Conclusion: Our DIR-QA platform demonstrated inter- and intra-operator variability on the order of one voxel (1mm by 1mm by 2.5mm). Machine-generated feature points can serve as a measure of the quality of deformable image registration.

EP-1902
Impact of image quality on DIR performances: results from a multi-institutional study  
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Purpose or Objective: To investigate the accuracy and robustness, against image noise and artifacts (typical of CBCT images), of various commercial algorithms for deformable image registration (DIR), to propagate regions of interest (ROIs) in computational phantoms based on patient images. This work is part of an Italian multi-institutional study.

Material and Methods: Thirteen institutions with six available commercial solutions provided data to assess the agreement of DIR-propagated ROIs with automatically drawn ROIs considered as ground-truth for the comparison. The DIR algorithms were tested on real patient data from three different anatomical districts: head and neck, thorax and pelvis. For each dataset, two specific Deformation Vector Fields (DVF) were applied to the reference data set (CTref) using the ImSimQA software. To each one of these datasets two different level of noise and capping artifacts were applied to simulate CBCT images (fig.1, panel a -b). Every center had to perform DIR between CTref, two deformed CTs and four CBCT for each anatomical district. The different software used in this study were: VelocityAI, Mirada, MIM, RayStation, ABAS, SmartAdapt. A four way ANOVA was performed to identify major predictors of DIR performances followed by a post hoc Sceffè test for analyzing intergroup differences; the logit transform of the Jaccard Conformity Index (JCI) was used as metric.

Results: More than 2000 DIR-mapped ROIs were analyzed, and many results were carried out. We report only the most relevant results for clinical applications. The ANOVA test states that the differences in DIR performances are not statistically significant between the head and neck and prostate cases, while lung case shows a significant difference; they depend from the strength of the deformation; and they are very sensitive to image quality (capping artifacts and noise) (Fig1 panel c). There is statistical evidence that the center #7 performs worst than the others with significant differences respect all the other centers except the number #2 and #11(fig1, panel d).

Conclusion: This work illustrates the effect of image noise to DIR performances in some clinical scenarios with well-known DVFs. Some clinical issues (like ART or Dose Accumulation) need accurate and robust DIR software. This work put in evidence the presence of an important inter-software variability (in terms of JCI parameter), and the need of accurate system commissioning and quality control about the robustness of some commercial system against image quality. Regarding the results in fig1, panel c, the worst scenario (CBCT2) the DIR performances appear slightly better than in CBCT1: what does it mean? Probably the results are very sensitive to image quality but there is a threshold in image degradation above which adding noise or artifacts doesn’t impact on DIR algorithms. This finding suggests the opportunity to test other situations to tune at a finest level noise and artifacts.

EP-1903
Application of the Enhanced ChainMail algorithm with inter-element rotation in adaptive radiotherapy  
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Purpose or Objective: In adaptive radiotherapy positioning uncertainties, due to e.g. tissue deformations in the course of fractionated therapy, can result in a dose delivery that strongly deviates from the planned dose. Especially with regard to particle therapy, it is therefore important to quantify such deviations and to evaluate the need for...
replanning [Tilly 2013]. Since the current deformable image registration (DIR) methods still fall short concerning anatomically correct deformations and therefore do not reach the required accuracy expectations, we have developed a tissue-dependent transformation model. With this we aim at improving the characteristic deformation behavior of rigid and soft tissue without the need of time-consuming tissue delineation.

Material and Methods: We adapted the Enhanced ChainMail (ECM) algorithm [Schill 1998], which was originally developed for surgical simulations, to CT-images by assigning each voxel of the image elastic properties according to its HU-value. The deformation, initialized by shifts of anatomical landmarks, is then propagated by adjusting the deformation limits for every individual element. In addition to deformation limits for stretching, contraction and shear between neighboring elements (voxels), we also introduced an element orientation, which allows for an initial rotation to decay within elastic material.

Results: The ECM algorithm has successfully been applied to phantom as well as real CT-images. Due to the simple deformation rules the algorithm takes less than two minutes for a high-resolution CT-image (dimension: 512 x 512 x 170), but still approximates the shape and geometry of the deformed image in a physically realistic manner. Since tissue parameters can be assigned based on HU-values, the deformation is adapted to different material properties without the necessity of segmentation of different organs. This is in contrast to finite element methods, which represent the state of the art in deformation accuracy [Brock 2006].

Conclusion: This is one of the first applications of the ECM-based transformation model for DIR in radiotherapy. With the extension by inter-element rotation, the algorithm is now able to register deformed and locally rotated organs in CT-images without the requirement of time-consuming segmentation. On the long-term the ECM-algorithm will allow fast and physically realistic registrations, promising to cope with the strict accuracy requirements in deformation detection for particle therapy.

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