

Evaluation of the CIVCO Indexed Patient Position System (IPPS) MRI-Overlay for Positioning and Immobilization of Radiotherapy Patients

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Abstract

The emerging development in modern radiotherapy planning (RTP) requires sophisticated imaging modalities. RTP for high precision requires exact delineation of the tumor, but this is currently the weakest link in the whole RTP process [1]. Therefore Magnetic resonance imaging (MRI) is of increasing interest in radiotherapy treatment planning because it has a superior soft tissue contrast, making it possible to define tumors and surrounding healthy organs with greater accuracy. The way to use MRI in radiotherapy can be different. The MRI datasets can be used as secondary images to support the tumor delineation. This is routinely in use in many radiotherapy departments. Two other methods of MRI guidance in the RTP process are until now only research

projects, but interest in them is increasing. The first method is to use MRI data as the primary and only image dataset and the second is the application of the MRI data as reference dataset for a so-called 'MRI-guided radiotherapy in hybrid systems' (Linear Accelerator (Linac) or Cobalt RT units combined with MRI). For all cases it is essential to create the MRI datasets in the radiotherapy treatment position. For this reason the CIVCO Indexed Patient Positioning System (IPPS) MRI-Overlay was introduced and tested with our Siemens MAGNETOM Aera MRI Scanner.

Introduction

Although computed tomography (CT) images are the current gold standard in radiotherapy planning, MRI

becomes more and more interesting. Whilst CT has limitations in accuracy concerning the visualization of boundaries between tumor and surrounding healthy organs, MRI can overcome these problems by yielding superior soft tissue contrast. Currently there are three different possible strategies by which MRI can help to improve radiotherapy treatment planning:

The MRI datasets can be used as secondary images for treatment planning. These MR images can be used to delineate the tumor and the surrounding organs, whilst the CT images – the primary planning data – are necessary to calculate the 3D dose distribution. The two image datasets have to be co-registered thoroughly to ensure that the anatomy correlates (see for example [2]). The registration



1 1.5T MAGNETOM Aera with the standard cushion on the MRI couch.



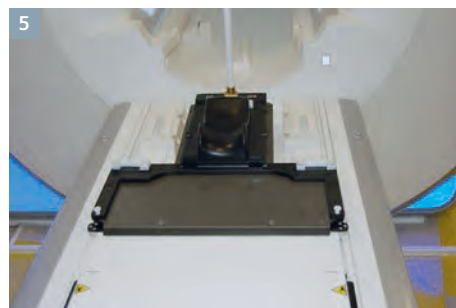
2 After the removal of the standard cushion the CIVCO IPPS MRI-Overlay can be mounted.



3 The lines indicate the position for the index bars.



4 One index bar is latched to the MRI-Overlay.



5 The mask system for head and neck fits to the index bar to avoid movement.

accuracy strongly depends on the MRI scan position. Hanvey et al. [3] and Brunt et al. [4] have shown that it is indispensable for the MRI dataset to be created in the treatment position which is primarily defined by the CT scan.

The MRI dataset can also feasibly be used as the only dataset. Because of the lack of electron density information, which is required for dosimetric calculations, bulk densities have to be applied to the MRI images. For this purpose the different anatomic regions like bone, lung, air cavities and soft tissue have to be overwritten with the physical densities. With this method it is possible to achieve dose calculation results quite similar to the calculation in the CT dataset in the head and neck region [5, 6] as well as in the pelvic region [7]. The advantage of this method is that by avoiding the CT scan you save some time and money. In this case it is necessary for the treatment position to be determined during the MRI scan, hence the MRI scanner has to be equipped with the same positioning and immobilization tools as the Linac. Further problems to overcome are the evaluation and correction of possible image distortions and the determination of accurate bulk densities.

After the RTP process there are a lot of remaining uncertainties such as set-up errors, motion of the target structures and during the treatment changes of the tumor volume and shrinking. This problem can be overcome with the so-called image-guided radiotherapy (IGRT). IGRT involves

a periodical verification (weekly or more frequent) of tumor position and size with appropriate imaging systems. It is evident that IGRT is only as good as the accuracy with which the target structures can be defined. For this reason some groups try to develop hybrid systems, where a Linac or a cobalt treatment unit is combined with an MRI scanner for a so-called MR-guided radiotherapy [8-10]. Again: MR-guided radiotherapy can only be successful when the reference MRI dataset has been created in the treatment position.

In any of the above three cases, where MRI can be helpful to improve the accuracy of radiotherapy, it is strongly advised that one has a robust and reproducible patient positioning and immobilization system, mainly at the MRI scanner, which is used for MR-guided RTP. Siemens provides with the CIVCO IPPS MRI-Overlay a suitable solution. In our clinic we have introduced and tested this MRI-overlay, especially for patients with tumors in the pelvis and for brain tumors and metastasis.

Method

Our 1.5T MAGNETOM Aera system (Siemens Healthcare, Erlangen, Germany) is located in the radiology department and can temporarily be used by the staff of the radiotherapy department. For the purpose of MR-guided RTP we have equipped the MAGNETOM Aera with the CIVCO IPPS MRI-Overlay. This overlay enables the fixation of positioning and immobilization tools necessary for radio-

therapy treatments. For our purpose we have used an MR compatible mask system for head and neck cases and vacuum cushions for patients with diseases in the pelvic region both from Medical Intelligence (Elekta, Schwabmünchen, Germany). These tools can all be fixed with so-called index bars (Figs. 4, 12) at the MRI-Overlay. These index bars are custom designed for our purpose by Innovative Technologies Völp (IT-V, Innsbruck, Austria) for the MRI-Overlay and for use in the high field magnetic environment. For the correct positioning of the patients, the laser system Dorado 3 (LAP, Lüneburg, Germany) was additionally installed in the MRI room. The preliminary modifications and the patient positioning is described in the following for two cases.

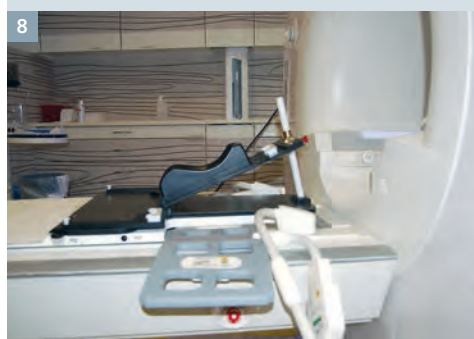
The first case describes the procedure for a patient with a head tumor. The first step is the removal of the standard cushion of the MRI couch and the mounting of the MRI-Overlay (Figs. 1–3). One index bar is necessary to fix the mask system on the overlay (Figs. 4, 5) to avoid movements and rotations during the scan. Because the standard head coil set cannot be used with the mask system, two flex coils (Flex4 Large) have to be prepared (Figs. 6–8). In figure 8 one can see, that the correct head angle could be adjusted. Now the patient is placed on the overlay and in the mask system. The patient's head can be immobilized with the real and proper mask made from thermoplastic material called iCAST (Medical Intelligence, Elekta, Schwabmünchen, Germany)



6
Two flex coils (Flex4 Large) are prepared.



7
The flex coils have to be positioned partly under the mask system, because the whole head of the patient should be covered.



8
It is possible to adjust the head angle in an appropriate and reproducible position that is comfortable for the patient.



9
Now the patient is immobilized using a custom-made mask made from thermo-plastic material.



10
The flex coils are closed with hook-and-loop tapes.



11
The patient is ready for the scan.



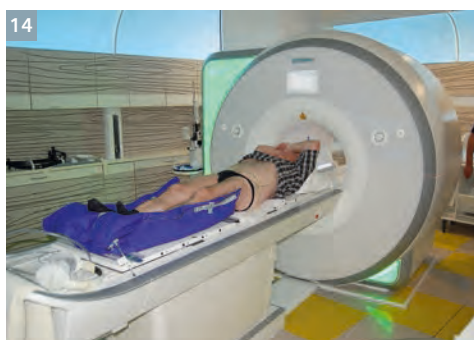
12 A custom-made vacuum cushion for the lower extremities is latched to the MRI-Overlay with two index bars.



13 A second vacuum cushion is positioned on the table to fix the arms and shoulders and keep the patient in a comfortable position.

as can be seen in figure 9. Now the flex coils can be fixed with hook-and-loop tapes and placed very tight to the patient (Figs. 10, 11). Now the MRI scan can be started.

The second case describes the preparation before the MRI scan for a patient with a tumor in the pelvic region. The first two steps are identical, the remove of the standard cushion followed by the mount of the overlay (Figs. 1, 2). Then a custom-made vacuum cushion for the lower extremities is attached to the overlay with two index bars (Figs. 12, 13). For a robust position of the patients with diseases in the pelvis it is very important to keep the legs in well-defined position – not only during imaging but also throughout the



14

Now the patient can be positioned.

15

The accurate position of the patient can be adjusted with the LAP laser system.

16

A mounting-frame for the flex coil has to be attached to the MRI-Overlay.

17

The mounting-frame from a side view.

18

The flex coil is fixed to the mounting-frame with hook-and-loop tapes.

19

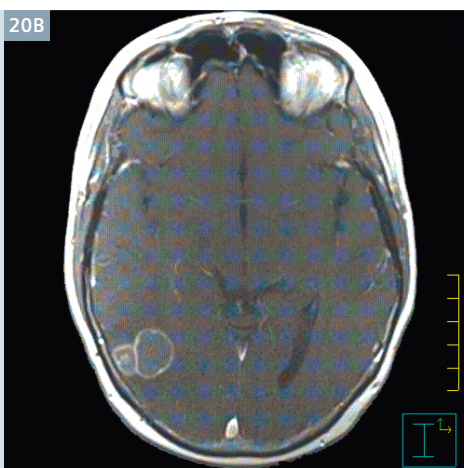
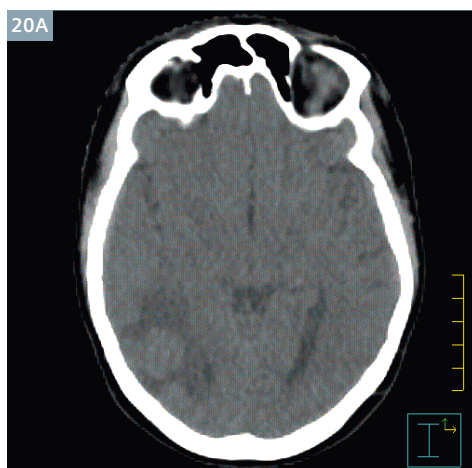
The patient is ready to start the scan.

whole treatment course, which spans over seven weeks. Any changes there can result in undesired rotations of the pelvis and in the end the tumor position and shape can also change. In figure 13 a second custom-made vacuum cushion can be seen. The only purpose of this vacuum cushion is to enable a comfortable position of the patient during scan and later during the treatment (Fig. 14). The more comfortably the patient lies on the table the more robust and reproducible is the positioning. Fortunately MAGNETOM Aera has a bore diameter of 70 cm, hence there are almost no limitations concerning patient positioning. Now the accurate position of the patient should be checked with the moveable laser-system (Fig. 15). This is neces-

sary to avoid rotations of the pelvis around the patients longitudinal and lateral axis. For the fixation of the flex-coil for the pelvic region a mounting-frame has to be attached to the overlay (Figs. 16, 17). This can be done with hook-and-loop tapes (Fig. 18). Now the patient set-up is completed and the MRI scan can be started (Fig. 19).

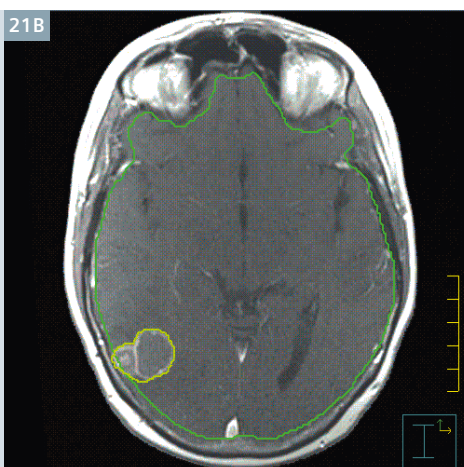
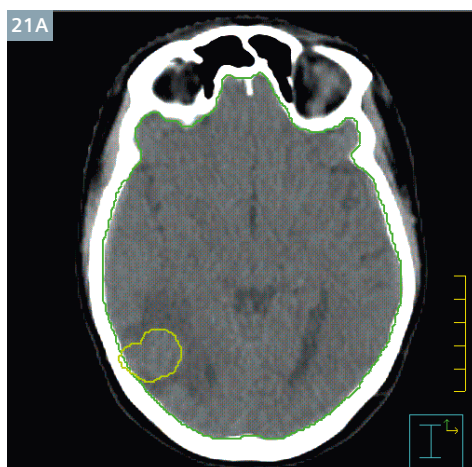
Results

Two examples are shown in the following pictures. In Fig. 20 you can see a brain tumor in two corresponding slices. The left picture shows the CT-slice and the right picture shows the corresponding MRI slice obtained with a T1-weighted sequence with contrast agent. It is clear to see that tumor boundary is much more pronounced in the MRI image. Figure 21 shows the same slices with structures created by the radiotherapists. It is also helpful to create some control structures, such as brain and ventricles, to check the accuracy of the registration. Figures 22 and 23 give an example of a patient with prostate cancer. In this case the MRI images on the right



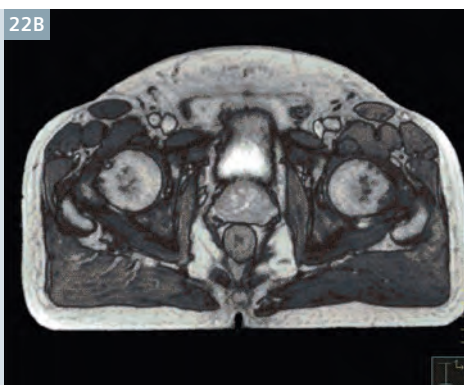
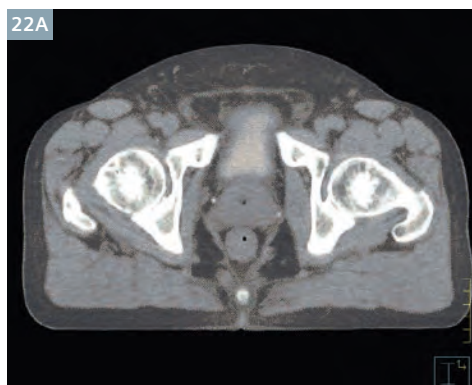
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Two corresponding slices of a brain scan: (20A) CT slice and (20B) MRI slice obtained using a T1-weighted sequence with contrast agent.



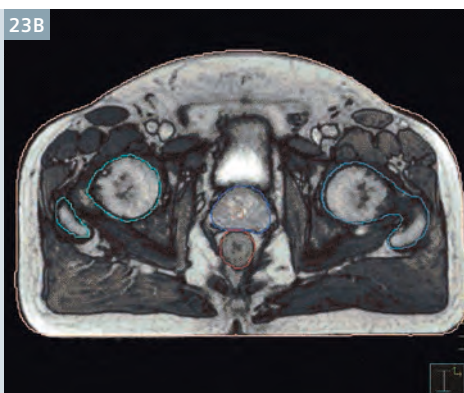
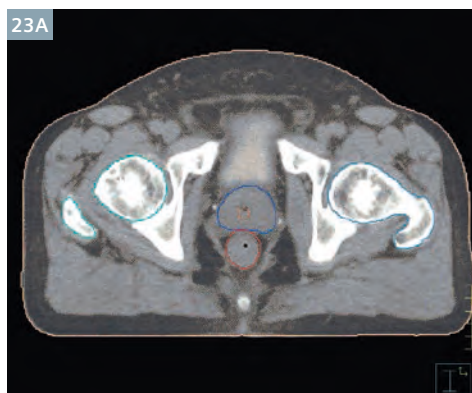
21

The same slices as in figure 20, but now with delineated tumor and help structures.



22

Two corresponding slices in the pelvic region of a patient with a prostate cancer: (22A) CT slice and (22B) MRI slice obtained with a T2-weighted TrueFISP sequence.



23

The important structures rectum and prostate as defined in the MRI slice are shown. The accuracy of the registration can be tested with the coincidence of help structures – like the femoral heads in this case – in both datasets.

are acquired using a T2-weighted TrueFISP sequence. The boundary of the prostate and the differentiation between prostate and rectum is much more easier to define in the MRI images. The control structures in this case are the femoral heads. For the head scans we normally use 3 sequences, a T1w SE with contrast agent, a T2w TSE and a FLAIR sequence. For the pelvis scans we normally use a T2w SPACE, a T2w TrueFISP and a T2w TSE sequence. The coordinate system should be the same for all sequences, that means same slices and same field-of-view. Hence one can use the same registration parameters for all sequences.

Conclusion and outlook

We can now look back over a period of two years working with the CIVKO IPPS MRI-Overlay. Our experience is very promising. The modifications on the table of the MRI scanner are very easy and can be executed and finished in only a couple of minutes. The procedure is well accepted by the radiologic technologists. To date, we have scanned more than 100 radiotherapy patients, mainly with diseases in the pelvis (rectum and prostate cancer) and in the head (brain tumors and metastasis). So far we have only used MRI dataset as a secondary image dataset. The co-registration with the CT datasets is now much

easier because we have nearly identical transversal slices in both image datasets.

As a conclusion we can say that we are very happy with the options we have to create MRI scans in the treatment positions. It has been demonstrated that the MRI dataset is now much more helpful in the radiotherapy planning process. We should mention the need for a quality assurance program to take possible image distortions into consideration. Our next step is to install such a program, which involves the testing of suitable phantoms. A further step will be to assess whether we can use MRI datasets alone for RTP.

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