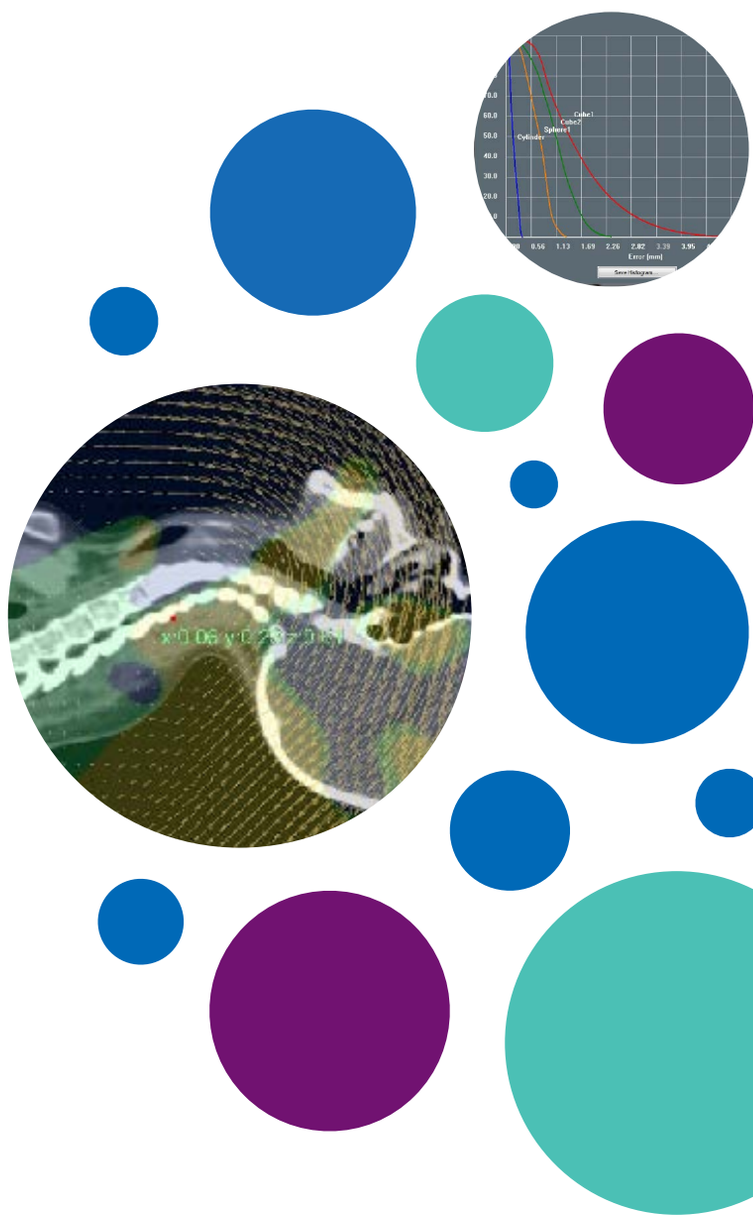
# ImSimQA™

Independent validation & QA of image registration & fusion software

## 3D Print Module now available

As used by TG-132

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# Why ImSimQA?

ImSimQA was developed to overcome the limitation of physical phantoms for testing of rigid and deformable image registration (RIR and DIR) found in multi-modality imaging, adaptive planning and image guided radiotherapy software. ImSimQA supports the testing of clinical applications:

- CT-MR /PET image fusion
- Adaptive re-planning & dose mapping
- Stereotactic radiotherapy
- Tumour response assessment
- Atlas & model based auto segmentation
- Cone beam CT / MVCT used in IGRT Stereotactic radiotherapy
- 4D planning and gated radiotherapy

# Closing the loop

ImSimQA is a software toolkit that generates ground-truth DICOM test images from virtual phantoms, or imported DICOM images, that are then used to validate clinical software systems using its quantitative analyses of RIR and DIR algorithms. ImSimQA creates gold standard test image data and measures and analyses the performance of clinical systems. ImSimQA closes the loop of testing.

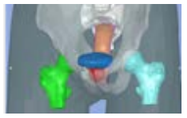
# Beyond image registration

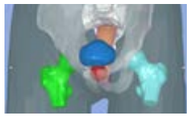
ImSimQA's virtual phantoms and quantitative testing go far beyond image registration: advanced contour comparison analyses; volume and distance measurements; QA of 3D margin algorithms, DRR and CT MPR reconstructions; auto-segmentation of branching structures; 4D CT series creation for 4D planning QA; models of commercial Quasar Body and MLC phantoms; and practically infinite customisation of phantoms for geometric testing.

# AAPM Task Group 132 Report

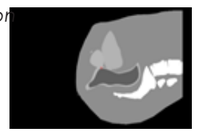
The ImSimQA scientific team have over many years communicated with Task Group members discussing image registration. Image datasets provided in the TG Report have been generated using ImSimQA, and as per the Report recommendations, this basic dataset should only be used as a starting point for testing and evaluation, as we all know how patients, positioning,techniques, image devices and protocols, and clinical judgement vary.

*Male Pelvis Virtual Phantom – testing effect of body roll, and bladder inflation on RIR and DIR*



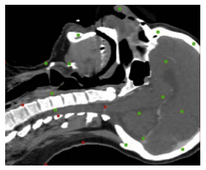


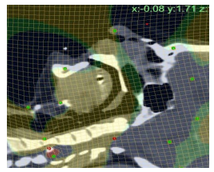
*Bladder inflated and body rotated for new test condition*



*Resulting ImSimQA CT of edited phantom position for export to clinical software for testing*

*Head and Neck imported DICOM phantom – testing effect of changed neck extension on RIR and DIR*



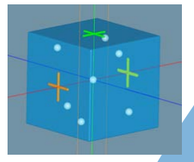


*Use known ImSimQA deformations to test the clinical system. Analyse with Jacobian colour wash & vector field display.*

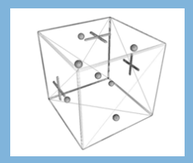
# Benefits of ImSimQA

- Extensive library of virtual phantoms provided
- Create customised clinic specific phantoms for new scenarios, with a few clicks
- Simple Pass/Fail metrics provide confidence in complex clinical software
- Provides quantitative and DIR testing not possible with physical phantoms
- Reduces physics QA time on scanners and clinical imaging devices
- Independent of the clinical software being tested
- Fully TG-132 compliant
- Now offers end-to-end testing with 3D print option

# From virtual phantoms to real phantoms



1. 3D virtual phantom



2. Conversion to STL

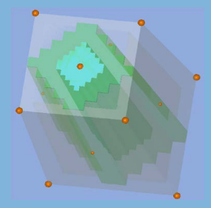
3. Printed phantom

# Phantom Library

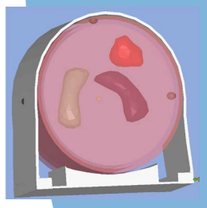
ImSimQA is installed with a minimum of 15 virtual phantoms both geometric and anthropomorphic. An additional 10 pairs of head & neck images are included within the 'dform' module. These phantoms can be easily added to by users, by simply importing DICOM & RT images, & all virtual phantoms & imported images can be extensively and precisely edited to model the test conditions.

Shapes phantom
Customise with 14 internal VOIs, outer bolus/mask that can be moved, deleted, re-sized, density filled.

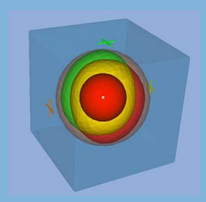
Male Pelvis phantom
Bladder, rectum and femoral heads can be filled with user densities e.g. prostheses, contrast.



MLC phantom
Model of Quasar phantom for QA of DRRs, CT MPRs and 3D reconstructions in RT planning and Vsim.



Simple Brain phantom
Mask, ventricles and tumour. Change size, position, re-size. Edit density of mask, fill ventricles with fluid density.



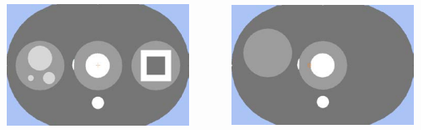
3D Spheres Margin phantom
Spheres of known volume within a cube with markers used to validate 3D margin growing algo-rithms.

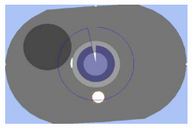
Thorax phantom
Lungs & heart can be moved, inflated, deflated. 4D phase CT series created from user/RPM imported signal.

# Creating and editing phantoms

## STEP 1: Editing virtual phantoms

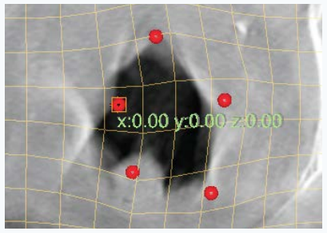
- VOI editing: body, internal structures, or masks can be switched on/off/copied/re-sized
- Markers: add, move, delete
- Transformation: any structure or marker can be precisely translated or rotated
- Density editing:  any structure or marker can be allocated a HU density value
- Convert final phantom setup to DICOM CT or simulated MR, PET or Cone beam CT
- Add noise patterns to images





"Virtual Body phantom is rotated, VOIs are moved, deleted and filled with user defined HU density."

## STEP 2: Editing imported DICOM images as phantoms




*Deform to precise marker points*

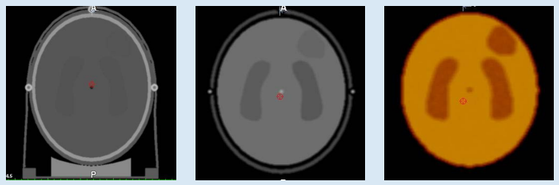
- Import DICOM-3/RT images from clinical system
- Contoured VOIs can be density edited by HU
- Transformations can be applied to whole image
- Deformations can be applied to any VOI
- Deformations can be local or global
- Deformations can be limited by stiffness
- Create, export, import and compare DVF
- Analyse with Jacobian Determinant colour wash

## STEP 3: DICOM editing in ImSimQA

- Create DICOM images & RTS series
- Edit DICOM UID
- Select FOV, slice resolution, number of slices for phantoms
- Re-create multiple series e.g. from 1mm slice resolution, create 2, 3, 5mm slice thickness from imported DICOM images

"Apply controlled transformations and changes to phantoms."

## STEP 4: DICOM export to clinical systems



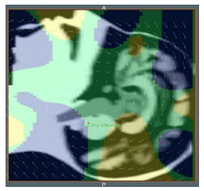
*Simple Brain phantom setup converted to DICOM CT and simulated MR and PET image series for export to clinical software for testing.*

- DICOM export to clinical system being tested for all image modalities
- Export edited DICOM series of phantom setup
- Apply technique on clinical software eg RIR, DIR, auto – contouring etc
- Export clinical images  back to ImSimQA for analysis

# How to test

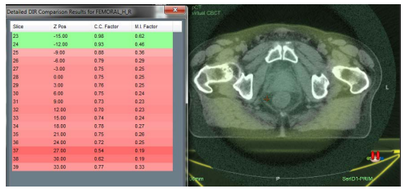
## Multi-modality RIR and DIR

- Create identical MR and CT phantoms
- Add transformations/deformations
- Check regularisation using Jacobian Determinant colour wash
- RIR QA - inverse translations & rotations calc



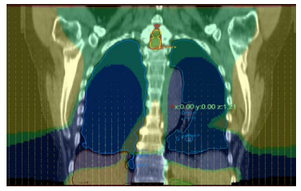
## IGRT

- Add noise to create a synthetic CBCT image
- Rotate, translate, deform
- Analyse image/VOI correlation



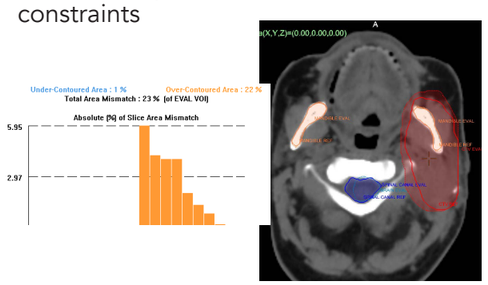
## 4D Planning

- Create gold standard inhale and exhale images
- Check deformation of clinical system
- Confidence for clinical use



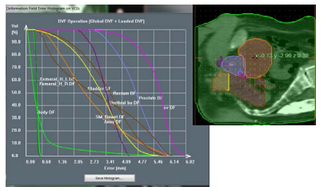
## Auto & Manual Contouring

- Automatically compare VOIs
- DSC and MDA comparison metrics
- Generate report with user defined constraints



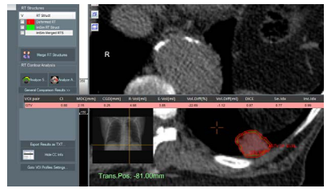

## Adaptive Planning

- Automatically 'fill' the bladder
- Check adaption of the clinical system
- Compare Target Registration Error (TRE)



## Tumour Assessment

- Assess changes in size/shape
- Monitor training/outlining
- Assess consistency



# DIR Validation & QA

Deformable image registration has become increasingly embedded in clinical imaging software used in radiotherapy. The clinical applications in which it is used range from multi modality imaging used in treatment and adaptive re-planning, automatic segmentation of anatomical structures and image guided radiotherapy. Tumour response assessment post treatment is a further application that benefits from DIR.

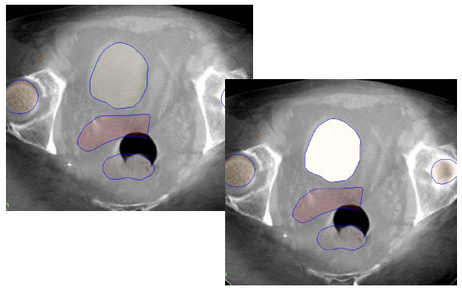
The software used for these applications is often complex and the user has little detailed knowledge of the exact algorithms implemented nor the accuracy for the wide range of clinical and technical scenarios encountered. The AAPM Task Group 132 report addresses these issues and recommends a series of tests for validation and QA of DIR and RIR, that include the use of virtual, or digital, phantoms, alongside specified quantitative analysis. ImSimQA incorporates these recommendations through its quantifiable testing and provides gold standard image test data from its virtual phantoms or imported DICOM images.

"ImSimQA applies know deformations to phantom images creating gold standard controlled test conditions."

| AAPM TG-132 recommendations for quality assurance and quality control of image registration (both rigid and deformable) | ImSimQA |
|---|---|
| Commissioning with virtual phantoms: geometrical & anthropomorphic CT/MR/PET/CBCT/MVCT | ✓ |
| Commissioning with clinical data by applying known deformations | ✓ |
| Comparison of known DVF to clinical systems DVF | ✓ |
| Quantitative: 95% of voxels within the phantom within 2mm, max error less than 5mm | ✓ |
| Landmark analysis | ✓ |
| Contour analysis | ✓ |
| Image comparison | ✓ |
| Target Registration Error | ✓ |
| Mean Distance to Agreement (mean distance to conformity) | ✓ |
| Dice Similarity Coefficient | ✓ |
| Jacobian Determinant | ✓ |
| Consistency to ensure that the registration is inverse consistent | ✓ |
| Is an independent QA platform from the clinical system under review | ✓ |

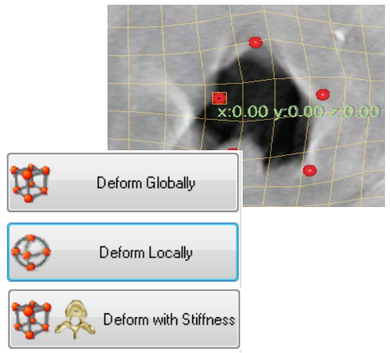
# Modules

## ImSimQA



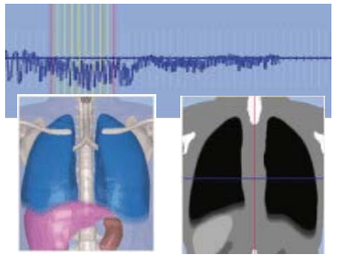
- Base module with virtual phantom library, DICOM editing, rigid transformations & scaling, density editing
- RIR QA: translations and rotations to virtual/imported phantoms to create gold standard test data; analysis report generation using inverse transformation parameters
- DICOM dataset and RTS import & export
- Noise can be added to DICOM images
- SQL database for DICOM-3/RTS and DVFs
- Client server architecture for multiple clients, remote CITRIX access

## ImSimQA dform



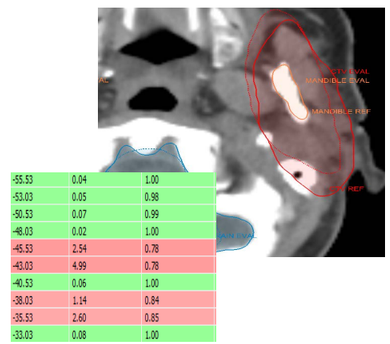

- Known deformation DVF applied to imported DICOM images to create gold standard test data
- Deformable QA analyses for validating DIR software: DVF comparison, Jacobian determinant, image comparison
- Import & export deformation fields
- Includes library of additional 10 original & deformed synthetic head & neck phantoms with ground truth DVFs
- Automatic DIR processes using Task Scheduler
- Deformations automatically applied to real clinical data
- DVFs stored in database, can be re-used

## ImSimQA 4d



- Creation of 4D CT image phases from virtual phantoms
- Individual structures can be assigned differing motion patterns
- Varian RPM signals can be applied to phantoms
- Phase Wizard for fast and systematic 4D creation
- Used for QA of gated radiotherapy, SRT, SABR and 4D phase auto-contouring

## ImSimQA contour




- Extensive contour analysis tool that measures difference in size, position and shape of structures
- Pass/fail report that can be printed or exported including conformity index (CI), Dice Similarity Coefficient (DSC) and mean distance to agreement (MD)
- Volume and distance measurements, DSC and MD are used for: auto-contouring QA; human user manual contouring comparisons; tumour response assessment
- VOIs out of tolerance directly navigate to slice

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