Introduction

Deformable registration of diagnostic or planning MRI to planning CT images may help in accurately contouring target and non-target regions on account of the better soft-tissue discrimination in MRI. However, such an approach requires accurate image alignment. The objective of this work was to assess the quality of a rigid and deformable CT-MR registration algorithm as a means to performing such an alignment.

Method

Diagnostic MR and planning CT image data were evaluated retrospectively for 13 patients from multiple sites and various scanners and included Head and Neck (n=4), Prostate (n=6) and Cervical (n=3) cancer cases to provide a broad assessment.

Automatic rigid and deformable registrations were performed using a clinical workstation, Mirada XD (Mirada Medical, Oxford, UK).

Qualitative Evaluation:

Registration quality was evaluated qualitatively for the purpose of RT contouring. Four clinical reviewers (CE, CS, PP, MF) independently rated the registration quality on a subset of cases using the scoring system defined in the table below.

<table>
<thead>
<tr>
<th>Score</th>
<th>Meaning for rigid</th>
<th>Meaning for deformable</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Case unusable for contouring</td>
<td>Case unusable for contouring or rigid is preferred</td>
</tr>
<tr>
<td>2</td>
<td>Alignment to optimal manual rigid achieved following significant manual intervention</td>
<td>The deformable registration gives a minor improvement to the rigid alignment or a significant degree manual intervention would be required prior to use</td>
</tr>
<tr>
<td>3</td>
<td>Alignment to optimal manual rigid achieved following moderate manual intervention</td>
<td>The deformable registration gives a moderate improvement to the rigid alignment or a moderate degree manual intervention would be required prior to use</td>
</tr>
<tr>
<td>4</td>
<td>Alignment to optimal manual rigid with no significant manual intervention</td>
<td>The deformable registration gives a significant improvement to the rigid alignment or no significant intervention is required prior to use</td>
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</tbody>
</table>

Quantitative Evaluation:

All registrations were also assessed quantitatively using 10 anatomical landmark pairs per case, as placed by an imaging expert on the MR and CT images independently prior to registration. The landmarks were chosen as well defined anatomical features, visible in both images and well spaced throughout the volume of overlap of the images. Target registration error (TRE) was assessed following both rigid and deformable registrations. The proportion of landmarks with TRE below 4mm was assessed, as this was considered to be the limit of acceptability for contouring accuracy.

Results & Discussion

Qualitative Evaluation:

A summary of the qualitative assessment is presented in the chart. Three of the reviewers scored the rigid quite broadly, since in their opinion it was either good enough for contouring, or insufficient and therefore unusable. The other reviewer scored the rigid more highly on the basis that it was close to the best manual rigid achievable.

All of the reviewers scored to deformable to be moderately to significantly better than rigid, suggesting little improvement would be required prior to use. The only exception to this was for Cervix 2.

Quantitative Evaluation:

The results of the quantitative assessment are shown in chart below. For all cases the target registration error was reduced by about 50% by applying deformable registration (from 5.8mm to 2.3mm), while the proportion of landmarks within 4mm was more than doubled (from 36.7% to 87.8%).

Conclusions

Use of deformable registration can improve the alignment between diagnostic MR and planning CT, approximately halving the registration error compared to rigid alignment.

Automatic CT-MR deformable registration was found to be of an acceptable quality for multimodal contouring when assessed by clinical users, requiring minimal user intervention prior to use.