

Sharp as a Tack

Measuring and Comparing Edge Sharpness in Motion Compensated Medical Image Reconstruction

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Introduction

- Motion during acquisition leads to blur unless compensated for.
- How to **compare motion-compensated reconstructions**?
- **Non-linear, object-dependent** reconstruction precludes MTF measurements.
- Typical approach: Estimate **edge sharpness** from line profile.

Materials and Methods

- **Problems with manual placement** of a single profile line:

Susceptibility to Noise	Susceptibility to Artifacts
Placement Bias	Mismatch Desired/Measured Entity

- Proposed: **Semi-automatic evaluation of the whole edge** using an ensemble of profile lines (Fig. 1).

- Robust sharpness measure computed as median of profiles' least-square slope estimates:

$$\xi^* = \text{median}[\xi_0, \xi_1, \dots, \xi_{M-1}],$$

$$\xi_\ell = \frac{\text{cov}[s_\ell, I_\ell]}{\text{var}[s_\ell]} = \frac{\sum_i (s_{\ell,i} - \frac{1}{N_\ell} \sum_j s_{\ell,j})(I_{\ell,i} - \frac{1}{N_\ell} \sum_j I_{\ell,j})}{\sum_i (s_{\ell,i} - \frac{1}{N_\ell} \sum_j s_{\ell,j})^2}.$$

s_ℓ, I_ℓ are distances and intensities along profile line ℓ .

- Alternatively, compare improvement visually (Fig. 2).
- Experiments:
 - Simple validation on a synthetic phantom (Fig. 3).
 - **Cardiac motion-compensated C-arm CT** of porcine models [1, 6] (Fig. 4).
 - **Respiratory motion-compensated** whole-heart coronary **MRI** of volunteers [2] (Fig. 5).
- Implementation available on our website:

<http://www5.cs.fau.de/research/software/>



Results and Discussion

- Phantom study results (table in Fig. 3): **Influence of noise and artifacts reduced considerably**.
- Comparison with expert scores (N=7, scale from 0 to 4) for CT and MRI data (tables in Figs. 4 and 5): **Agreement with visual impression**.
- Limitation: Reconstruction methods enforcing sharp edges.
- Potential for improvement: Spline representation of edges, automatic edge pre-selection, different per-profile estimators.

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Figures

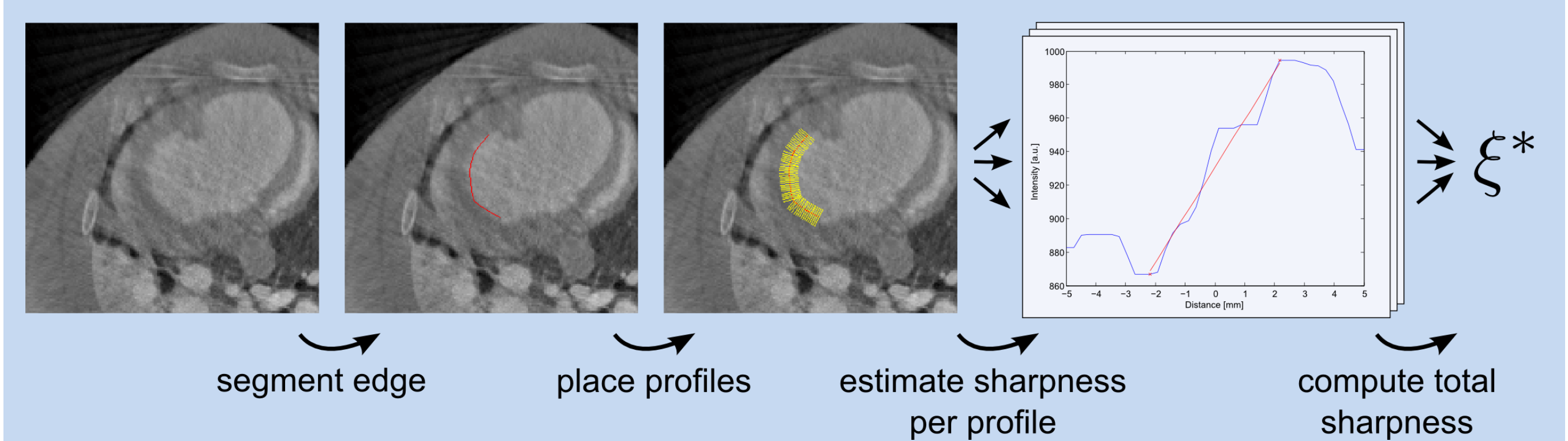


Figure 1. Schematic overview.

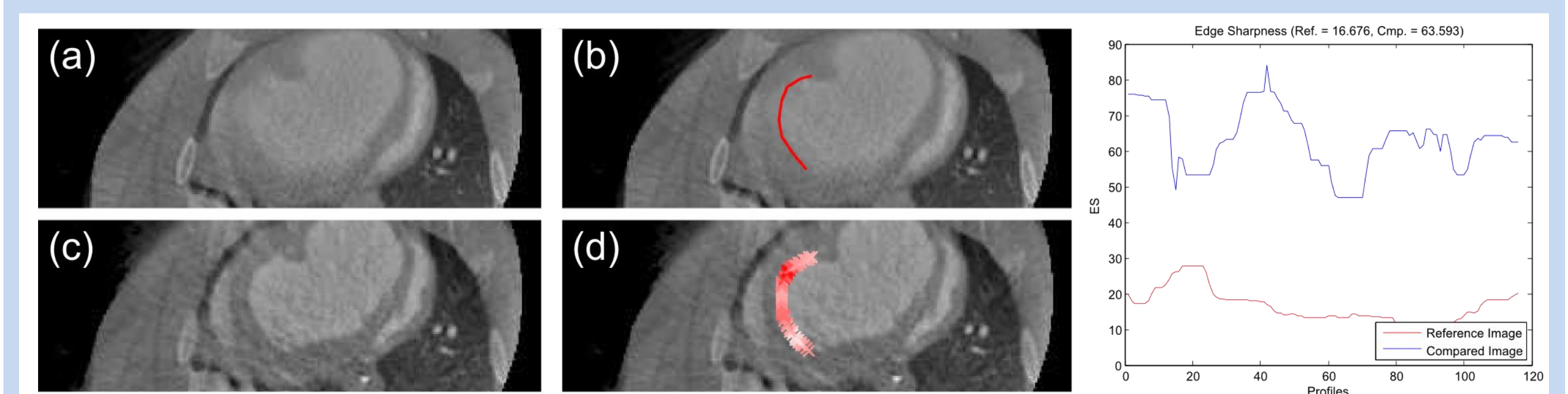


Figure 2. Top row: Motion-blurred image (a) and edge selected for comparison (b). Bottom row: Motion-compensated reconstruction (c) and edge sharpness increase (d).

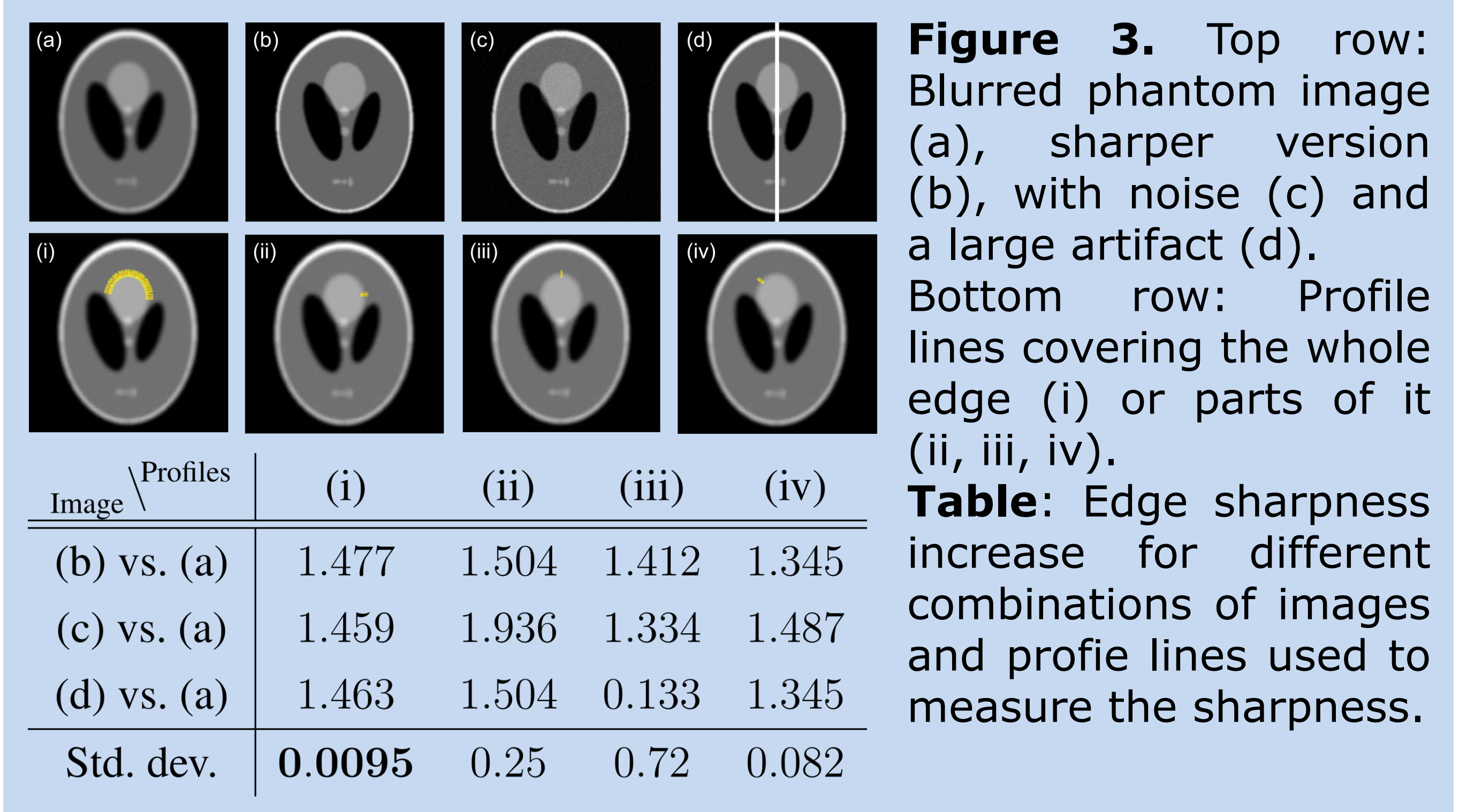


Figure 3. Top row: Blurred phantom image (a), sharper version (b), with noise (c) and a large artifact (d). Bottom row: Profile lines covering the whole edge (i) or parts of it (ii, iii, iv).

Table: Edge sharpness increase for different combinations of images and profile lines used to measure the sharpness.

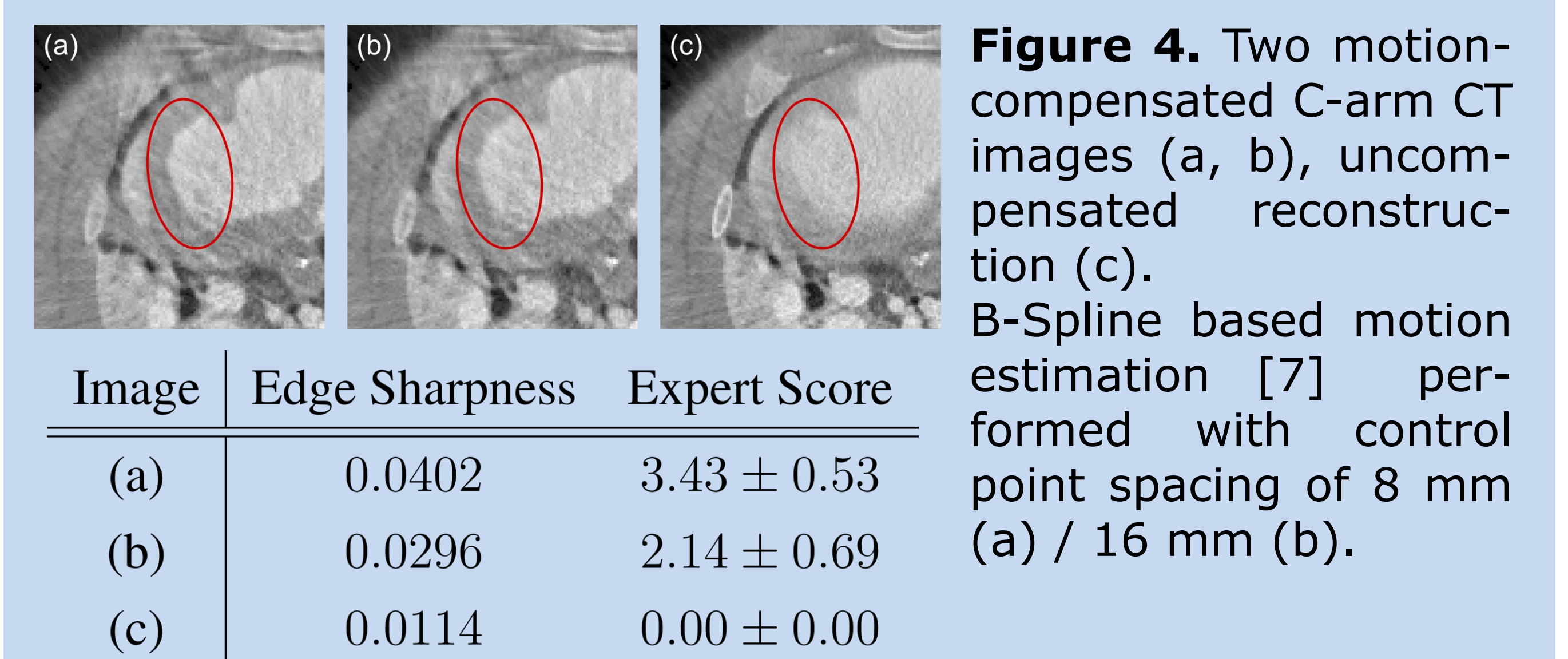


Figure 4. Two motion-compensated C-arm CT images (a, b), uncompensated reconstruction (c). B-Spline based motion estimation [7] performed with control point spacing of 8 mm (a) / 16 mm (b).

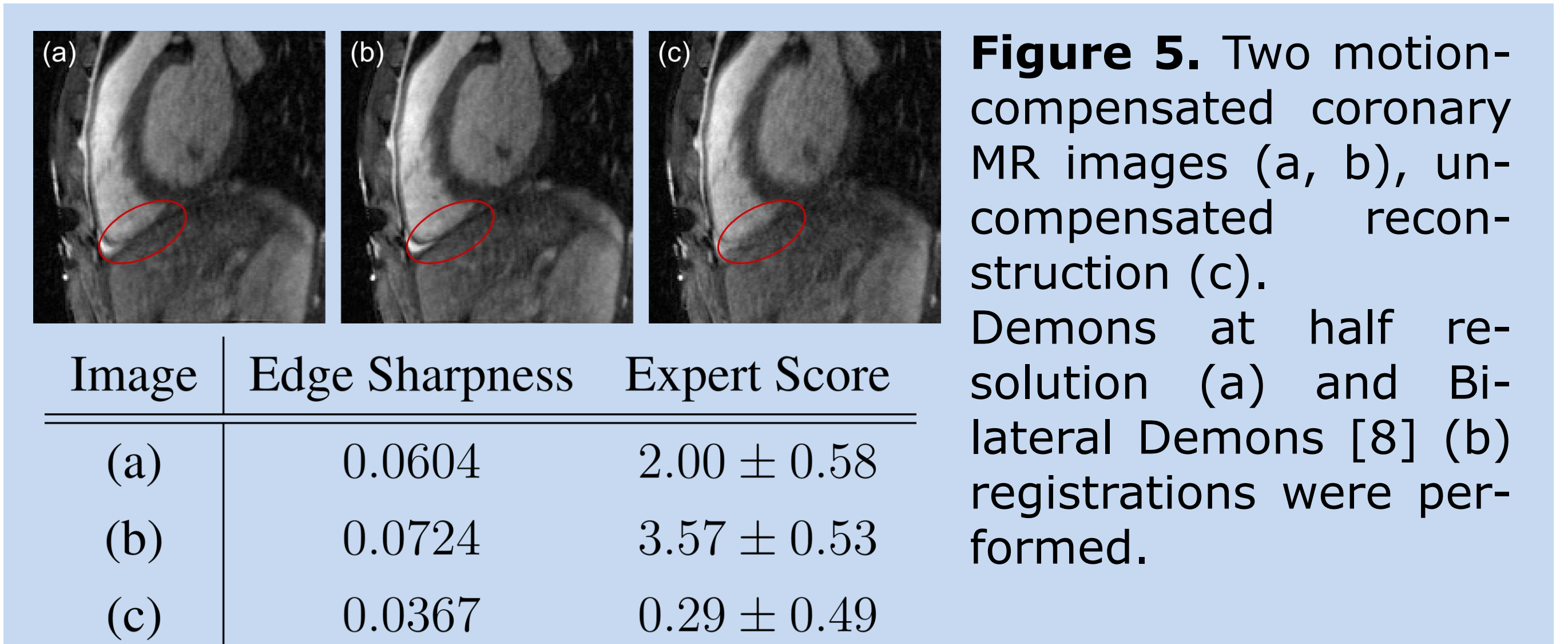


Figure 5. Two motion-compensated coronary MR images (a, b), uncompensated reconstruction (c). Demons at half resolution (a) and Bi-lateral Demons [8] (b) registrations were performed.

References

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