AN EVALUATION OF IMSIMQA AS A TOOL FOR COMMISSIONING 4DCT

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1. Purpose

4D CT scanning is used increasingly in radiotherapy departments to track the motion of tumours in relation to the respiratory cycle of the patient.

4D CT monitors the breathing cycle of the patient and can either:

a) acquire CT images at a certain point in the breathing cycle, based on a particular phase of the breathing cycle or the amplitude; or

b) acquire CT images over the whole breathing cycle and then sort by phase or amplitude.

This CT data is then used to either generate an ITV (Internal Target Volume) that encompasses the motion of the CTV; or to generate Average Image scans or MIP (maximum intensity projection) scans to aid in the definition of an ITV.

The aim of this paper is to commission the representation of the 4D CT dataset in a commercial planning system using the software tool ImSim^{QA}

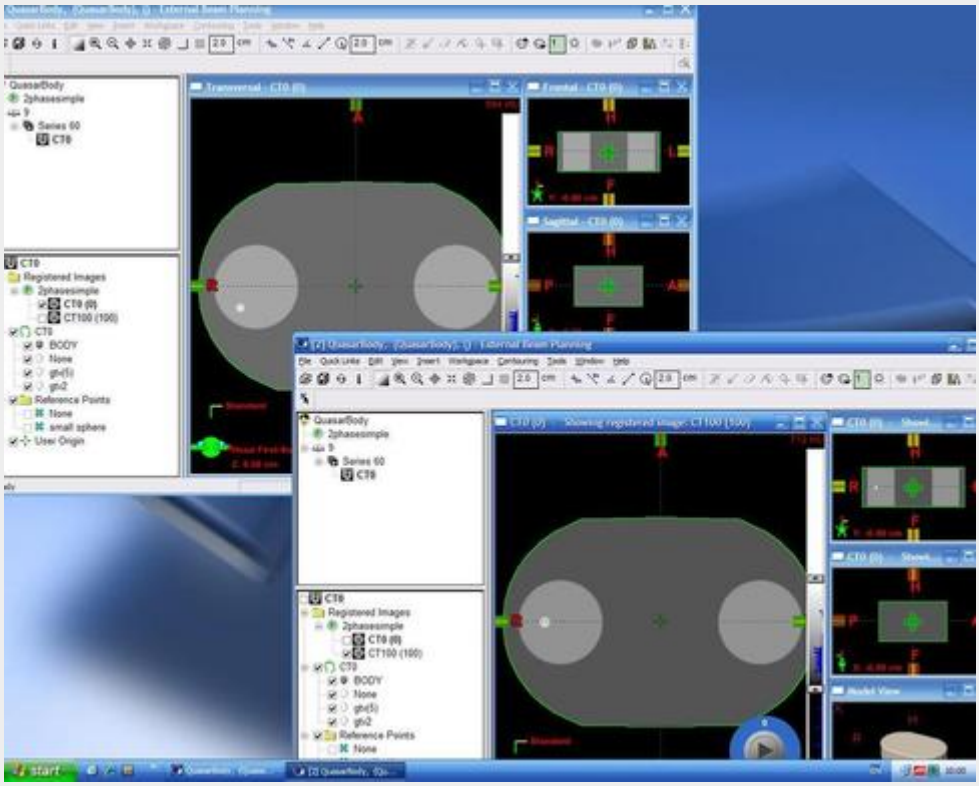
2. Methods

The software application ImSimQA is designed to aid physicists to commission image registration and other radiotherapy applications. It includes an optional 4D application to simulate respiratory gated images.

ImSimQA has the facility to generate virtual phantoms which can be modified and exported into treatment planning systems as DICOM images. The 4D option allows for translations, rotations and scaling of objects within the phantom to create a series of 4D DICOM CT images; and because the objects are being transformed by known amounts in each phase, the reproduction of this transformation in the treatment planning system (TPS) can be checked. The Maximum Intensity Projection (MIP) and Average Image (AI) generated in the CT scanner software can also be checked accurately.

In it's simplest form, a 4D dataset can be generated with just 2 phases and a single object moving and/or being scaled. This is exported to the TPS and the 4D CT representation can thus easily be checked (fig 1).

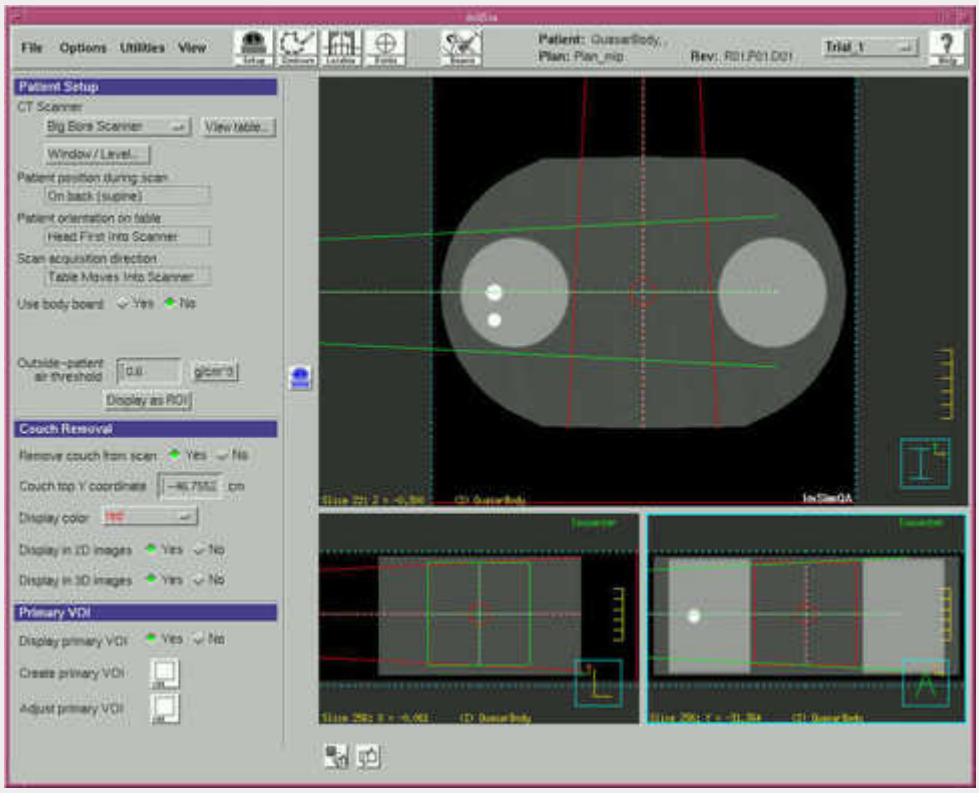
Figure 1



Eclipse representation of 2 phase 4DCT

Both the Hounsfield Units (HU) and geometric representation can be checked against the known values generated in ImSimQA. The AI and MIP images can also be checked (fig 2).

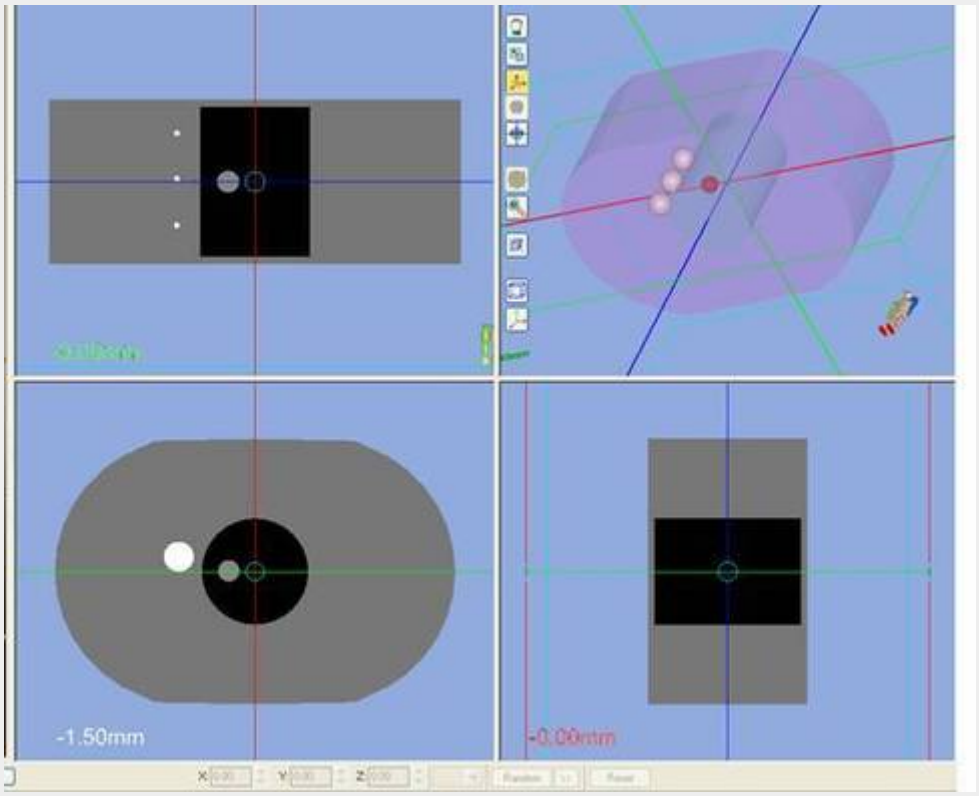
Figure 2



AcQSim representation of MIP

In the next example, a phantom was generated consisting of a body, a 'lung', three 'ribs' and a 'tumour' object. A range of phased image sets were generated with the objects either being scaled and/or translated (fig3).

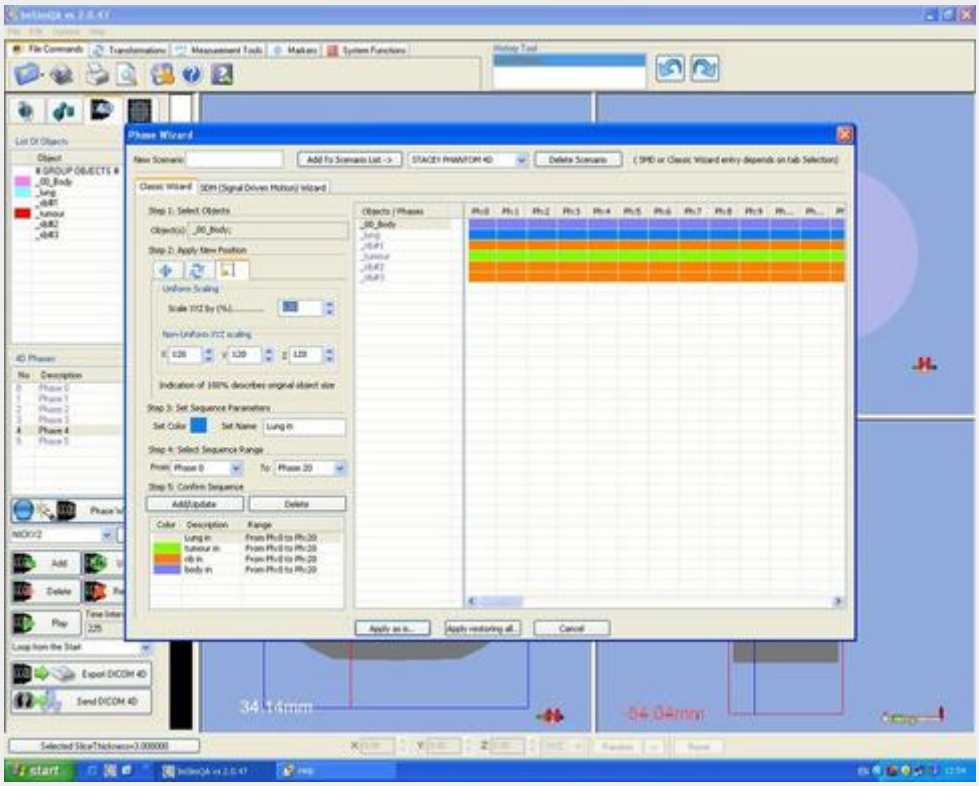
Figure 3



Phantom generated in ImSimQA

Using the classic wizard as shown in figure 4, the lung and body were expanded to 120% of the original size over the pre-set number of phases; and the ribs were set to translate 3cm in the X and Y directions. The 'tumour' was translated 1cm in the Z direction (Movie 1).

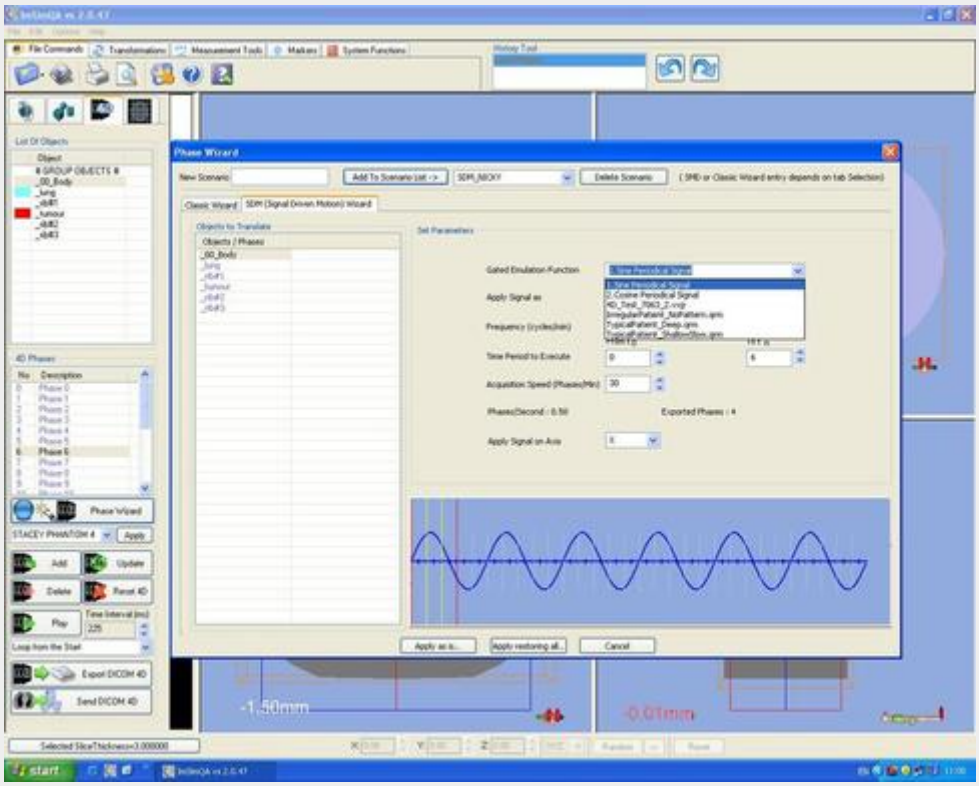
Figure 4



Classic wizard for generating respiratory cycles

The signal driven wizard could also be used to generate 4D images. This wizard uses sinusoidal or co-sinusoidal signals that can be modified by the user; or pre-defined breathing cycles. Objects are translated or scaled according to the signal (fig 5).

Figure 5



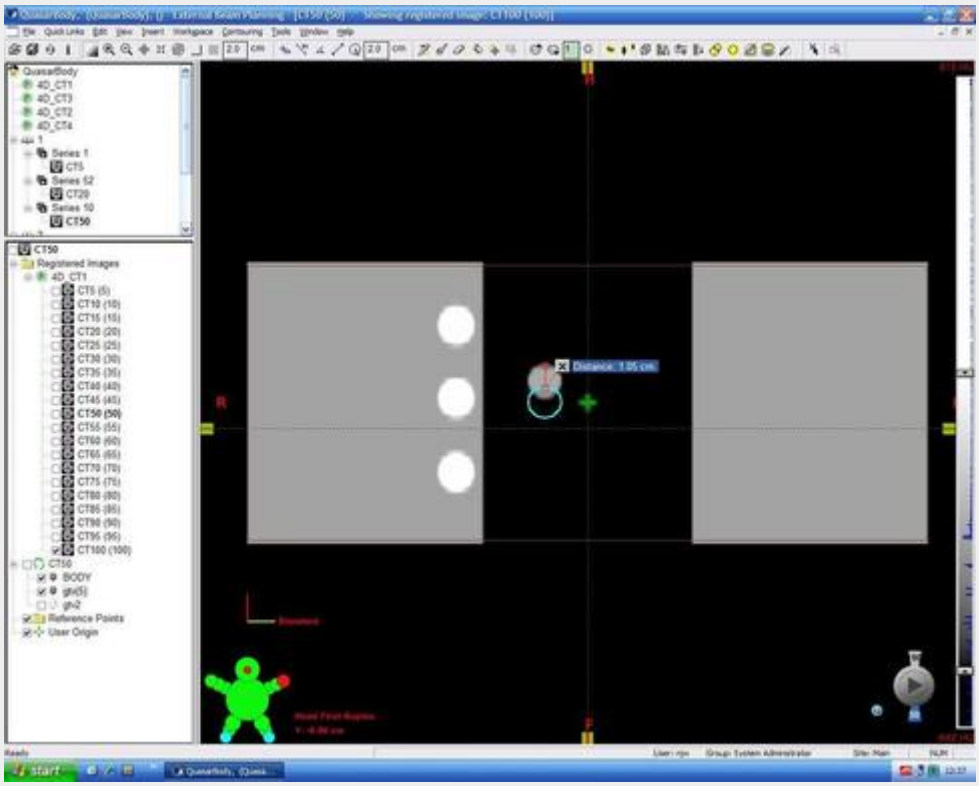
Signal driven wizard

3. Results

A range of 4D CT datasets, from simple 2 phase scans with a single object translation to non-sinusoidal multiphase 4D CT datasets, were imported into both TPSs. In all cases, the 4D CT dataset was generated correctly; and the movie loop correctly predicted the position of the objects at the correct part of the phased scan.

In the second example given in the Method, figure 6 shows the final phase with the 'tumour' translated 1cm in the Y direction.

Figure 7

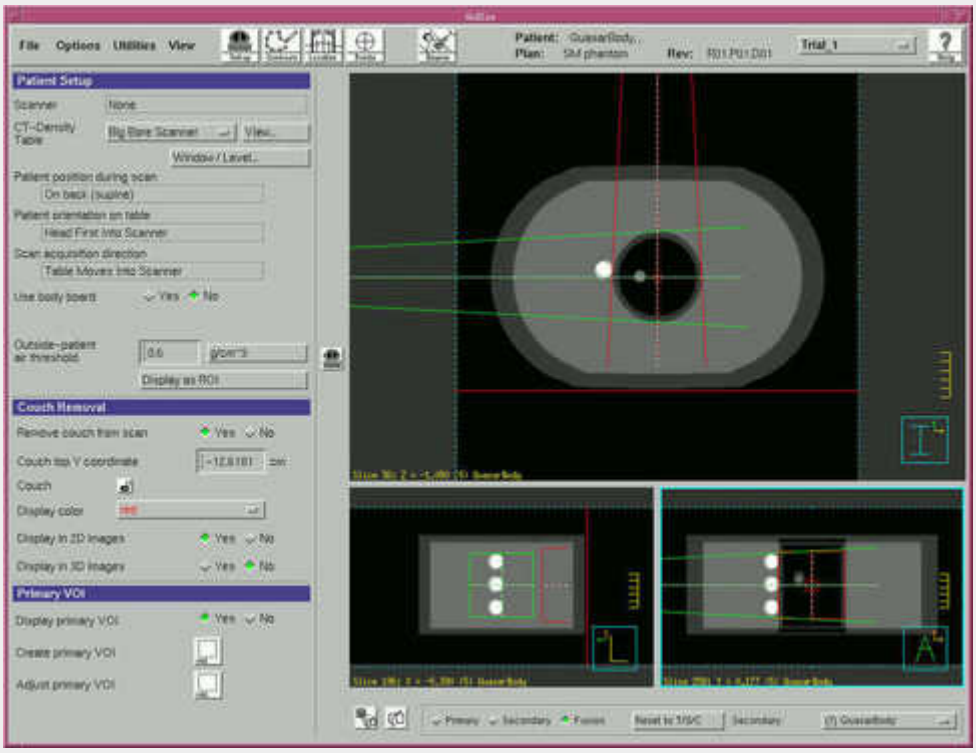


Eclipse check of translation of 'tumour'

All Hounsfield Units for all the phased scans, AI and MIPs were correctly transferred for both TPSs used.

Figure 7 shows the images from 2 phases overlaid in AcQSim.

Figure 8



AcQsim representation of 2 overlaid phases

4. Conclusions

a) Using virtually generated CT data, one can test the TPSs more thoroughly than physical phantoms and to a finer degree of accuracy than true phantoms as the movements are digitally defined and have an almost infinite degree of freedom.

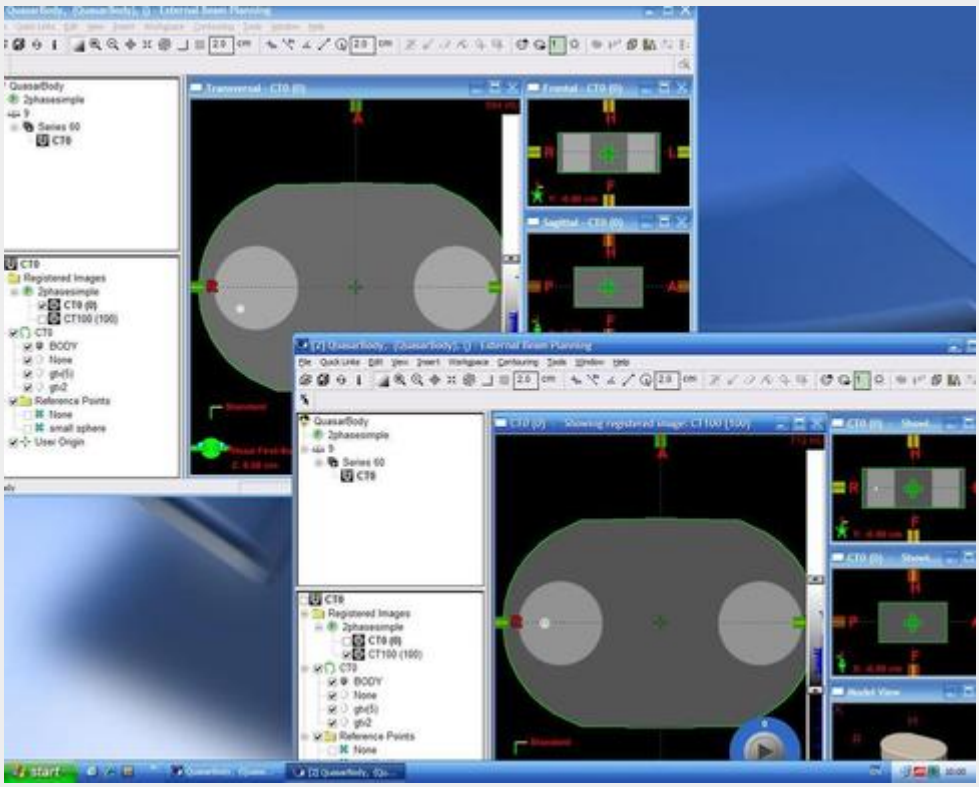
b) Eclipse and AcQSim can accurately reproduce and represent image data required for planning gated radiotherapy treatments.

c) As a training tool ImSimQA gives physicists and clinicians a greater understanding of how respiratory gating can be planned.

With special thanks to Grigorios Karengelis of OSL, and Stacey McGowan.

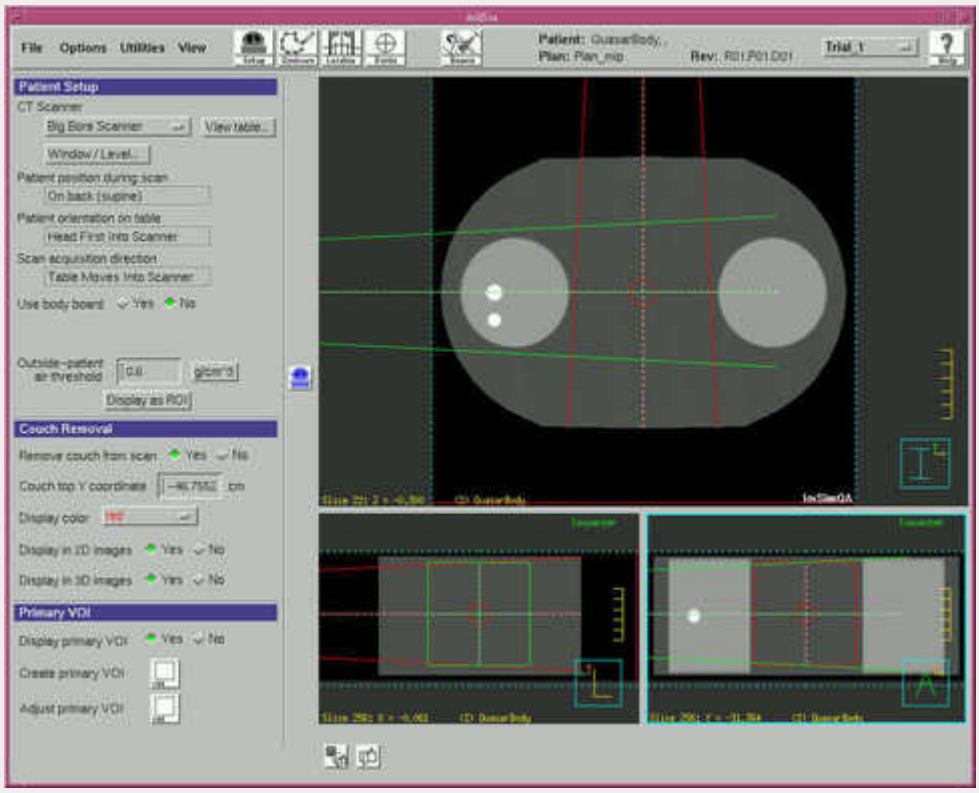
5. Mediafiles

Figure 1



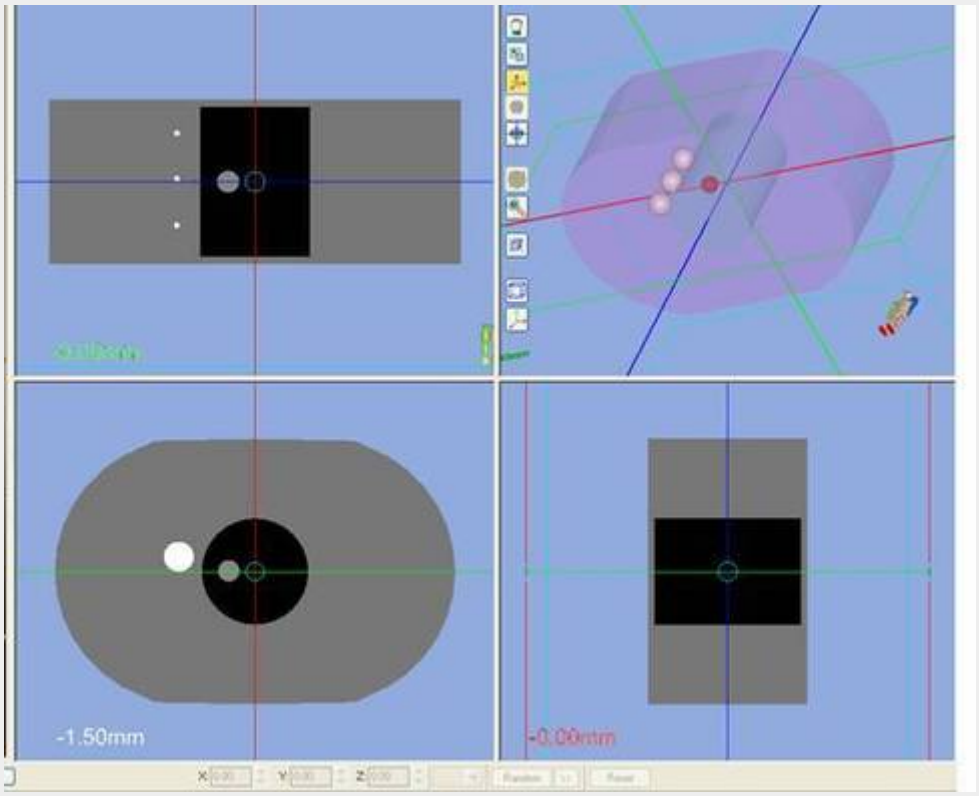
Eclipse representation of 2 phase 4DCT

Figure 2



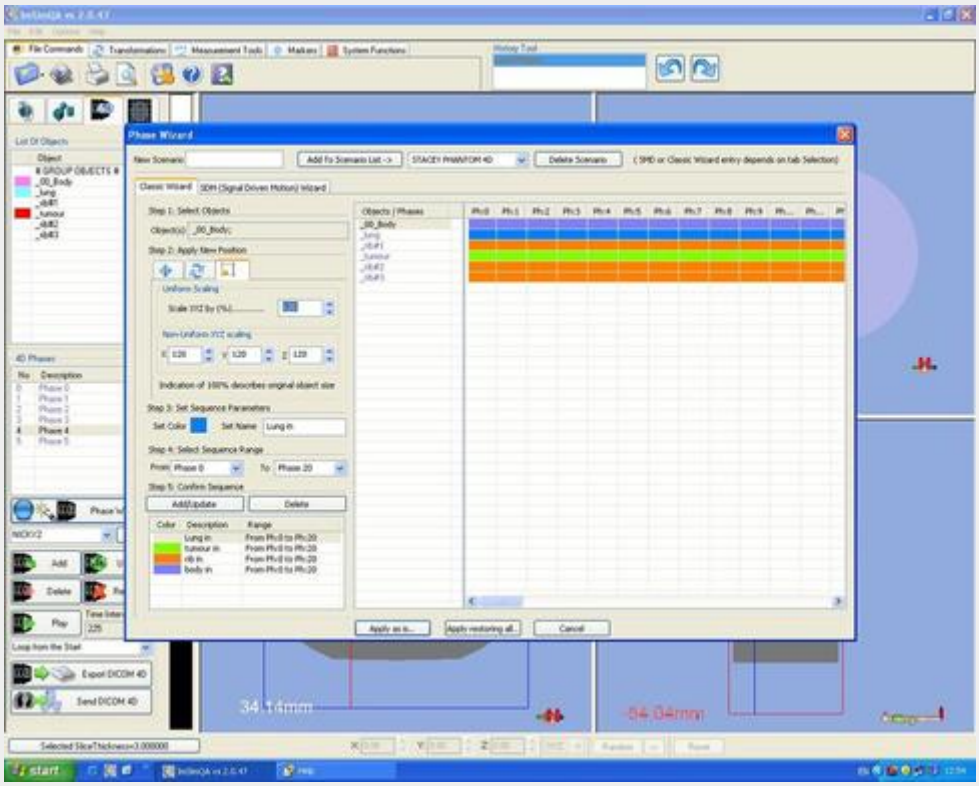
AcQSim representation of MIP

Figure 3



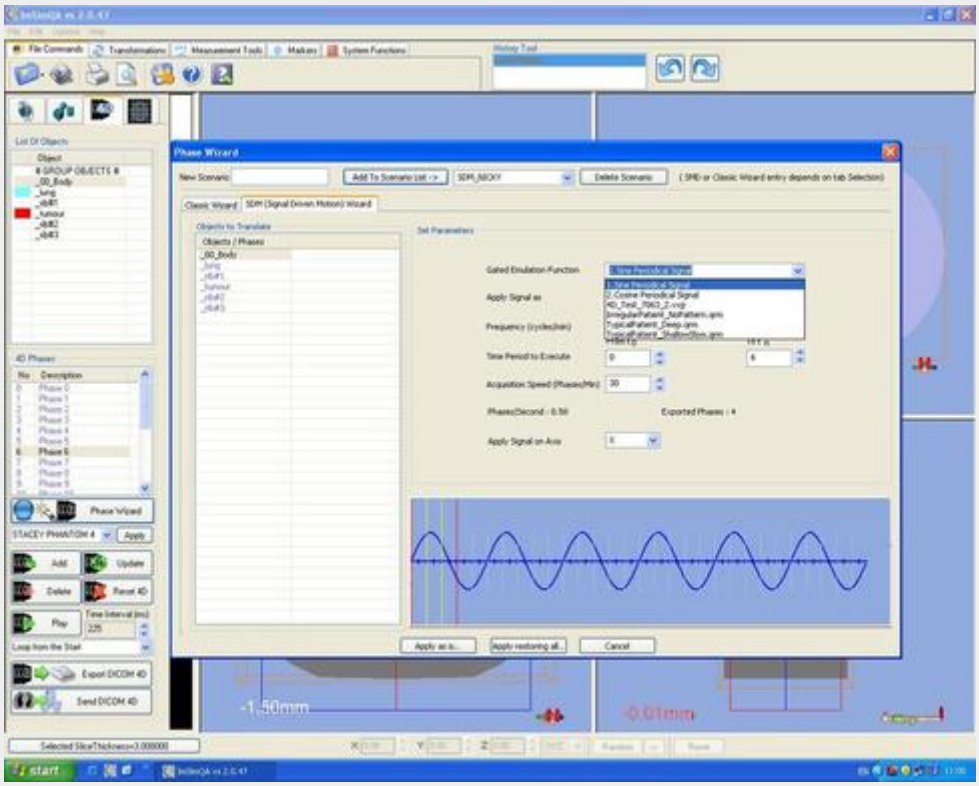
Phantom generated in ImSimQA

Figure 4



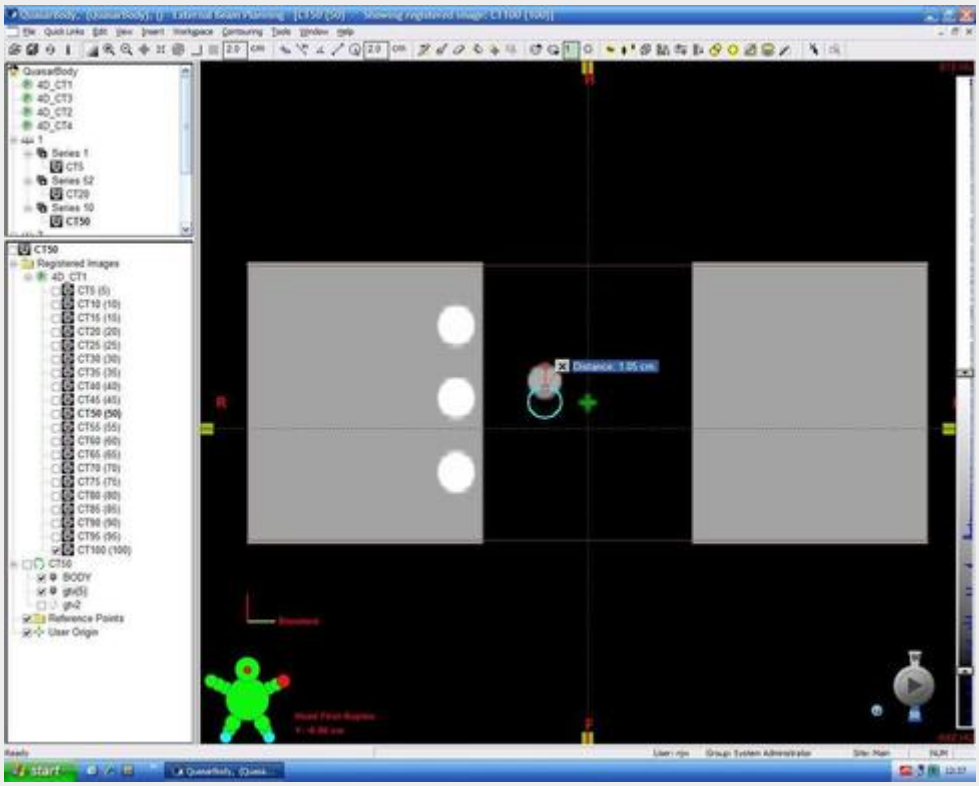
Classic wizard for generating respiratory cycles

Figure 5



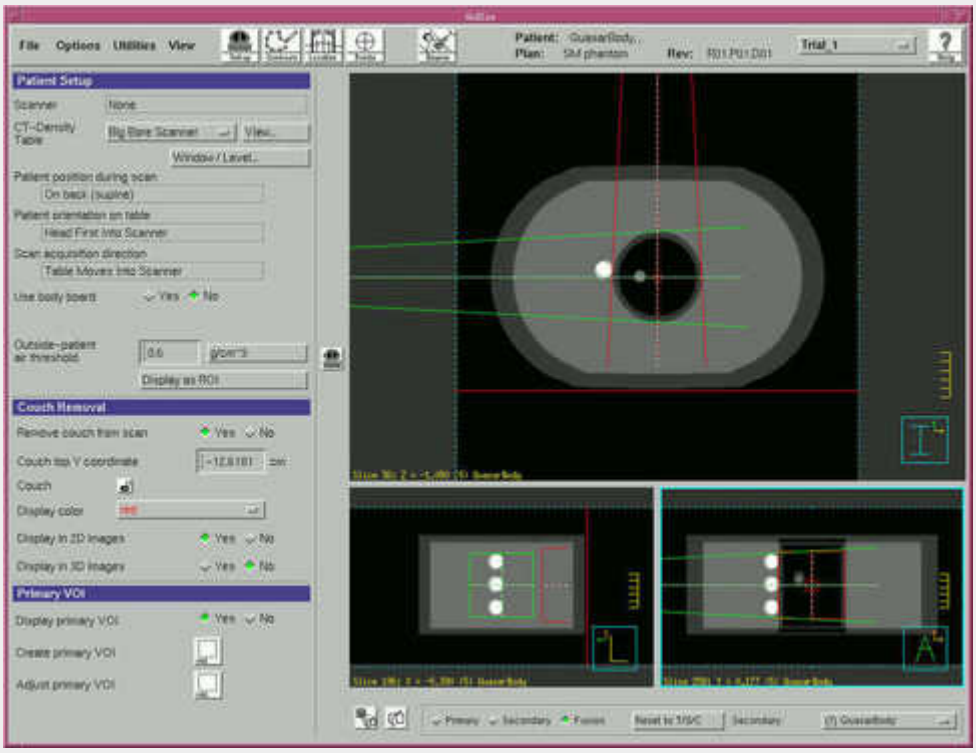
Signal driven wizard

Figure 7



Eclipse check of translation of 'tumour'

Figure 8



AcQsim representation of 2 overlaid phases

Movie 1

The 4D dataset generated in ImSimQA