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Image registration, deformation, and enhanced contouring for radiotherapy with Velocity

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Outline

- **Rigid and deformable registration**
- **Adaptive contouring**
- **Advanced segmentation tools**
- **Atlas-based segmentation**
  - **Initial experience**

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Overview

- **Our experience**
- **Started using Velocity in 2009**
- **Currently running version 2.6.1**
- **Approximately 175 patients**
  - **81% PET/CT fusion**
  - **13% CT/CT fusion**
  - **6% MR/CT fusion**
  - **7% Adaptive contouring**

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Treatment Planning Process

- Diagnostic PET-CT procedure followed by CT simulation
  - Different patient positioning
  - Registration accuracy difficult to achieve
- Deformable registration allows the user to deform diagnostic imaging exams taken in the non-treatment position into the position of the simulation CT

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Rigid and Deformable Registration

- Workflow
  - Simulation CT imported into Velocity
  - Diagnostic images imported into Velocity
    - CT (including conebeam CT)
    - MR
    - PET
    - SPECT
  - Manually align imaging data sets

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Rigid and Deformable Registration

- Workflow
  - Select user-defined region-of-interest (ROI)
  - Start registration
    - Rigid
    - Rigid and Scale
    - Deformable
    - Deformable Multi-pass

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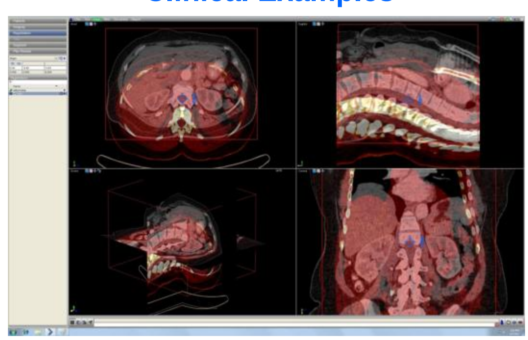
Clinical Examples



Pre-fusion setup

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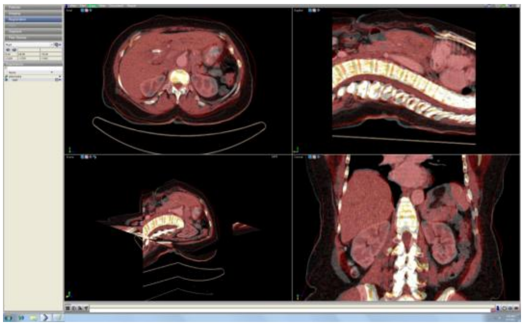
Clinical Examples



Rigid fusion

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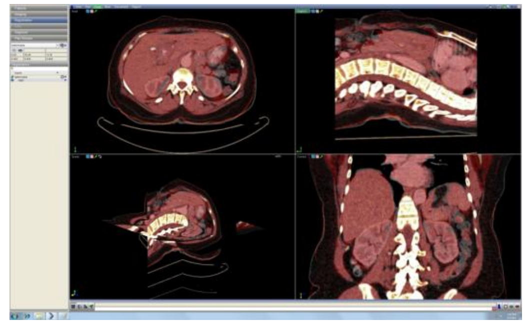

Deformable fusion

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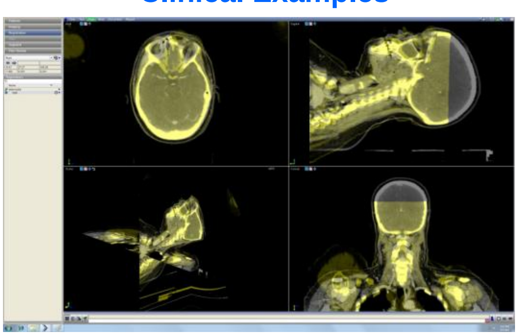
Clinical Examples



Rigid fusion

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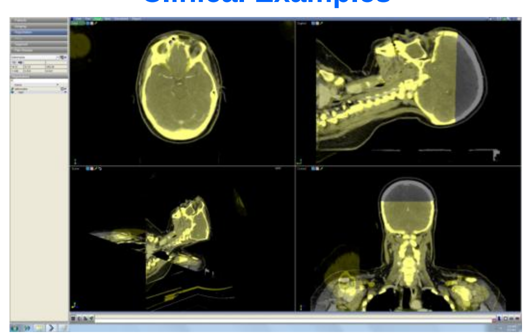
Clinical Examples



Deformable fusion

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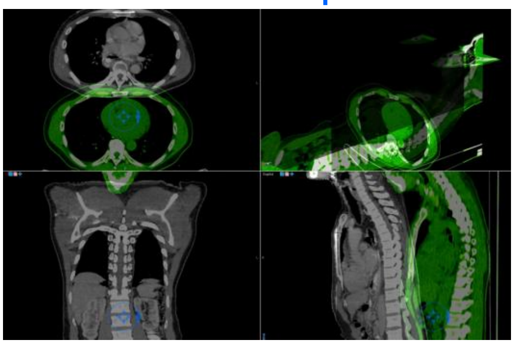
Clinical Examples



Pre-fusion setup

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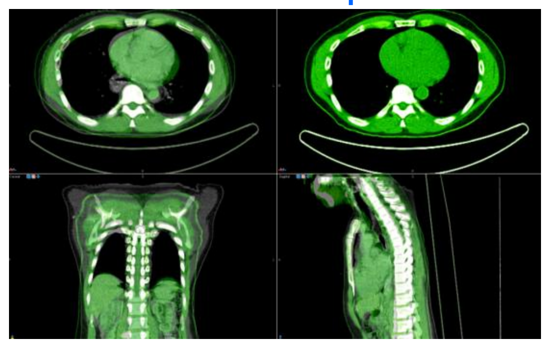
Clinical Examples



Rigid fusion

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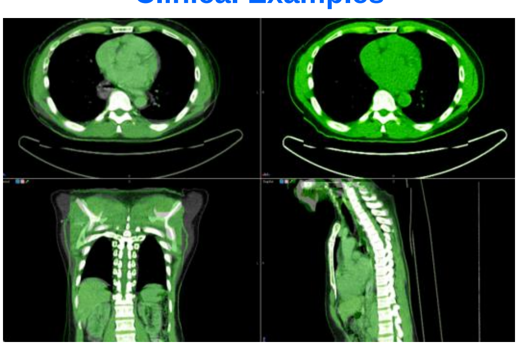
Clinical Examples



Deformable fusion

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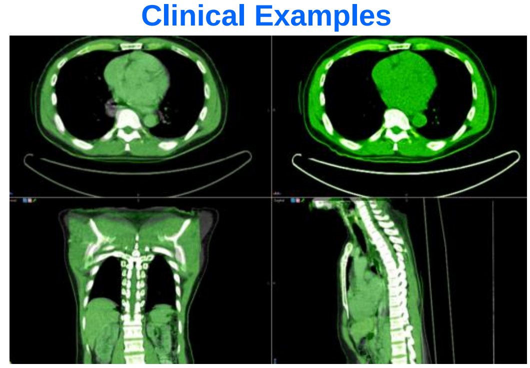
Clinical Examples



Deformable Multi-pass

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PET-CT Registration

- Using Registrations across Volumes
  - Create registration using one secondary volume (CT from PET/CT)
  - Use that same registration on another secondary volume (PET)
- PET-CT registration
  - Use secondary CT to compare to simulation CT
  - Reuse that registration to a PET secondary volume

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PET-CT Registration

- Workflow
  - Load PET and transmission CT (automatic registration)
  - Load simulation CT as primary, transmission CT as secondary
  - Registration
  - Change PET to secondary
  - Select registration

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Rigid and Deformable Registration

- Average Time for PET-CT Registration
  - Load PET-CT and register ~25 sec
  - Load simulation CT ~10 sec
  - Registration preparation ~60 sec
  - Rigid registration ~20 sec
  - Deformable registration ~80 sec
  - Multi-pass registration ~120 sec
  - Select PET as secondary and apply registration ~15 sec
- Total ~5 min 30 sec

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What To Look Out For

- **Patient position significantly different**
  - **Reduce ROI**
  - **Pre-op and post-op images**

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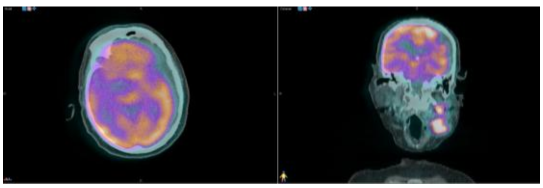
What To Look Out For

- DICOM registration for PET and transmission CT may not be accurate
  - Due to patient movement during PET/CT scan



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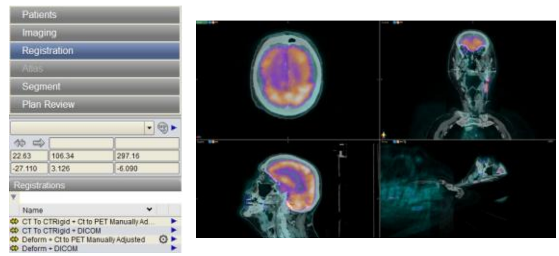
What To Look Out For



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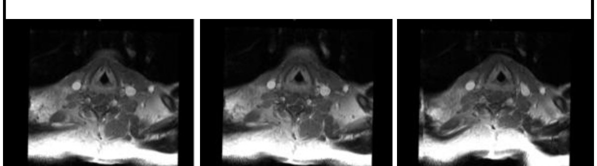
What To Look Out For

- MR deformable registration



Rigid | Rigid and Scale | Deformed

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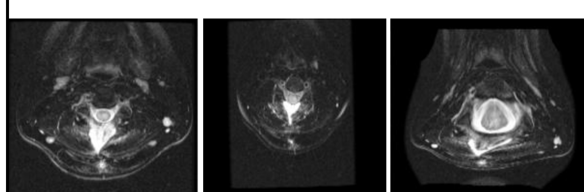
What To Look Out For



Rigid | Rigid and Scale | Deformed

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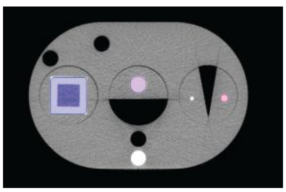
Acceptance Testing

Phantom Imaging Data

- **Verify distance and volume**
- **Conformality calculations**
- **DVH calculations**



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Evaluation of Registration

- **Physician reviews the registration before planning**
  - **Spyglass tool**
  - **Measurement tool**
- **Software does not provide quantitative evaluation tools (uncertainty value)**
- **Decide if registration is useful and appropriate**

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Evaluation of Registration

Med. Phys. **37**, 3126 (2010); doi:10.1118/1.3468142

AbstractID: 13957 Title: A Quantitative Evaluation of Velocity AI Deformable Image Registration

Purpose: We designed an experiment to quantitatively evaluate the feasibility of the VelocityAI version 2.0 deformable image registration algorithm (DIRA), rigid scale (RS) and rigid only (RO) for adaptive radiotherapy. **Method and Materials**: A phantom made of a Lucite box, bolus material, solid water and a Radiadyne balloon was developed to simulate a prostate patient. A deformable prostate was simulated using a balloon filled with 65 cc water and eighty Visicoil derived golden markers spaced on a 10 mm grid were attached to the balloon's surface. A native computer tomography (CT) scan was taken with 1.5 mm slice thickness. Subsequently the balloon was deformed and the corresponding CT data set was collected using the same acquisition protocol and registered to the native image. The resampled data sets were created using the DIRA, RS and RO algorithms. The position of the makers in the resampled image was compared to that of native image by three independent observers. The accuracy of DIRA was studied when different ROIs were employed. **Results**: When applying DIRA, the range of markers' shifts was reduced from 0-3.0 mm to 0-2.5 mm laterally (x), 3.6-10.45 mm to 0-3.6 mm anterior-posteriorly (z) and increased from 0.1-2.0 mm to 0-3.4 mm superior-inferiorly (y) while the range of markers' 3D position decreased from 3.6-10.45 mm to 0.37-3.94 mm. Results from all three algorithms were within 1 mm and their accuracy ranged from 3.94 to 4.75 mm. When the ROI was decreased (15 mm to 3mm) from the balloon the accuracy of DIRA was improved by ~ 2mm (5.55 to 3.21 mm). **Conclusion**: The DIRA technique had the best accuracy (≤ 4 mm) and can be improved within 1mm by decreasing the ROI and it may have the potential to be used in adaptive radiation therapy.

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Adaptive contouring

- **Deformation of contours**
  - **Useful when a patient setup changes, requiring new CT scan**
  - **Reduces the time it takes to replan**
- **4D contour propagation**
  - **Contours on one phase of respiratory cycle are propagated onto all phases**

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Adaptive contouring

- Workflow
  - Import primary image set
  - Import secondary image set with contours
  - Register primary and secondary image sets
  - Drag list of secondary contours to primary list
    - automatically deforms contours (DICOM structure)

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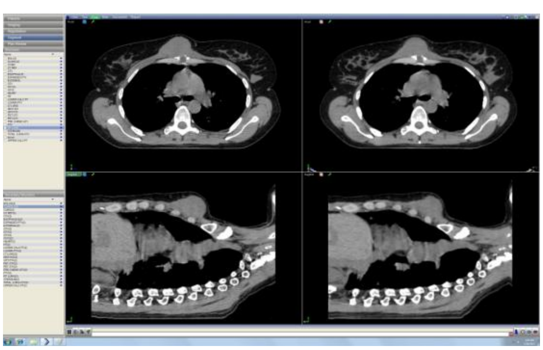
Deformation of Contours



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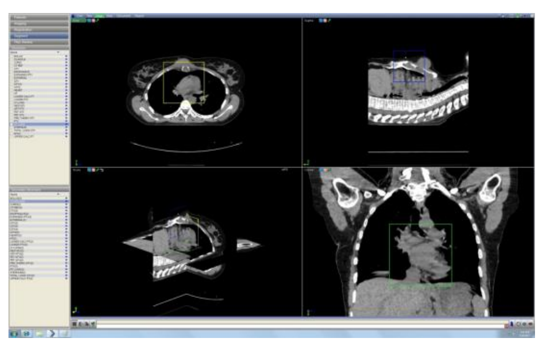
Deformation of Contours



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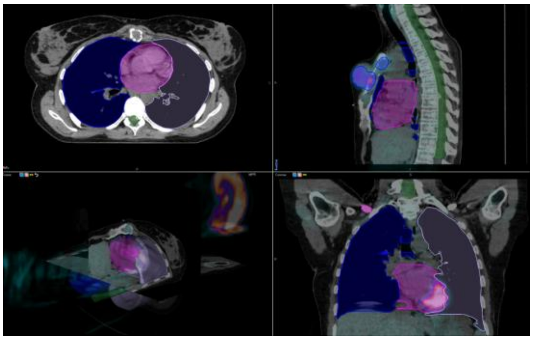
Deformation of Contours



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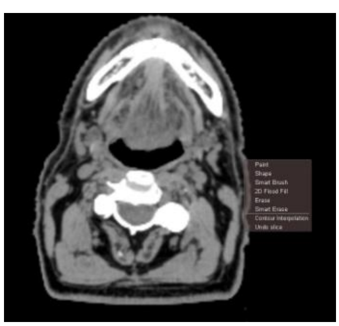
Advanced Segmentation Tools

- Allows contouring in any of the views:
  - Axial
  - Sagittal
  - Coronal



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PET Tumor Volume Segmentation

- Uncertainty introduced by manual segmentation
  - Target edges are based on subjective assessment of area's hotness
- Quantitative segmentation could provide more consistency in segmentation of target volumes
- Velocity uses standardized uptake value (SUV) data
  - % of max SUV
  - SUV threshold value

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PET/CT Tumor Volume Segmentation

- Workflow
  - Planning CT and PET-CT imported into Velocity
  - PET-CT registered to planning CT
  - ROI created surrounding gross disease on PET scan
  - GTV generated using % of max SUV, SUV threshold, or manually adjusting isointensity tool

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PET/CT Tumor Volume Segmentation

- Workflow
  - Adjust to gradient
  - GTV (DICOM structure) exported from Velocity, imported into TPS

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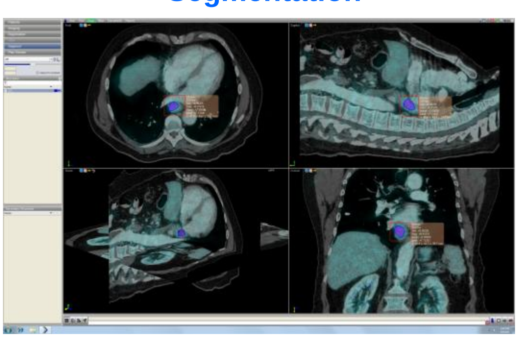
PET/CT Tumor Volume Segmentation



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Atlas-based Segmentation

- The atlas consists of a set of contoured structures
  - Can be transferred to a CT scan and deformed
  - Can then be modified by physician
- Both Velocity atlas (Head/Neck, Brain, Thorax, and Pelvis) and user-defined
- User-defined uses single “generic” CT scan

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Atlas-based Segmentation

- Potential to reduce
  - Contouring time
  - Variation among physicians
- This requires
  - Efficiency
  - Accuracy

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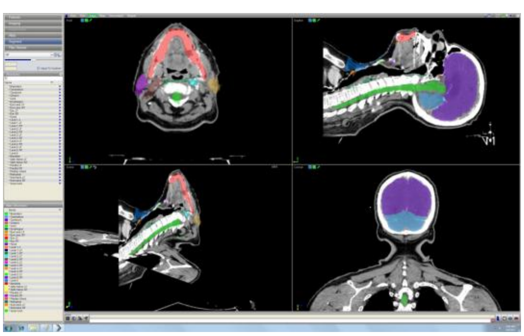
Atlas-based Segmentation



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Atlas-based Segmentation

- In our initial experience this didn’t save time
- Not useful because
  - Too much editing required
    - Faster to manually contour and interpolate
  - Pinnacle automatic contouring features have improved
- Improvements in atlas-based segmentation expected in future releases of Velocity