Innovation/Impact: We consider our 4DCBCT reconstruction algorithm to be innovative, because of two reasons. One is that it works on conventional CBCT dataset and does not demand elongated scanning time or excessive patient dose. The other one is the improved image quality compared with traditional retrospective sorting technique, which reconstructs from sorted same phase projections and are usually with artifacts due to undersampling.

Method/Materials: In our algorithm, a subtraction step is introduced to improve the image quality. A detailed description of the method is in the abstract. The workflow is depicted as follows. Here CT motion is a full reconstruction from projections of all phases, CT subtraction is reconstructed from the subtraction projections, and the CT no motion is the desired same phase reconstruction.

The 4DCBCT technique was implemented using Varian Trilogy accelerator OBI system. Two phantoms were studied. A simple shape phantom which consists a cube, a sphere, and a line was studied in static and with superior-inferior motion. To quantify the impact, we further carried out another experiment with Catphan phantom (The Phantom Laboratory, Salem, NY) under situations of both no motion.

Key Findings: Two major findings are resulted from our phantom experiments. One is the image improvement with fewer artifacts compared with the conventional 4DCBCT pathway. The other finding is the de-blurring from the full reconstruction CT_m. Figure 2 a-c) show coronal views from a full reconstruction, an undersampled reconstruction, and reconstruction from our algorithm for the shape phantom in static case. The nonzero CTs comes from the approximate analytical FDK reconstruction from the same location subtraction projection images. This CTs also provides a goal for our motion phantom calculation. Apparently from the static phantom experiment, CT_nm in 2c) has better quality, compared to the traditional same phase reconstruction in 2b). Data from the same phantom with S-I motion of 3s cycle period has shown the same result in coronal view, as shown in figure 2 d-f). For information, a transverse view of the same data is also demonstrated in figure 2, as in g)-i). One advantage of the Catphan is that we can quantify the image quality by counting the contrast rods. Table 1 lists the counted numbers and corresponding situations. The observations on Catphan data, as in the last three parts of figure 2 reinforce the notion that our method improves image quality with conventional CBCT dataset, even without the interpolation step. Figure 3 plots the profiles from the line labeled places in figure 2d) and 2f). The CT_nm profile is narrower and flatter compared the CT_m profile. This indicates the de-blurring effect.
Figure 2. CT\textsubscript{nm} from our algorithm has fewer artifacts.

Figure 3. The deblurring effect from CT\textsubscript{m} to CT\textsubscript{nm}.

Table 1. Contrast counts from the Catphan phantom experiment.

<table>
<thead>
<tr>
<th></th>
<th>High Contrast Counts</th>
<th>Low Contrast Counts</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Full Recon</td>
<td>Sorted Recon</td>
</tr>
<tr>
<td></td>
<td>Full Recon</td>
<td>Sorted Recon</td>
</tr>
<tr>
<td>Static</td>
<td>65</td>
<td>41</td>
</tr>
<tr>
<td>Static</td>
<td>15</td>
<td>11</td>
</tr>
</tbody>
</table>

**Future Work:** It is our belief that filling the angular gap with interpolations of subtraction projections during CT\textsubscript{r} reconstruction will further improve the resulted CT\textsubscript{nm} quality. At present we are working on this part. The effect on motion phantom is also under study now.