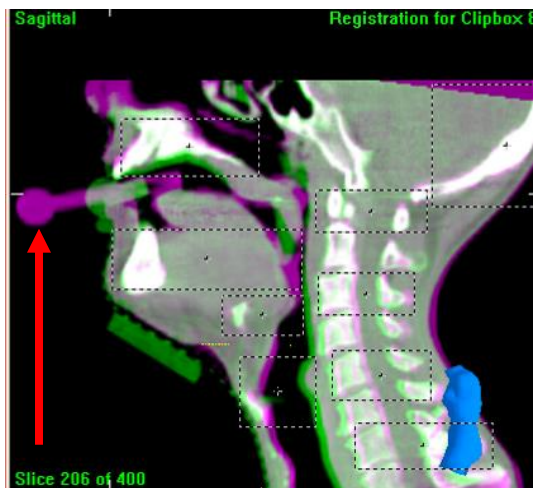
The tongue depressor on the pCT (purple) was bigger then the tongue depressor on the CBCT
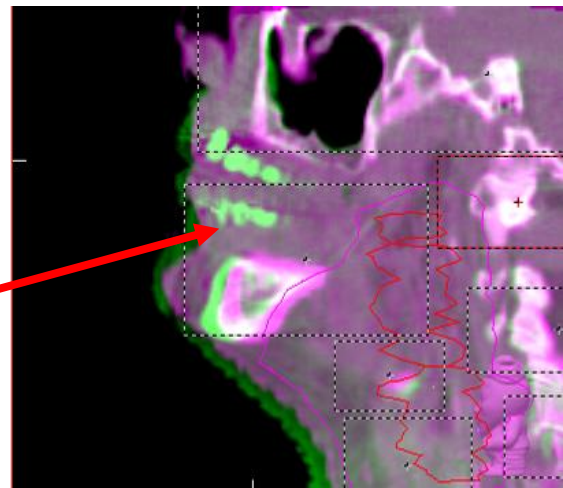
This patient forgot to remove his dentures
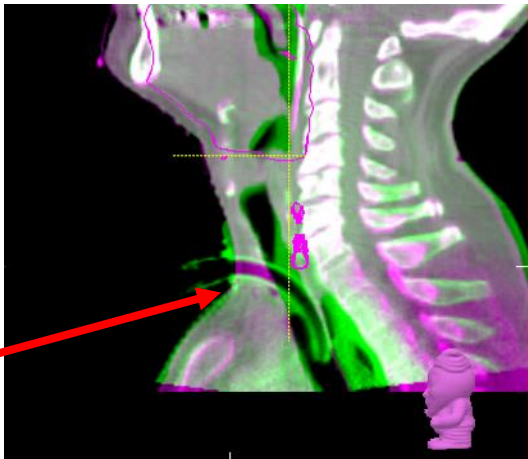
The tracheostomy was in place during the course of treatment.
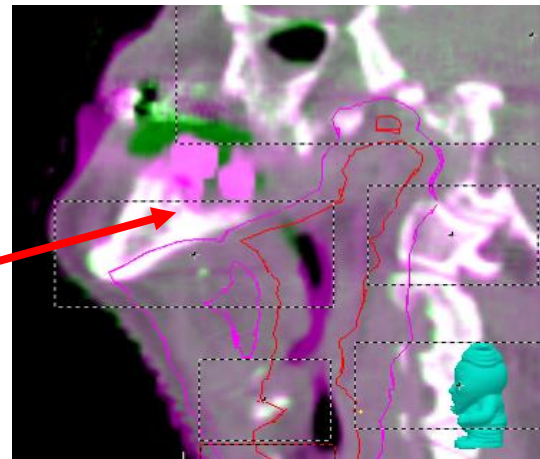
The patient had his teeth extracted after the pCT.

In some cases (top right), the patients require extra instructions.

Otherwise the Radiation Oncologist needs to be informed.

Lung

See literature reference [19]

Tumour progression/regression
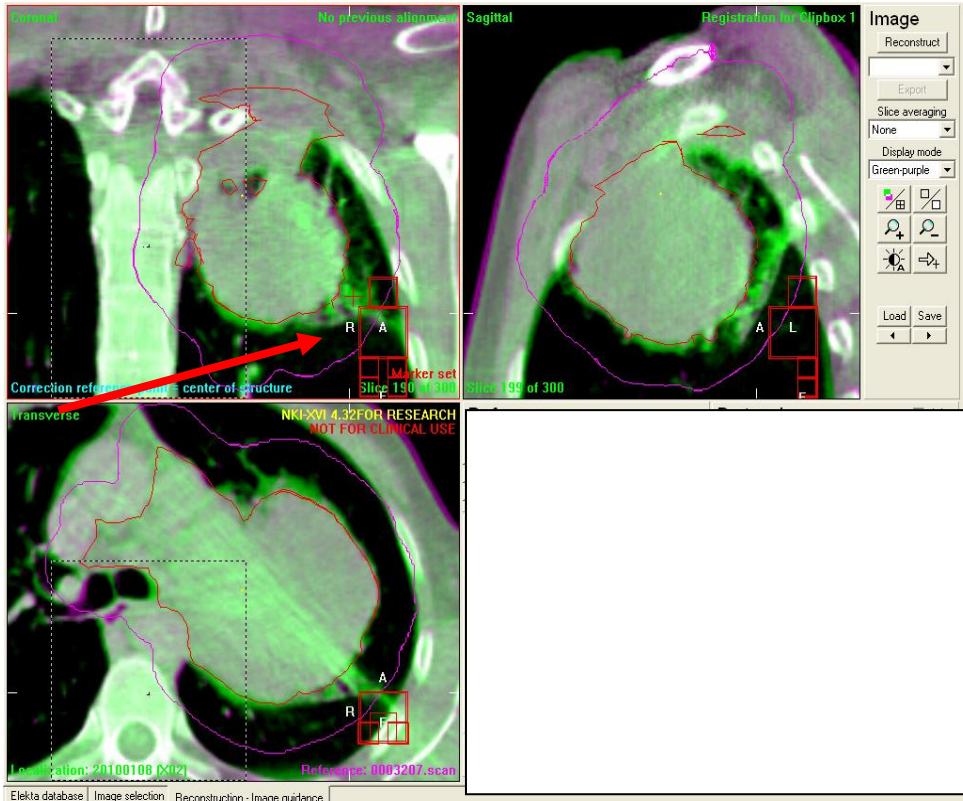
Tumour progression.

Progression within the PTV:	■
Progression only just inside PTV:	■
Progression, outside PTV:	■
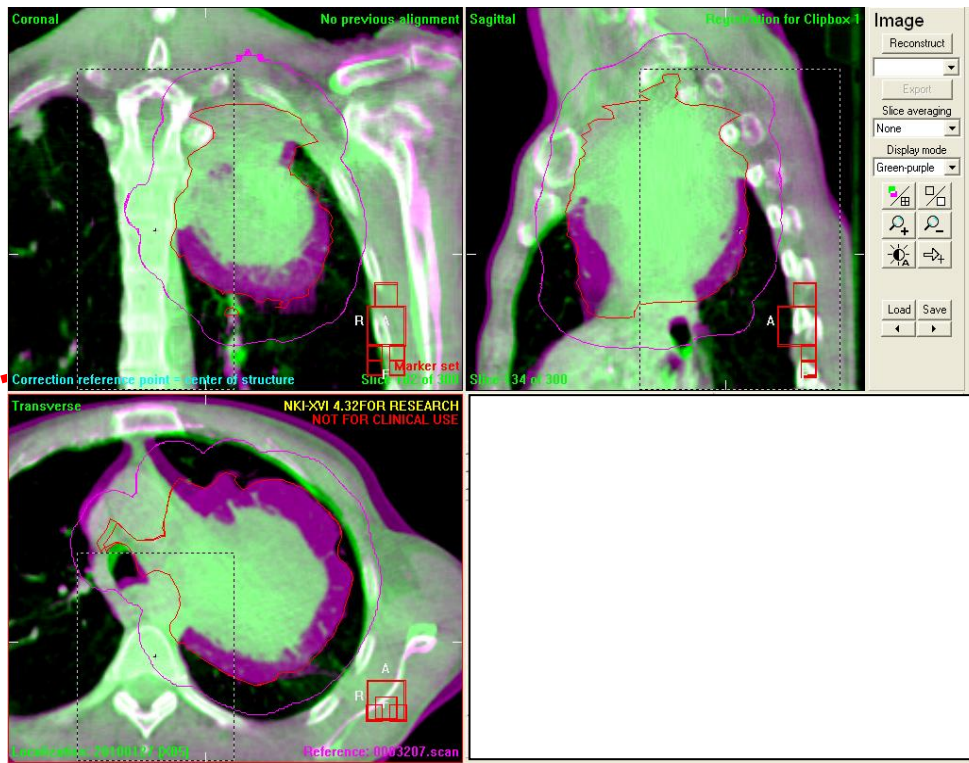
Tumour regression. ▮

Tumour shift
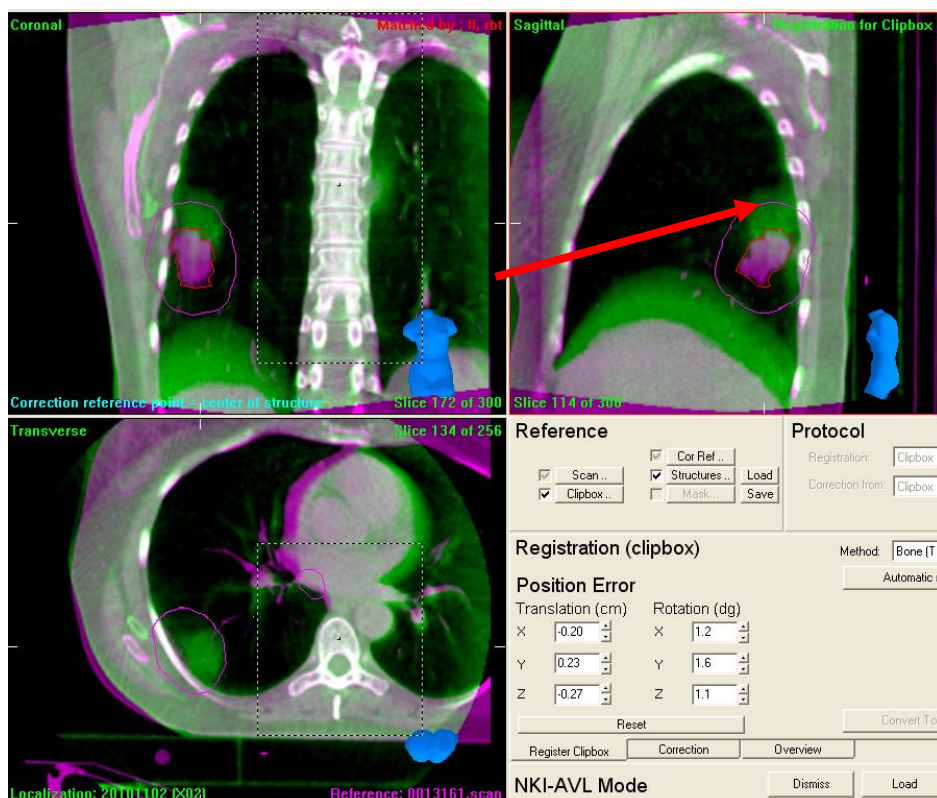
Tumour shift

Tumour shift within the PTV:	▮
Tumour shift outside the PTV:	▮

Other lung changes
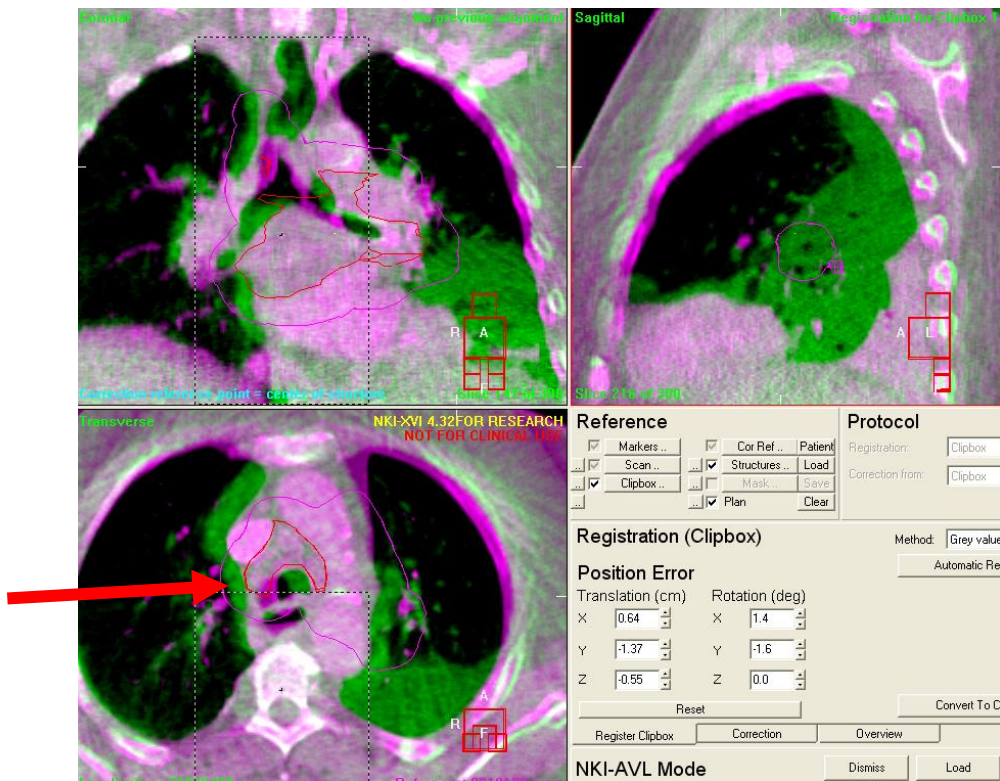
Increase of atelectasis (green); this causes a shift of the mediastinum (red arrow).

The lymph nodes can shift outside the PTV.
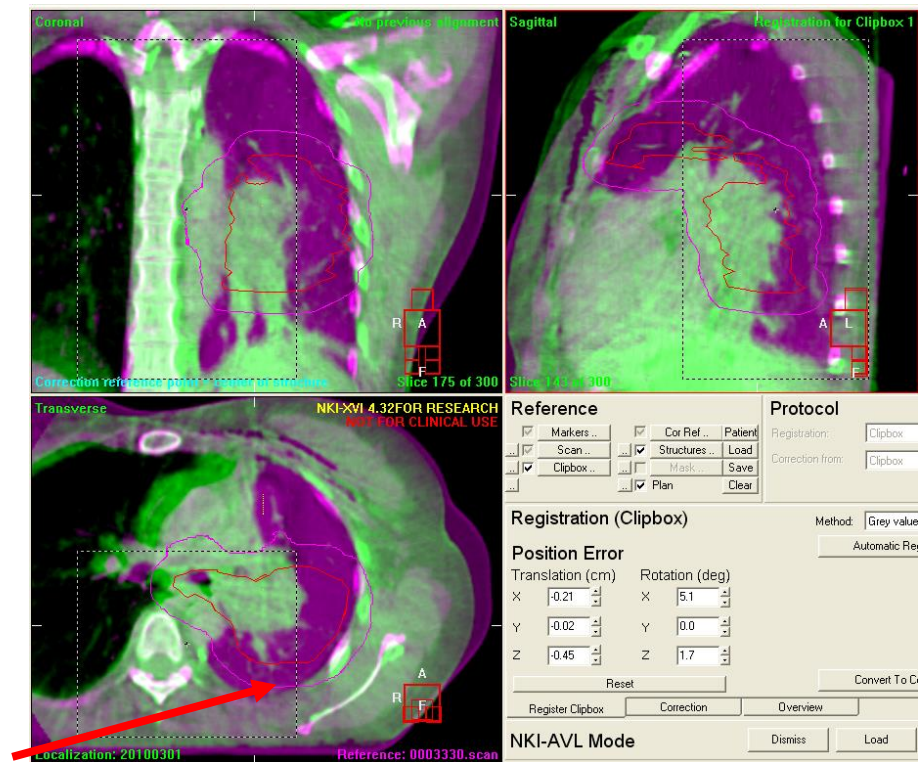
Decrease of atelectasis (purple). The tumour and mediastinum have shifted more towards

the normal anatomical position. It is difficult to interpret the effect on the dose distribution.
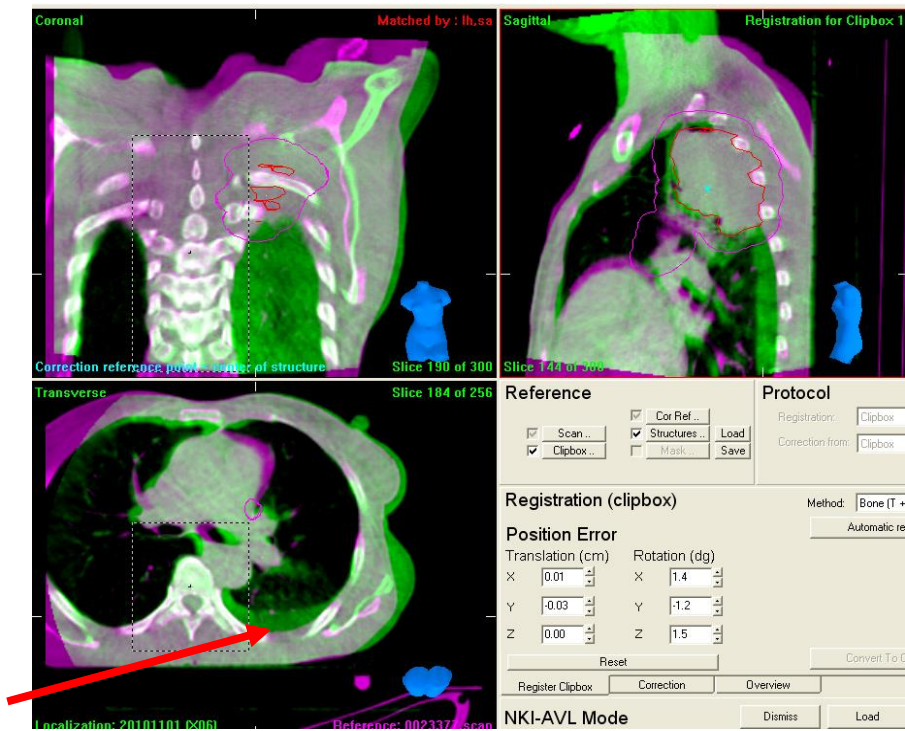
Pleural effusion. 🟧

This patient has pneumonia.

If the patient has fever and cough.	🟥
No fever or cough.	🟧

Mamma
Contour changes
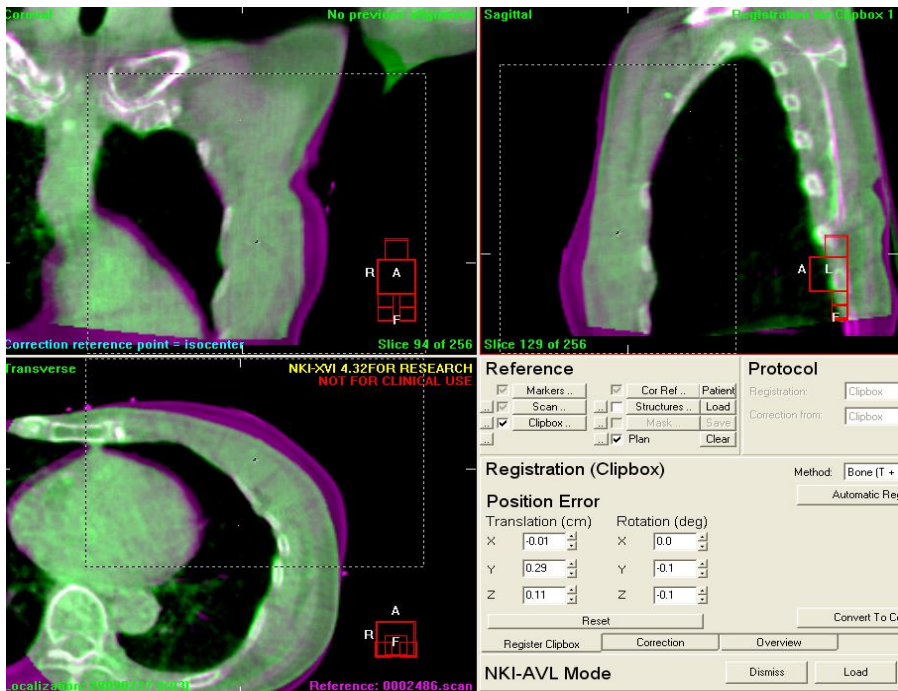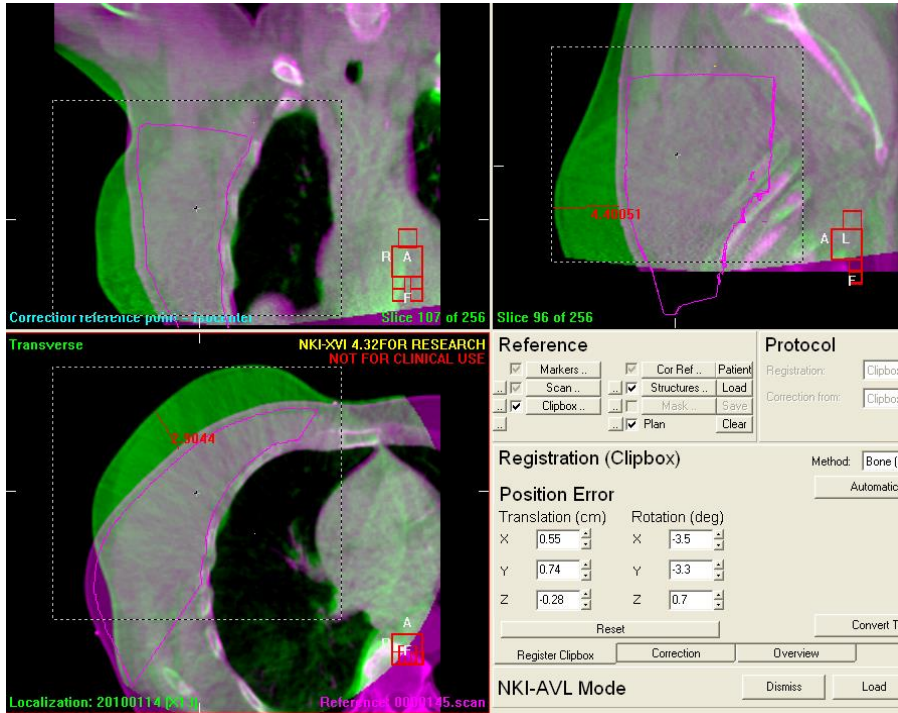
Top; Increase in external contour.
Bottom; Decrease in external contour
    (Measure distances in XVI ALT+left)

Contour change is < 2 cm.	🟩
Contour change is ≥ 2 cm.	🟧

Increase of seroma
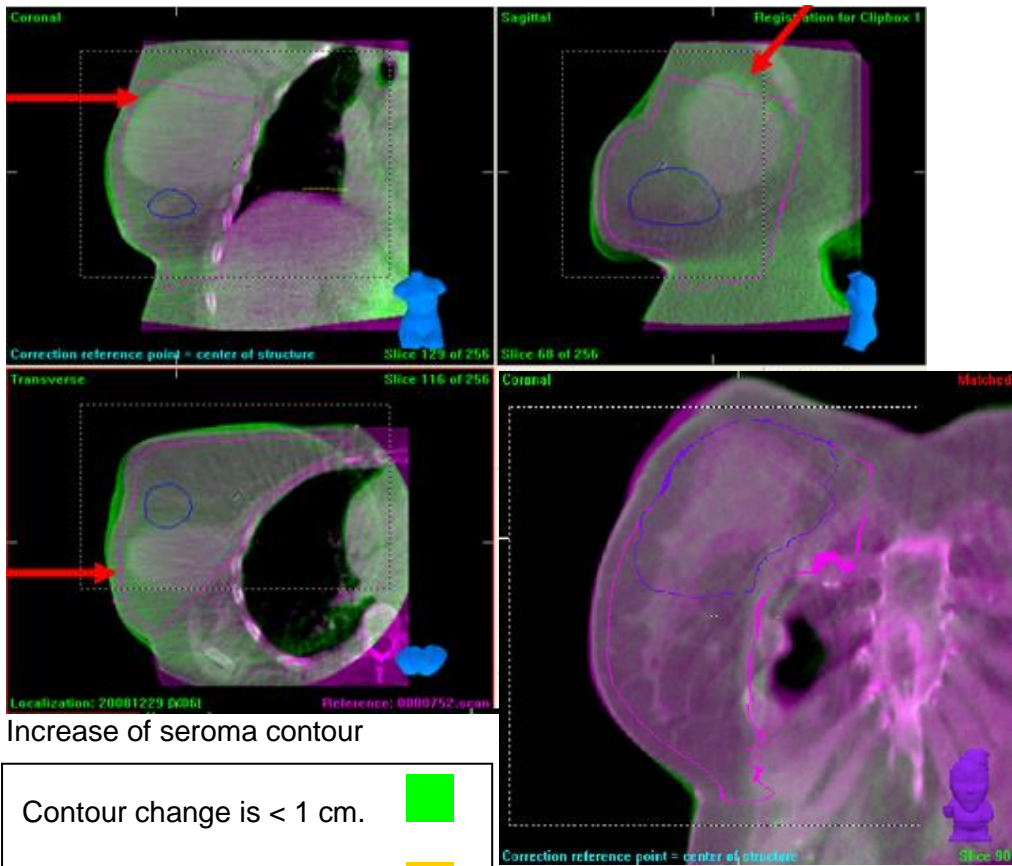
Increase of seroma contour

Contour change is < 1 cm.	(green)
Contour change is ≥ 1 cm.	(orange)

Urology

Patients treated in the pelvic area, are given instructions for bladder filling. The bladder and rectum on the pCT should be representative for the whole radiotherapy serie.
When the bladder is too full or empty during the course of treatment, the patient will be alerted by the RTT and given further instructions.
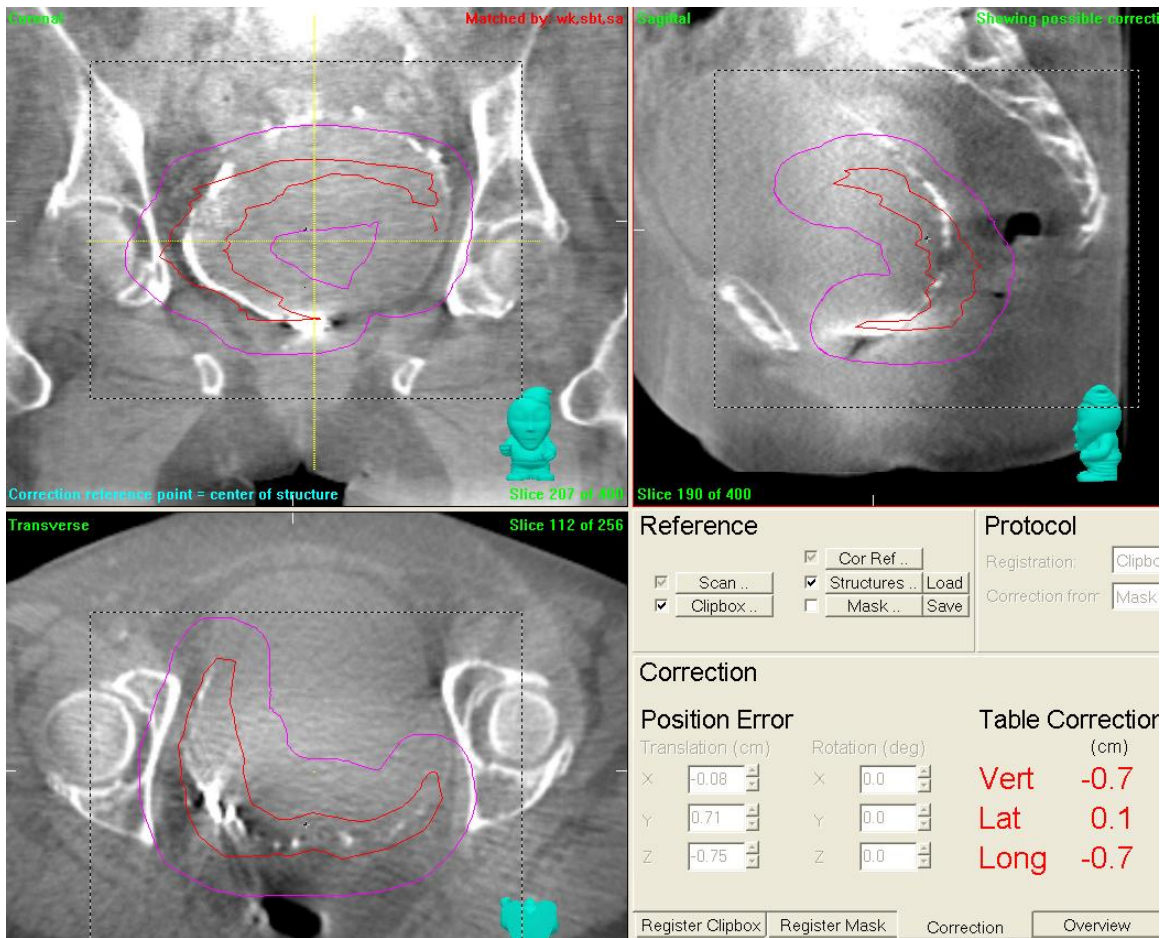
Partial bladder with lipiodol

Lipiodol is a fatty substance that is injected around the tumour by the urologist during cystoscopy. The lipiodol serves as a surrogate for the tumour and can be used for registration. It is typically used in partial bladder irradiation, with a full bladder drinking protocol.
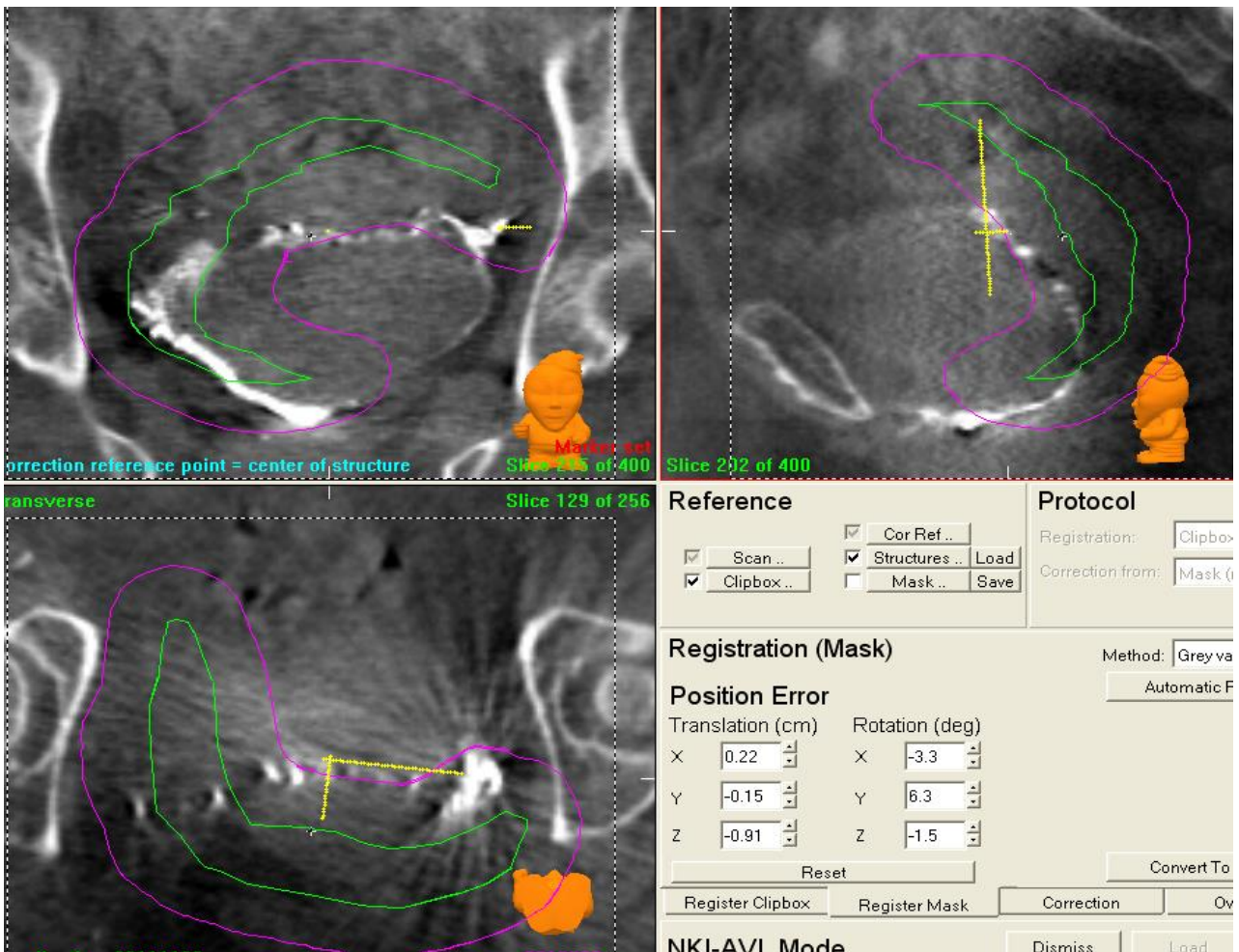
This patient had a full bladder on the pCT, however this CBCT shows an empty bladder. The lipiodol should be inside the CTV (green line).
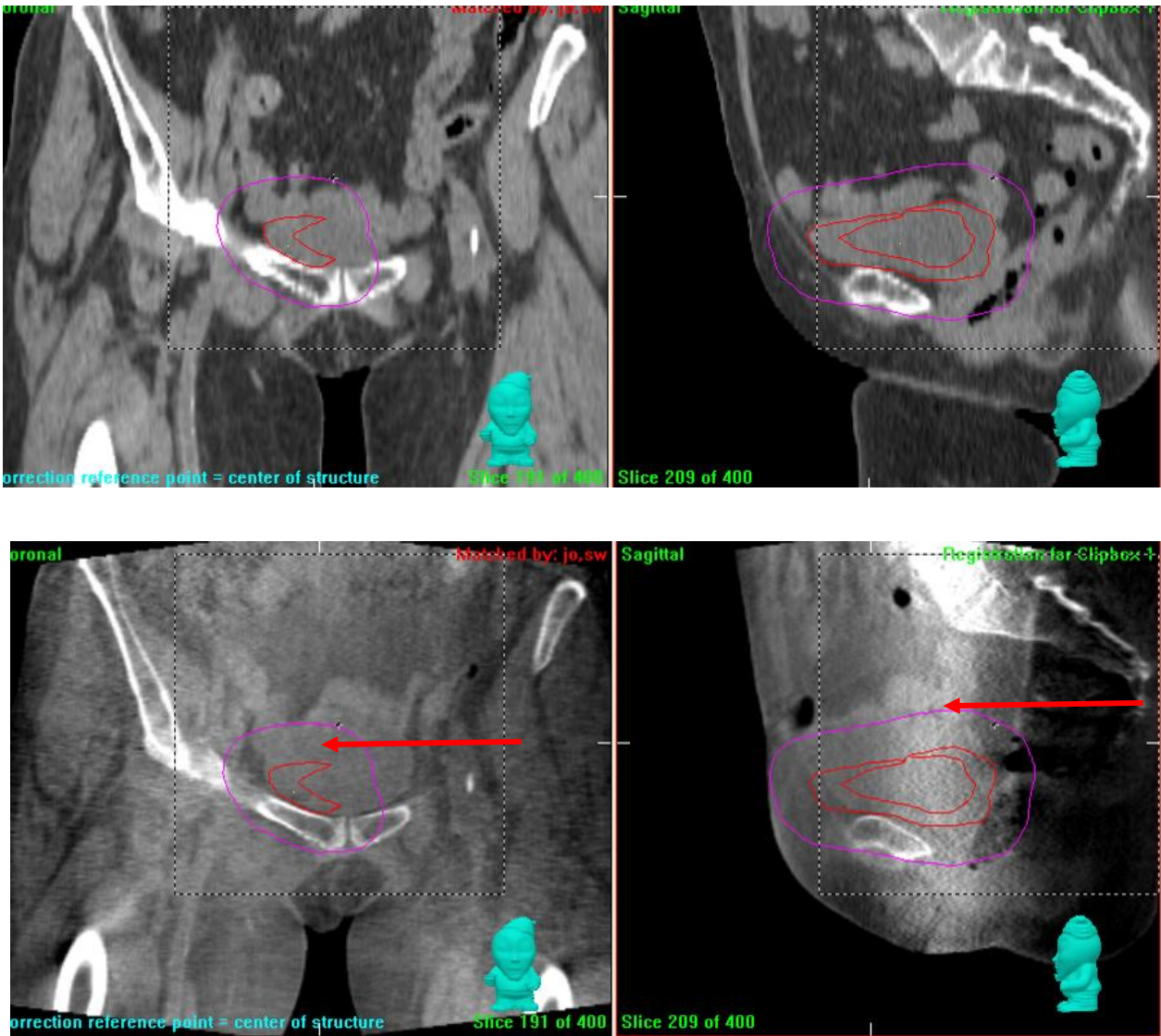
1st fraction outside the PTV:

2nd fraction outside the PTV:

The bladder of this patient is extremely full. The lipiodol should be inside the red line (=CTV). The bladder wall has moved out of the PTV (purple line). The CTV is outside the PTV.

1st fraction outside the PTV:
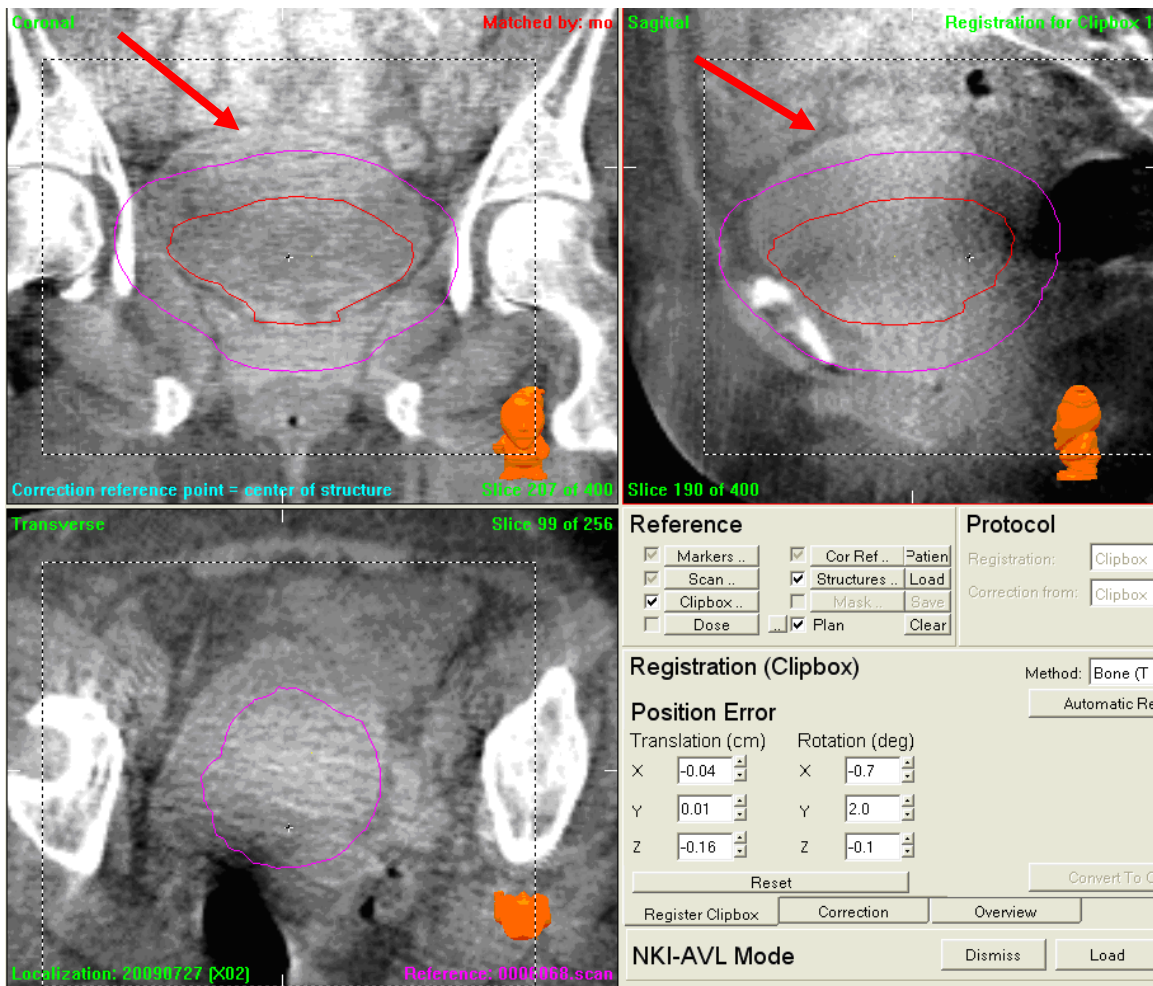
2nd fraction outside the PTV:

Partial bladder without lipiodol

Upper left CT coronal view, upper right CT sagittal view. Bottom left CBCT coronal view, bladder is full. The cranial part of the bladder wall has moved outside the PTV (purple). Bottom right sagittal view of the CBCT of the bladder.

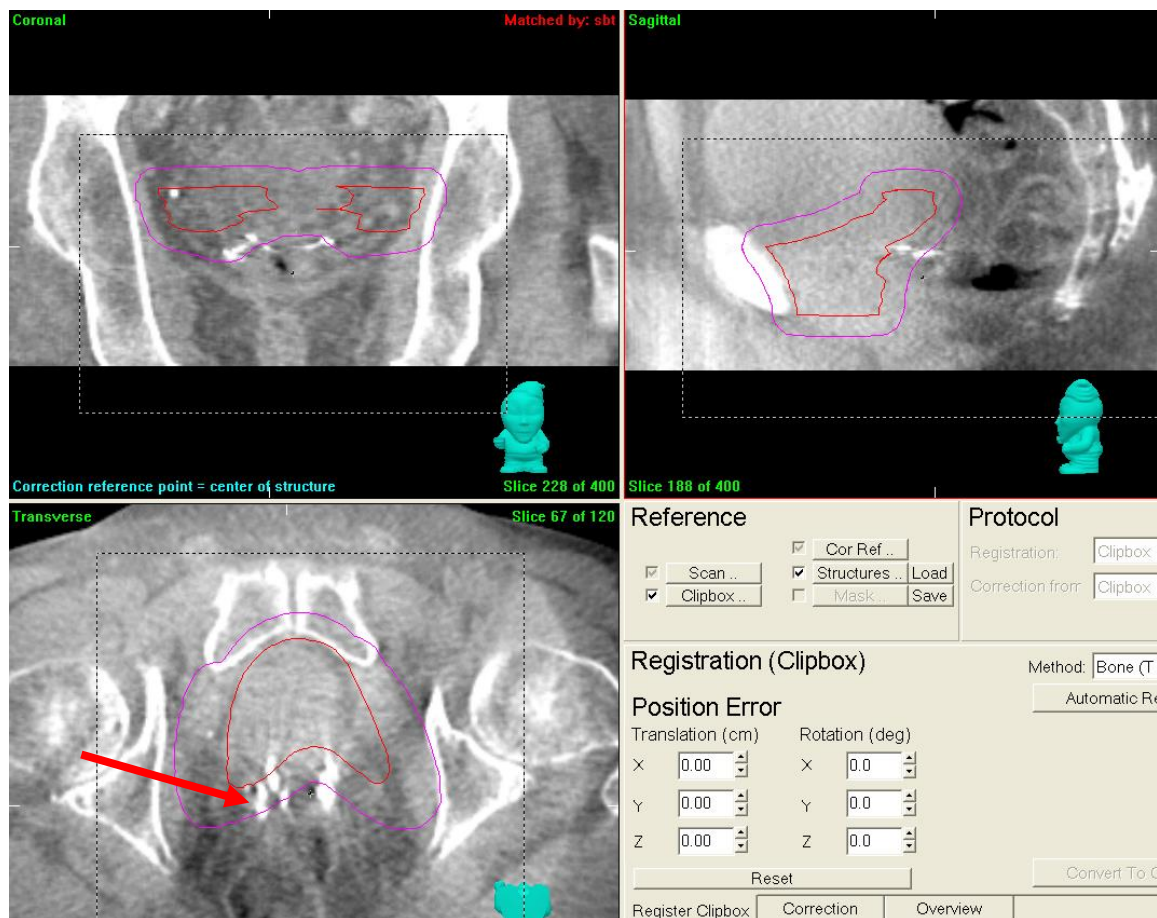|	
1st fraction outside the PTV:	🟧
2nd fraction outside the PTV:	🟥

Bladder

CBCT of the bladder. The red line = CTV bladder, the purple line = PTV. The bladder is full and now partially outside the PTV.

1st fraction outside the PTV:

2nd fraction outside the PTV:
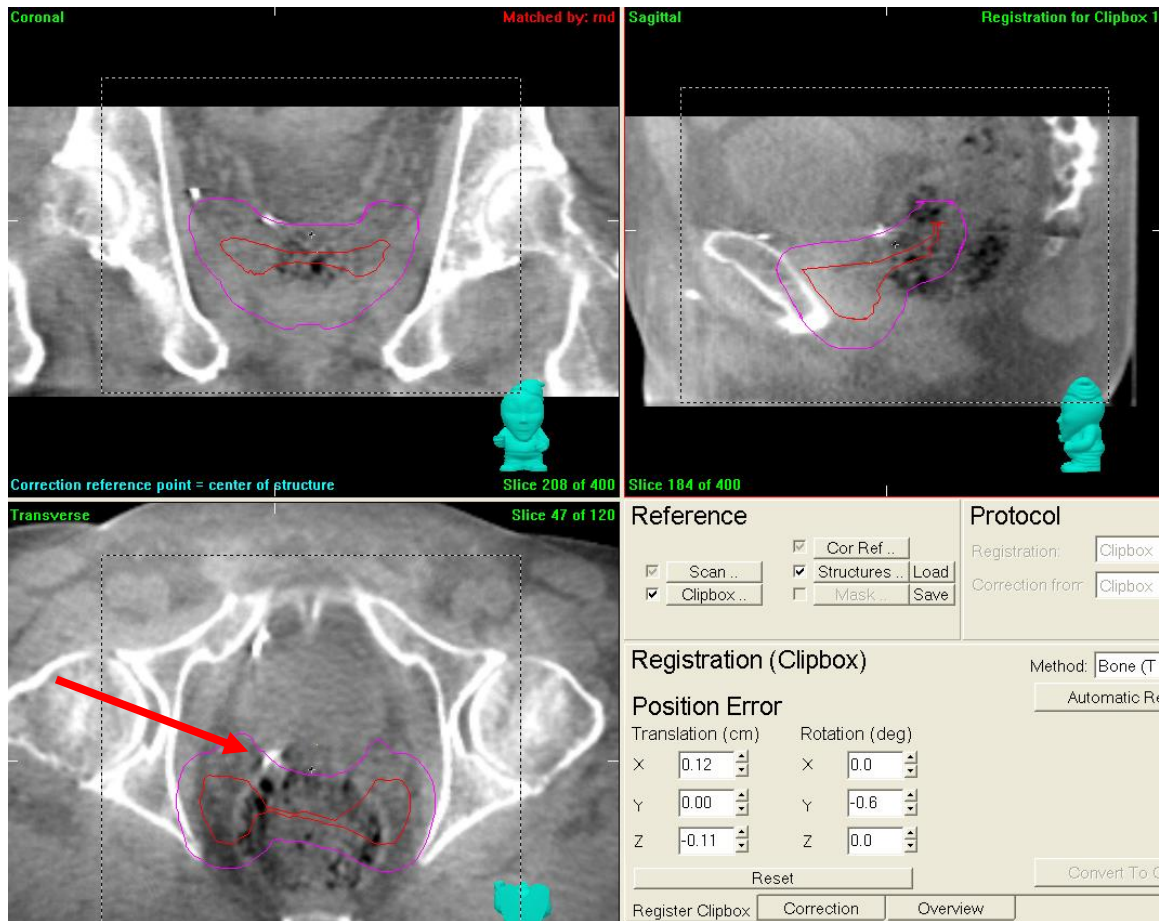
Post-operative Prostate

The clips from the operation should be within the red line (CTV)
This patient has a full bladder on this CBCT and the rectum is empty, the clips have shifted outside of the PTV (purple line).

1st fraction outside the PTV:
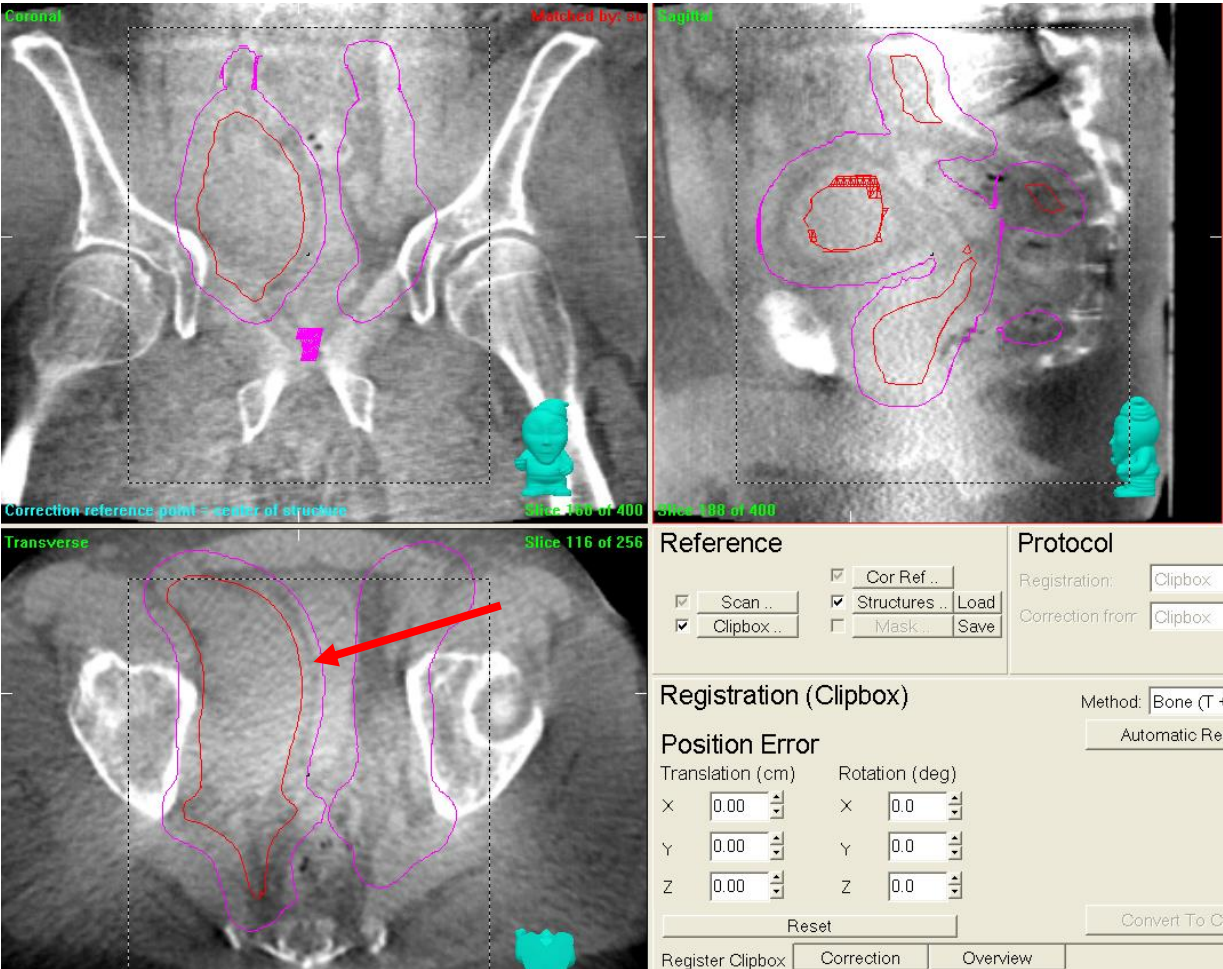
2nd fraction outside the PTV:

3rd fraction outside the PTV:

The clips from the operation should be within the red line (CTV)
This patient has a full rectum on this CBCT; this causes a shift in the position of the clips.

1st fraction outside the PTV:	■ (yellow)
2nd fraction outside the PTV:	■ (orange)
3rd fraction outside the PTV:	■ (red)

Prostate with nodal involvement

This patient has progression in the right lymph nodes.

1st fraction outside the PTV:	⬜ (yellow)
2nd fraction outside the PTV:	⬜ (orange)
3rd fraction outside the PTV:	⬜ (red)

Prostate

Left: Air in rectum.   *Middle: Empty rectum.*   *Right: Empty bladder*

1st fraction outside the PTV:	🟨
2nd fraction outside the PTV:	🟨
3rd fraction outside the PTV:	🟧
4th fraction outside the PTV:	🟥

Gynaecology

The following are a few examples of the traffic light protocol. Markers are implanted in patients with cervix, endometrium or vagina carcinomas. These markers can help us to define the position of the cervical structures.
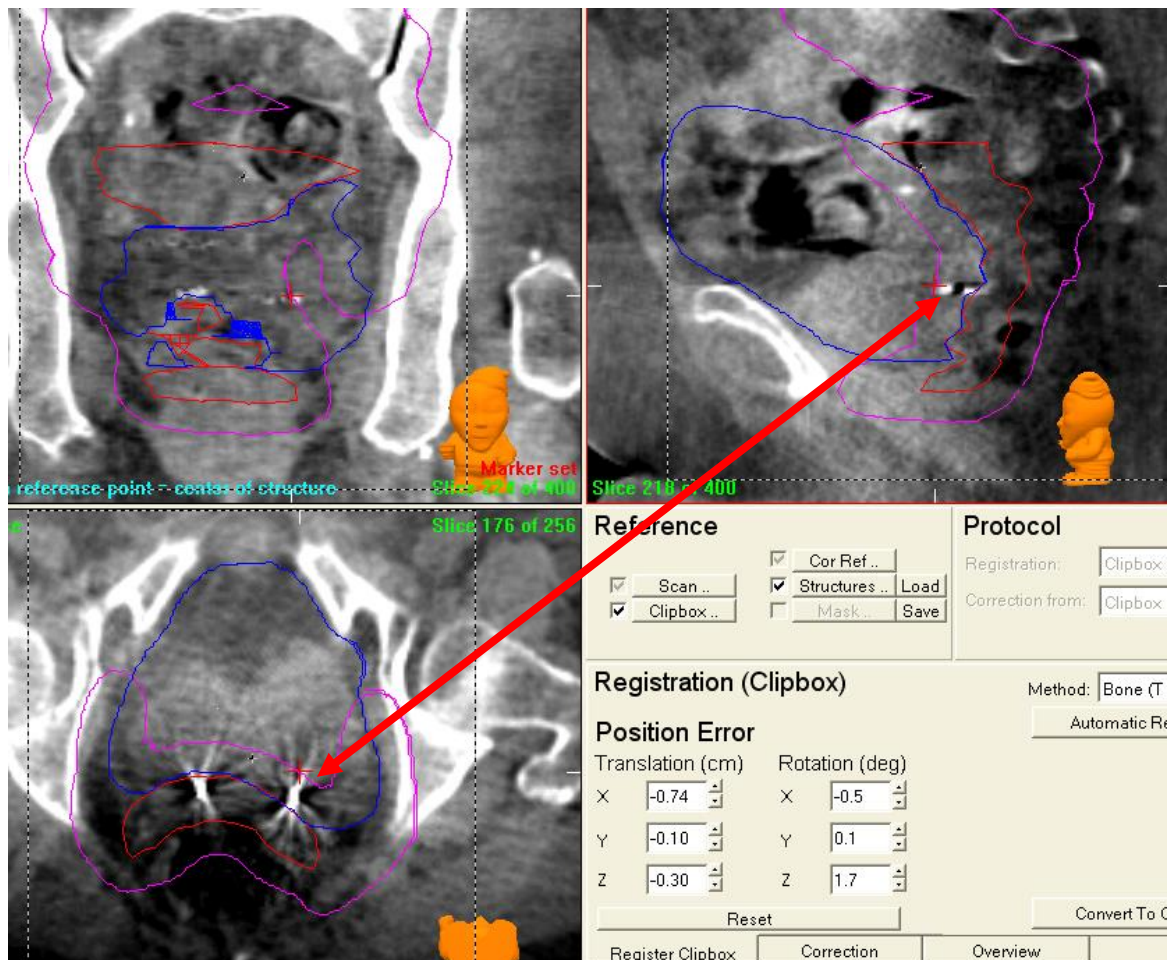
The blue line is the contour of the bladder on the pCT. The red line is the CTV and the purple line the PTV. The bladder is empty. The position of de markers has changed and the markers are now only just inside the PTV. (Red arrow)

The red line is the CTV and the purple line the PTV The rectum is empty, the full bladder pushes the CTV posteriorly. The marker should be well inside the CTV and is now only just inside the PTV.

Post surgery

1st fraction outside the PTV: [yellow]

2nd fraction outside the PTV: [orange]

3rd fraction outside the PTV: [red]

Without surgery or Recurrence

1st fraction outside the PTV: [orange]

2nd fraction outside the PTV: [red]

Gastro-enterology
Rectum

Air in Rectum
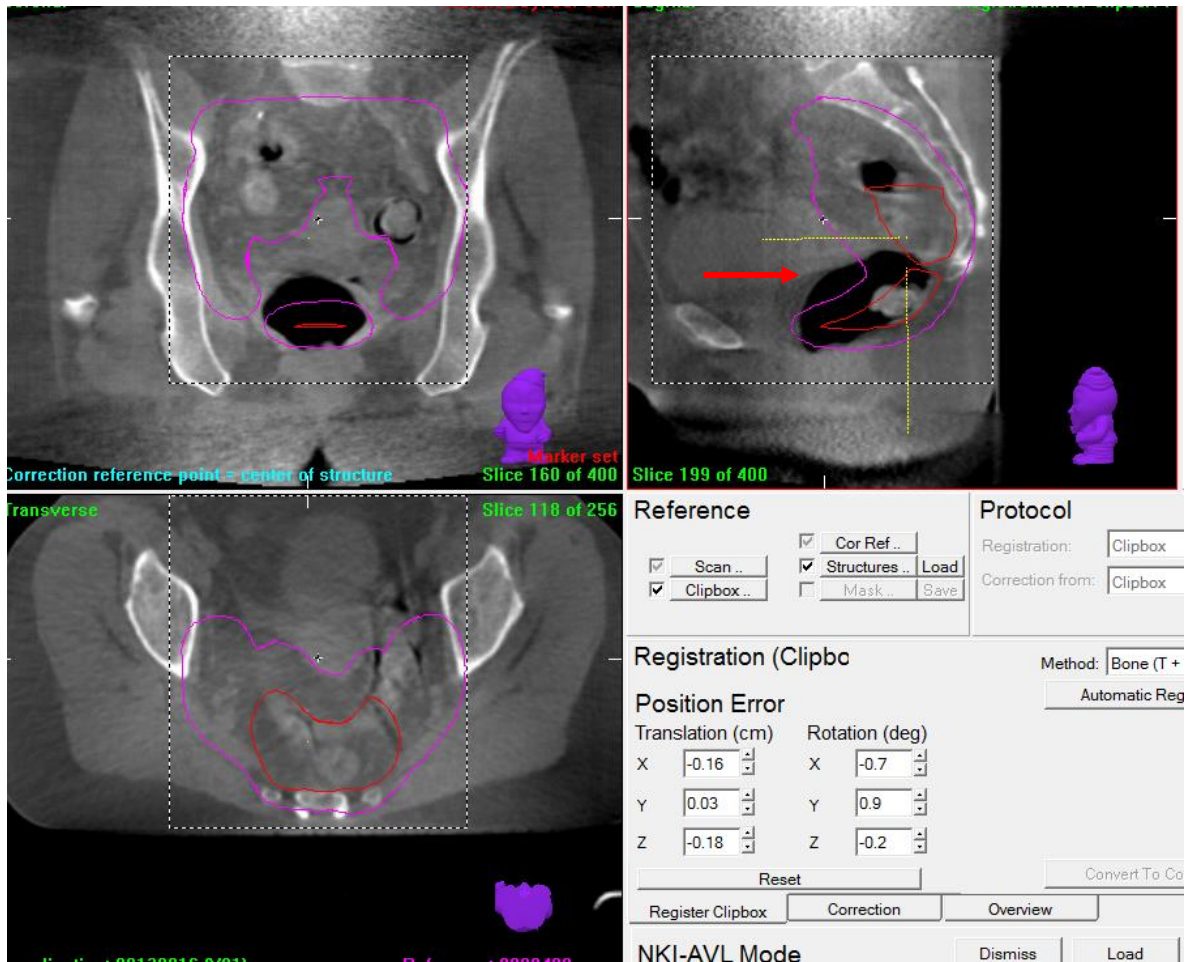
The red line is the CTV, the purple line the PTV. The air has pushed the rectum wall out of the PTV (red arrow).

25x2 Gy	
1st fraction outside the PTV:	

25x2 Gy		5x5 Gy	
1st fraction outside the PTV:	🟨	1st fraction outside the PTV:	🟧
2nd fraction outside the PTV:	🟧	2nd fraction outside the PTV:	🟥
3rd fraction outside the PTV:	🟥		

Empty bladder
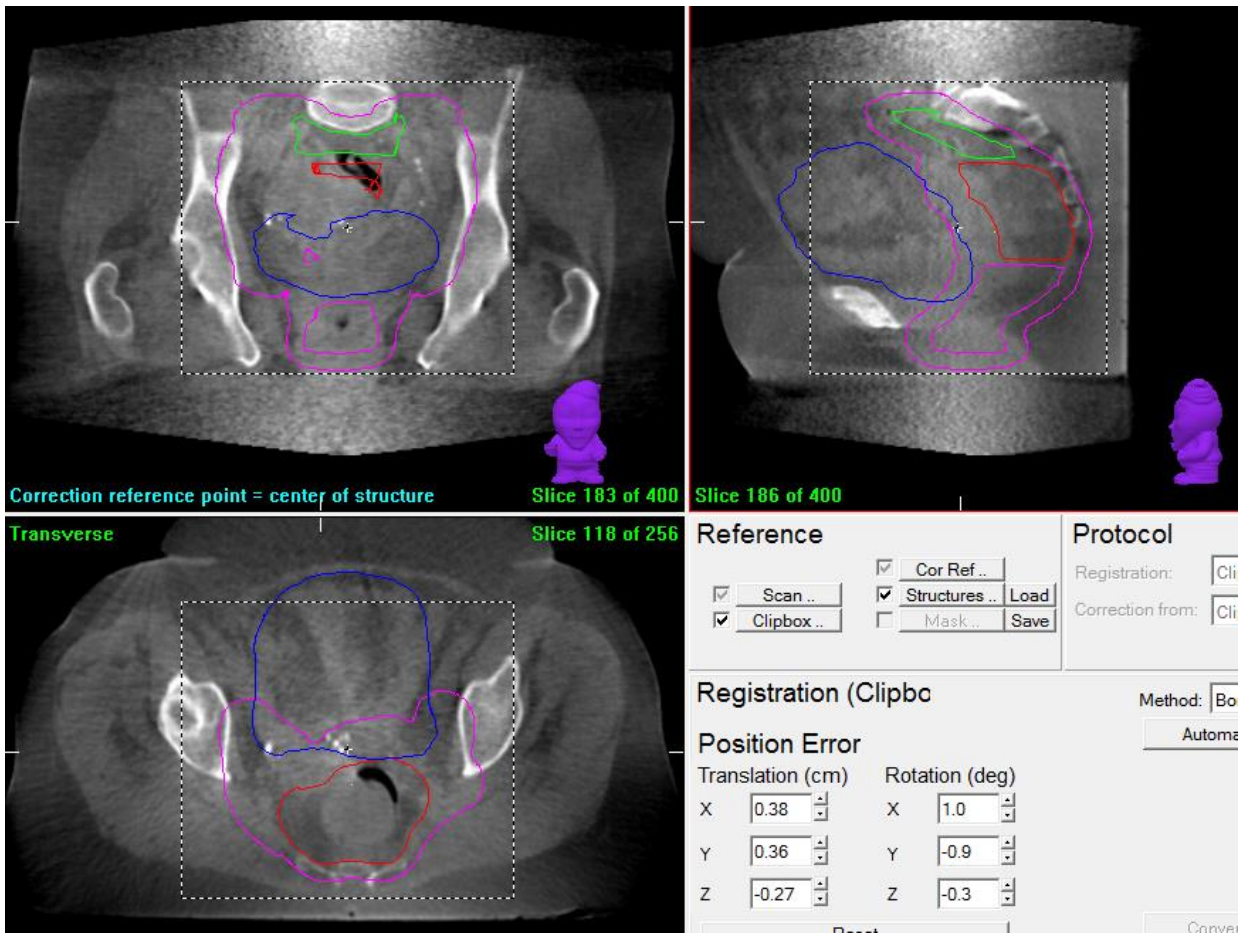
The patient has an empty bladder on the CBCT, while the bladder was full on de pCT (blue contour).
There is now a caudal shift of the bowel, which can lead to a higher dose in the bowel.

25x2 Gy	
1st fraction empty bladder	🟩
2nd fraction empty bladder	🟨
3rd fraction empty bladder	🟧

5x5 Gy	
1st fraction empty bladder	🟧
2nd fraction empty bladder	🟥

Regression of the CTV
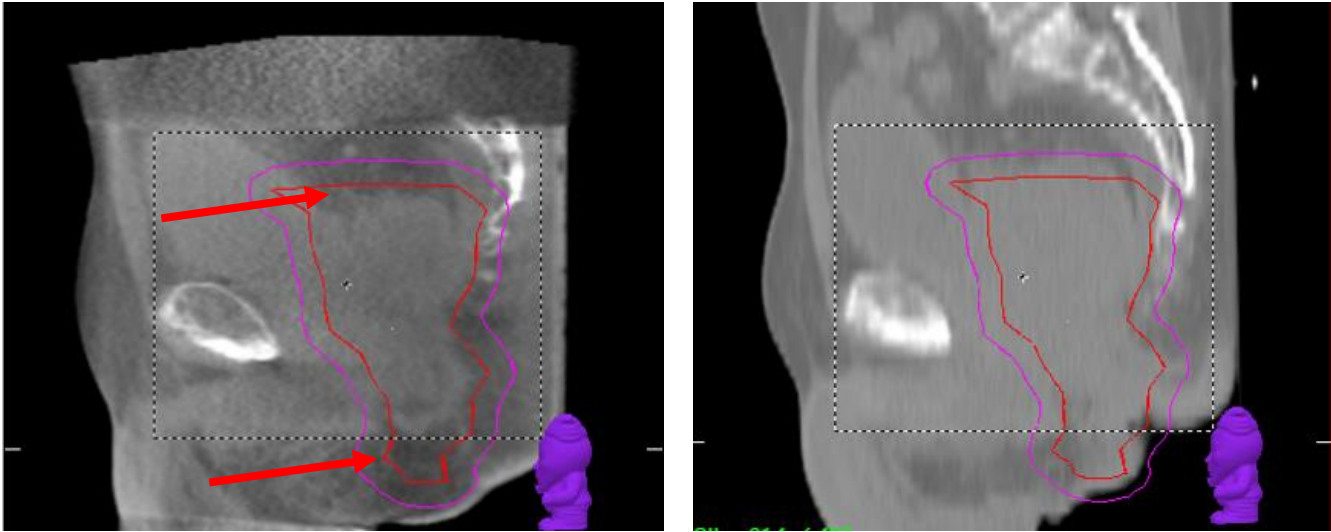
CBCT left, pCT right; Regression of the tumour could have an impact on the dose distribution. The bowel could shift inside the PTV.

Contour changes
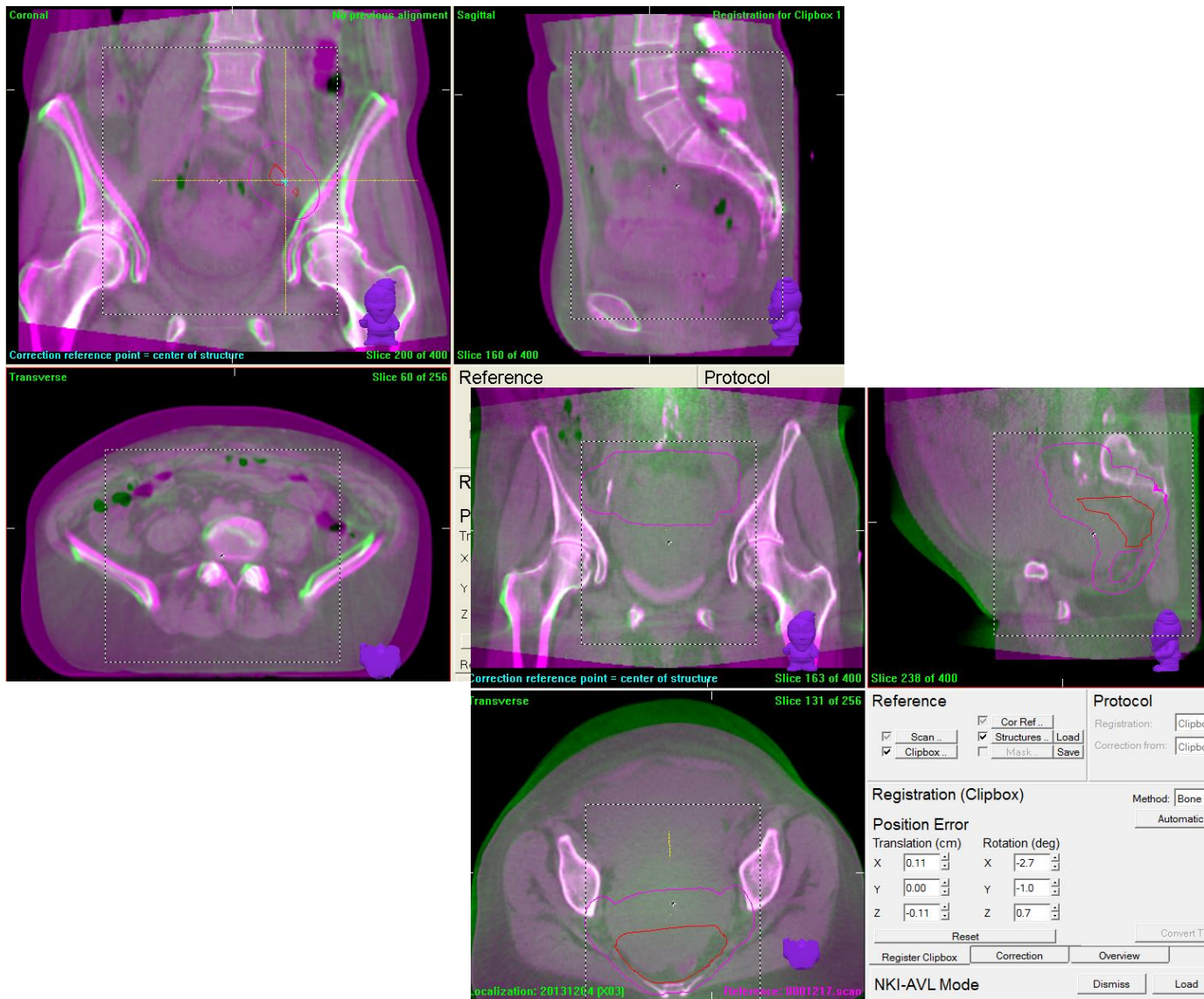
Upper left: This example shows a decrease in the external patient contour (purple). Bottom right: Example of an increase in the external patient contour. (green)

25x2 Gy	
Contour change < 2 cm:	🟩
Contour change > 2 cm:	🟧

5x5 Gy	
Contour change < 2 cm:	🟩
Contour change 2-3 cm:	🟧
Contour change > 3 cm:	🟥

Stomach
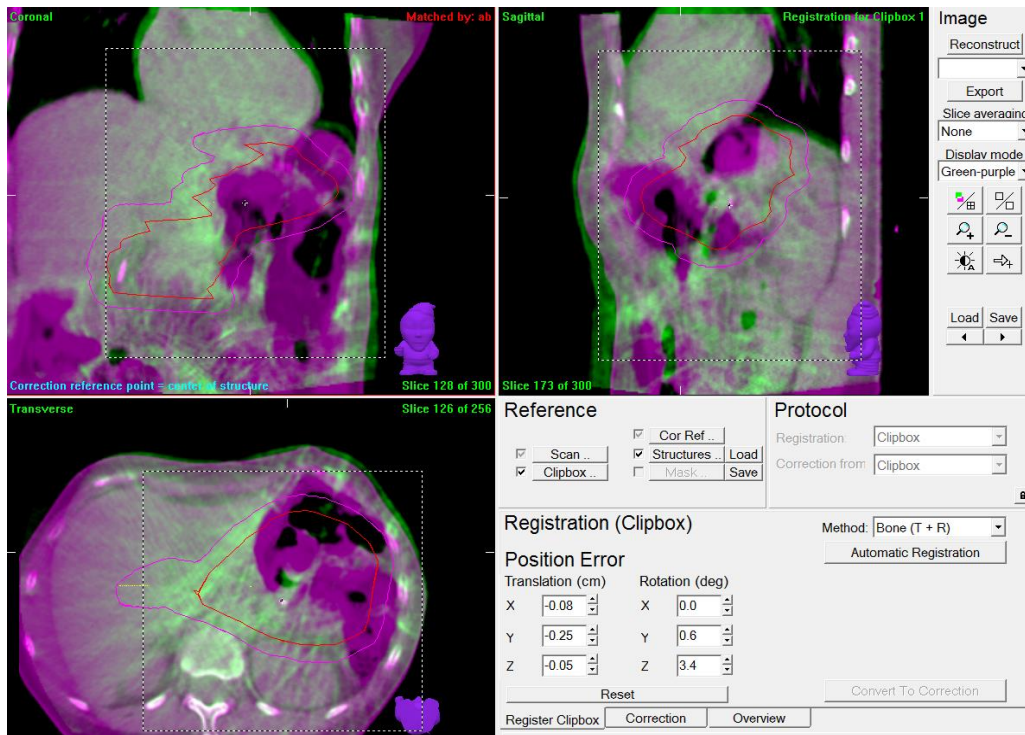
The amount of air within the PTV has increased compared to the planning CT(pCT).
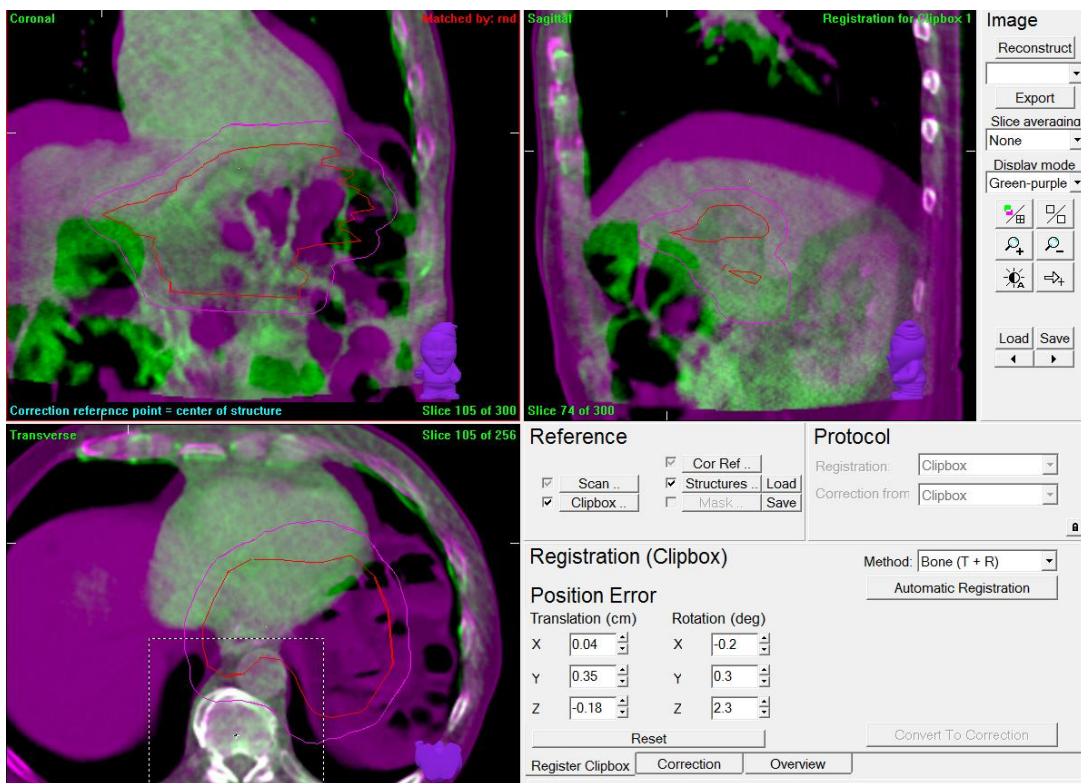
The position of the diaphragm has changed; this causes a shift of the CTV.

CTV within PTV:

CTV outside PTV:

Oesophagus
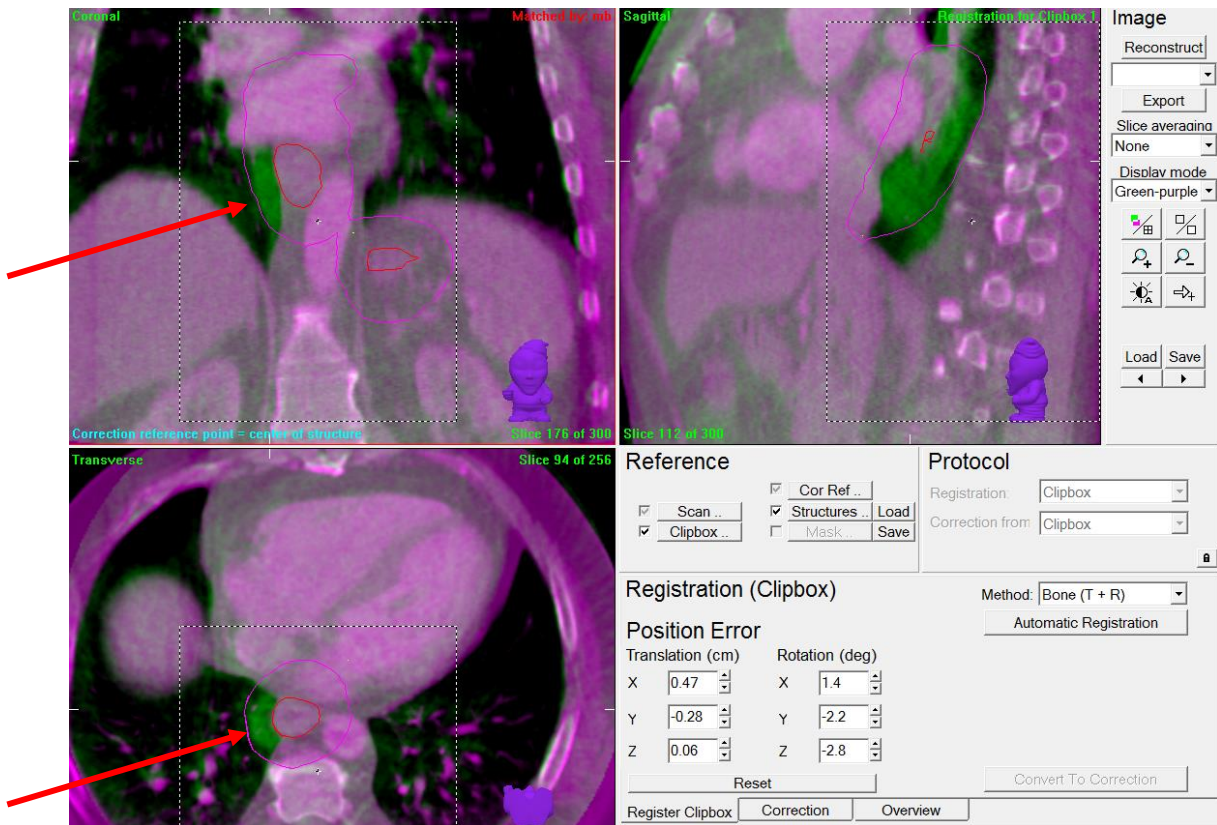
Progession or shift of the CTV.

Within PTV:

Outside PTV:

Sarcoma
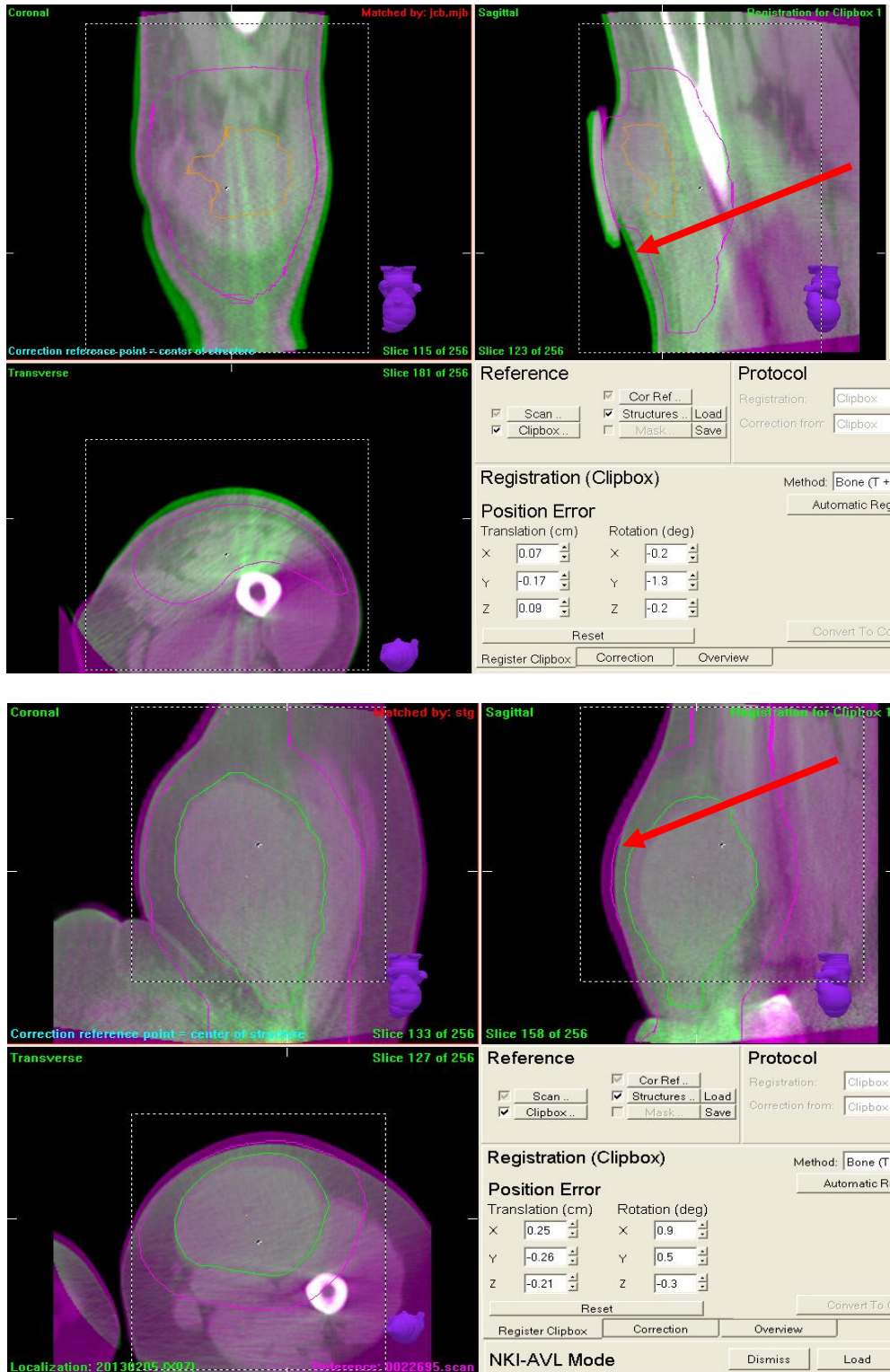
Top; Increase in external contour. Bottom; Decrease in external contour
(Measure distances in XVI ALT+left)

Contour change is < 1 cm

Contour change is ≥ 1cm

Tumour contour change

Contour change < 0.5 cm	🟩
Contour change ≥ 0.5 cm	🟧

Take action protocol

Until recently Traffic Light Protocols have been developed to recognize and react to Anatomical Changes (AC) seen on CBCT scans for the most common treatment sites. This involves alerting the Radiation Oncologist, handing over findings, and RO providing the final decision, making it quite labour-intensive for the ROs as well as the RTTs. A new approach was developed to act on anatomical changes: the Take Action Protocol. In this protocol the RTTs do not only have a role in detecting the anatomical changes, but also decide on the appropriate action and follow up, resulting in a significant shift in responsibility. [20]

In this part of the document you will find some examples of our action protocol used at the Netherlands Cancer Institute. This protocol is in no way meant as a gold standard. They have been derived from our own clinical experience and are a result of collaboration between RTT's, physicians, and physicists. This document can be used as a guideline, when designing your own protocol.

The Take action protocol consists of two elements:

1. A primary guideline describes how to act on the AC for online CBCT. Prior to the actual treatment a decision is made, whether an intervention is necessary to reduce the dosimetrical impact of the AC or if the appearance of the AC needs to be reviewed on the CBCT in the next fraction.
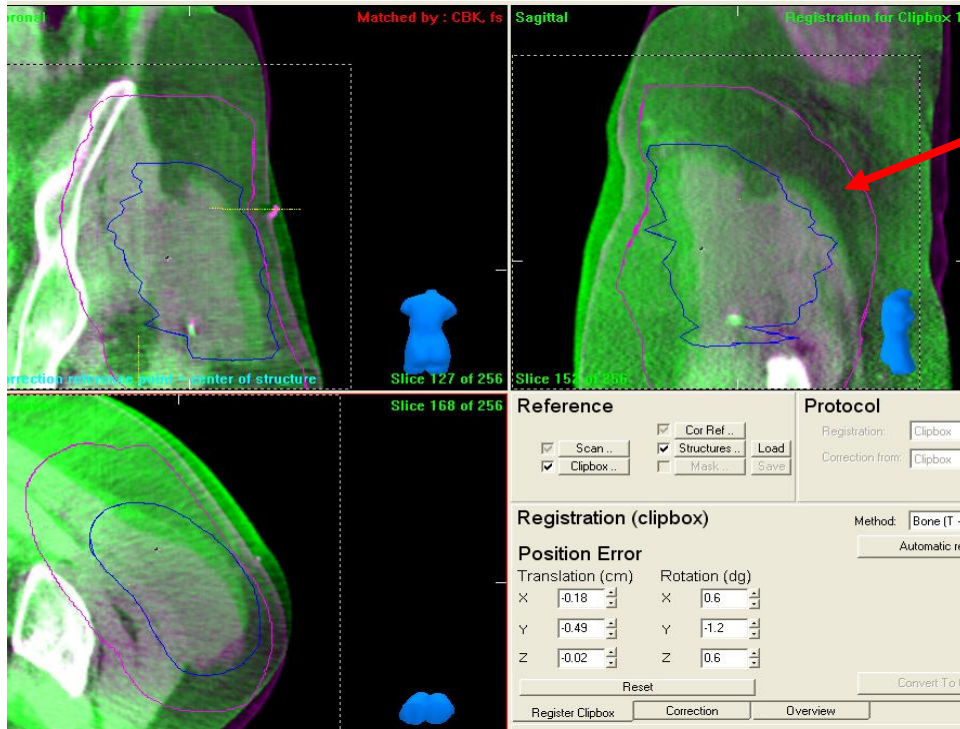
2. When the AC appears to be systematic (e.g. CTV is out of PTV > 3 fractions), a flow chart guides the decision regarding the following fractions. This decision can be made after the actual treatment, unless the ACs have a large impact on the treatment, then the RO, physicist, dosimetrist or IGRT RTT will be consulted.

For further background information about action protocol and the rationale, see literature reference [20]

Take action: Coverage is at risk

For example prostate (+vesiculae) 5x7.25 Gy

CTV outside PTV	
When in doubt call RTT imaging	
1st fraction CTV outside PTV	**No irradiation, proceed with flowchart!**

Main Cause
CTV out of PTV

Air in rectum → Apply intervention when CTV Is out of PTV: Flatulation tube

More rectum filling → Apply intervention when CTV Is out of PTV: Lavatory visit

Less Rectum filling → Accept and contact Radiation Onocologist

Fort the next fractions:
- Optimize patient schedule on defecation pattern
- Explain and instruct patient, laxation protocol and/ or eating pattern.

- Solutions do not have desired effect? —Yes→ Contact RO/Physicist Consider new planning CT

For example prostate (+vesiculae) other fractionation patterns

CTV outside PTV	
1st fraction CTV outside PTV	▪ No intervention ▪ Repeat bladder/rectal fill instructions to patient after treatment ▪ Acquire and review images next fraction
2nd fraction CTV outside PTV	▪ No intervention 35 fractions: ▪ Repeat bladder/rectal fill instructions to patient after treatment ▪ Acquire and review images next fraction 20 fractions ▪ Proceed with flowchart
3th fraction CTV outside PTV	35 fractions ▪ Intervention if necessary, flatulation tube, lavatory visit or bladder instructions. ▪ Proceed with Flowchart
3/4th fraction CTV outside PTV	▪ Intervention if necessary, flatulation tube, lavatory visit or bladder instructions. ▪ Solutions do not have desired effect, see flowchart
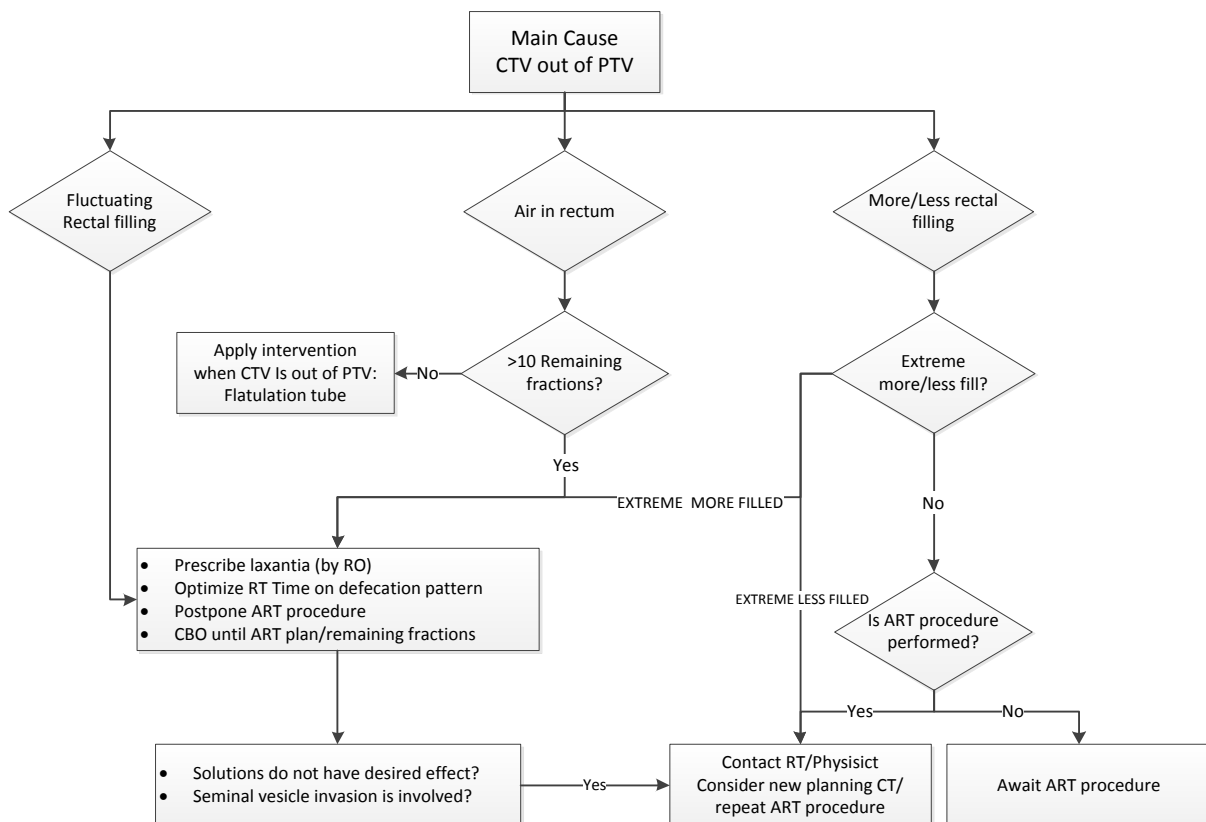
Take action: OAR dose changed

For example OAR dose in bladder patients:

Bladder is filled less than pCT, increase of OAR inside PTV	
1st fraction bladder filling is less than pCT, therefore >1cm OAR (bowel) inside PTV	▪ No intervention ▪ Re-evaluate the next fraction (extra CB if necessary)
2nd fraction bladder filled less than pCT, therefore >1cm OAR (bowel) inside PTV	▪ No intervention ▪ Re-evaluate the next fraction (extra CB if necessary)
3th fraction bladder filled less than pCT, therefore >1cm OAR (bowel) inside PTV	▪ No intervention ▪ Proceed with FlowChart
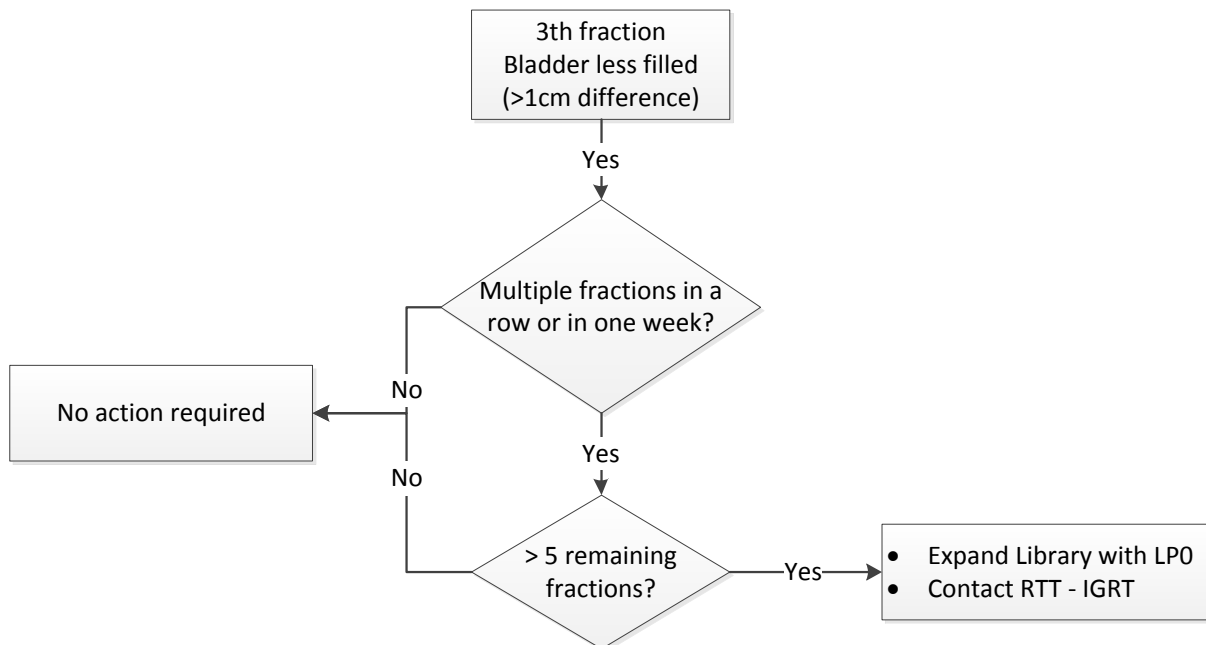
Take action: Dosimetric changes

For example contour changes in breast patients

Contour changes	

1st fraction contour changes	VMAT (> 1cm*)
	▪ No intervention
	▪ Proceed with flowchart
	
	Tangential fields (>2cm*)
	▪ Check if beams sufficiently enclose the whole target area
	   Yes: No intervention
	   No: No irradiation!
	▪ Proceed with flowchart

2nd fraction contour changes	▪ Adjust patient positioning if shoulder or rotations cause contour change, see example ▪ Write patient positioning advise for next fraction
3th fraction contour changes	▪ Adjust patient positioning if shoulder or rotations coast contour change, see example ▪ Proceed with Flowchart
* Restriction value should be determined in every individual department, hence it depends on your departments treatment plans and margins.	
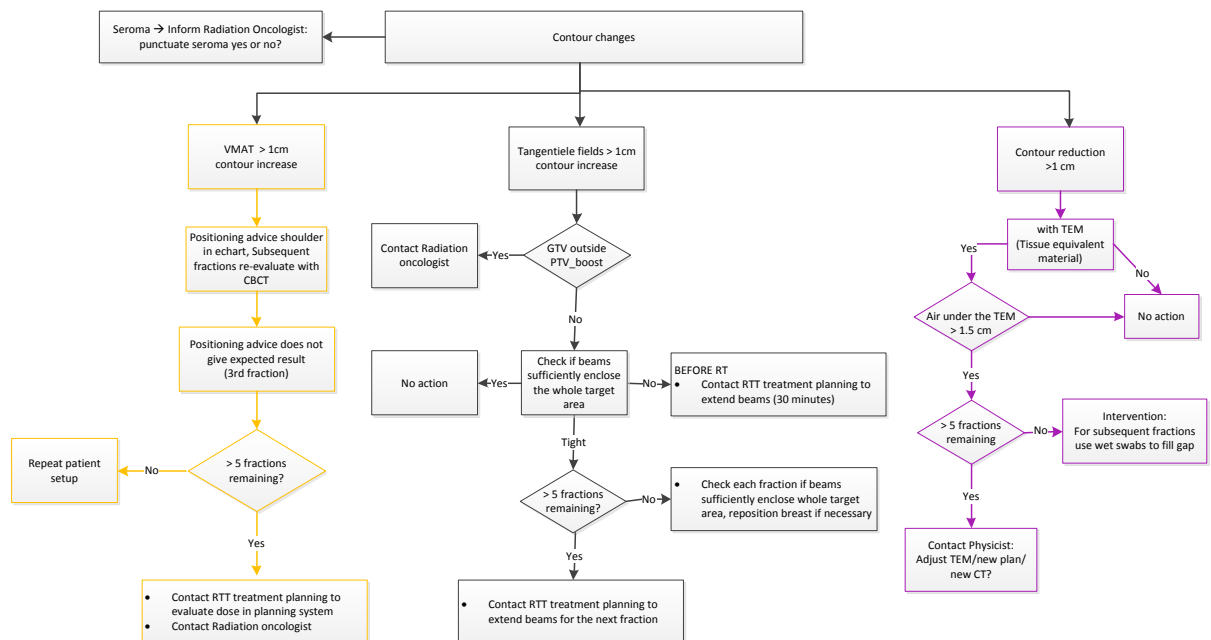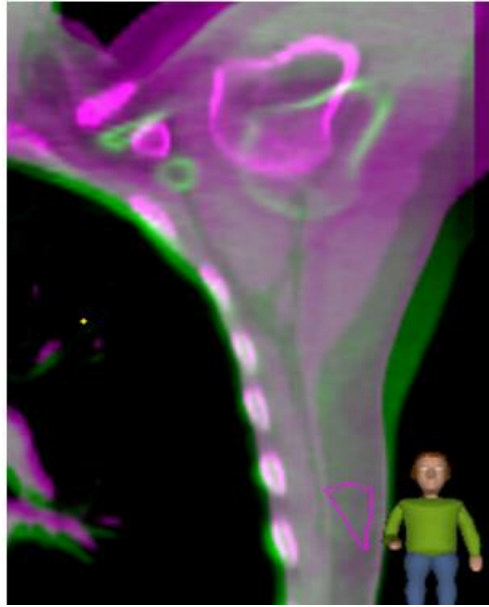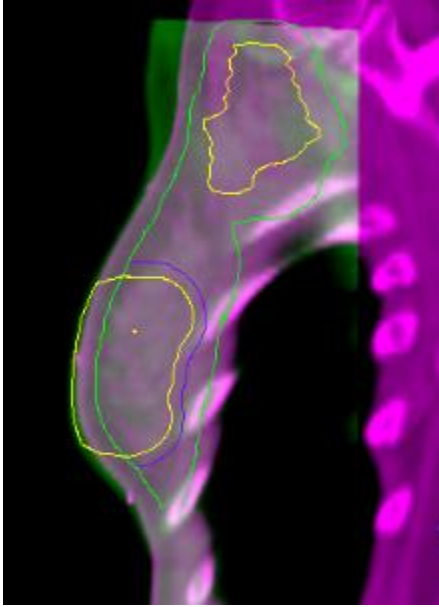
For example contour changes in pelvic patients

Countour changes	
1st fraction Contour changes > 2cm*	▪ No intervention ▪ Re-evaluate the next fraction (extra CB if necessary) ▪ Fraction dose > 4Gy
2nd fraction Contour changes > 2cm*	▪ No intervention ▪ Re-evaluate the next fraction (extra CB if necessary)
3th fraction Contour changes > 2cm*	▪ No intervention ▪ Proceed with flowchart
* Restriction value should be determined in every individual department, hence it depends on your departments treatment plans and margins.	

```
┌─────────────────────────────────────────┐
│          Contourchanges > 2cm            │
└─────────────────────────────────────────┘
                     │
                     ▼
                  ◇ > 50% fractions
┌───────────┐    ◇ or >10 fraction
│ No action │◄───◇ remaining?
└───────────┘    ◇
                     │
                     ▼
          ┌────────────────────────┐
          │ Contact RTT planning to │
          │ perform a Dose recalculate │
          └────────────────────────┘
```

NEW in the action light protocol

In-between the traffic light and the take action protocol we added some anatomical changes to take into account. For Example:

- Rotation setup which exceed the threshold
- Diaphragm difference in esophageal patients
- Breath hold performance in breath hold patients
- Post CBCT outcomes in library of plan patients
- Lymphnode outside PTV in pelvic region, see example

Example:
Individual lymphnode shift due to bladder filling difference
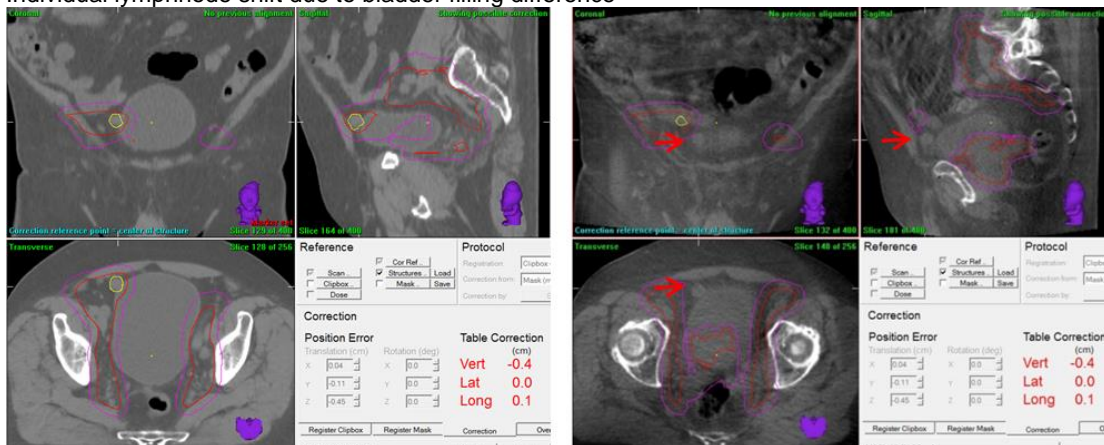
Example:
Retention bladder shifts bloodvessels and lymphnode area in cranio-ventral direction outside PTV.
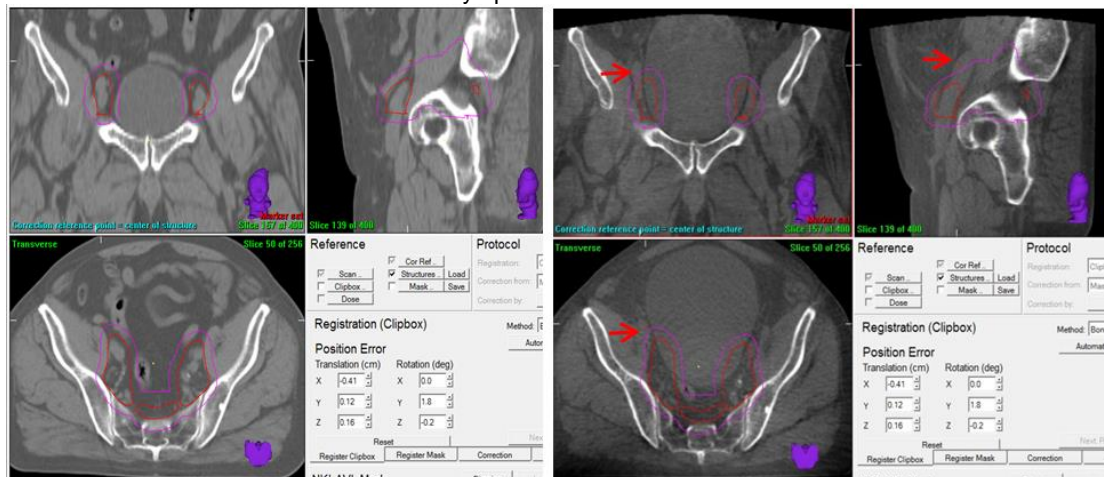
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