Usefulness of 2D-3D image overlay system ("3D Roadmap") using 3D-MR angiography dataset for endovascular abdominal aortic aneurysm repair.

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Purpose

3D Roadmapping technology during the endovascular aortic aneurysm repair (EVAR) was performed using perioperative 3D information of Cone Beam CT (CBCT) with contrast media. 3D Roadmapping makes us easy to recognize vessel anatomy such as access route of delivery system as well as orifice of important branches such as renal arteries or internal iliac arteries. However, it was serious problem to use much contrast-media for 3D Roadmapping during EVAR.

Then we introduced "3D Roadmap" (Phillips, Healthcare, Best, The Netherlands) using preoperative 3D-CT dataset for EVAR to reduce the of irradiation time and contrast media. "3D Roadmap" makes us possible to perform conventional EVAR with two times of angiography using less than 50ml of contrast material.

Moreover, volume of contrast material for preoperative CT should be reduced for the patients with severe renal dysfunction.

In the present study, we evaluate clinical value of "3D Roadmap" using 3D-MR angiography (3D-MRA) dataset which overlays on fluoroscopic images during endovascular aortic aneurysm repair (EVAR) in terms of X-ray irradiation time as well as the volume of contrast material.
Methods and Materials

Methods

In the present study we evaluate as follows:

1. To compare X-ray fluoroscopy time and the volume of contrast between the group of 71 cases with "3D Roadmap" and the group of 67 cases without "3D Roadmap". During EVAR procedure, the level of renal artery was checked using 10-25 ml of contrast material by mechanical injection and the level of bilateral iliac bifurcation was checked using 5ml of contrast material by manual injection. The total volume as well as the number of injection were also recorded.

2. The technical success of EVAR using "3D Roadmap" with 3D-MRA dataset was evaluated.

Materials and application software

A ceiling-mounted C-arm X-ray flat panel and a conventional operating table (Allura Xper FD20 and Magnus operating table, Philips Healthcare) provides the application functionalities of CBCT (XperCT) and MR/CT "3D Roadmap" with Xtravision workstation. CT (Siemens SOMATOM Definition Flash) and MRI (Siemens Magnetom Sonata) datasets obtained prior to EVAR were transferred to Xtravision workstation via DVD media.

For the "3D Roadmap", the step of taking perioperative XperCT and step of registration of preoperative MR/CT data and XperCT are necessary as follows:

3D rotational cone beam CT without contrast media was performed as a pre-processing step at the beginning of the EVAR procedure.

During scanning, geometrical settings like C-arm movement and the height of the table were recorded in their entirety. The scan itself should be done after complete fixation of the patient's position and immediately before high-level sanitizing and draping as rotational scanning might disturb it. This fixation should be the same as the preoperative CT and MRI except for the arm position. Adjustment of the spine, which is the landmark for the overlay system, especially improves the accuracy of the overlay image.

The CBCT and pre-acquired CT or MRI data are then registered in the 3D space by using an image-based registration algorithm, which will follow the C-arm movement, and pre-acquired CT and MRI data is accurately projected and overlaid on the live 2D fluoroscopic image.
Results

"3D Roadmap" was quite meaningful to identify the aortic branches such as renal arteries and iliac bifurcation. In addition, we can deploy the stent graft under the guide of "3D Roadmap".

1-1. The total volume of contrast media in patients with or without "3D Roadmap" was 77ml±31.1(25-185ml), 113±56.1(30-320ml) respectively. Then "3D Roadmap" made us reduce the contrast material to 68.1%. (Table.1, Figure.1).

1-2. Fluoroscopy time in patients with and without "3D Roadmap" was 36 minutes±18.4 (9-109 min), 41minutes±28.3 (6-146min) respectively. This result suggests that we can perform EVAR with time of 87.8%. (Table.2, Figure.2).

2# "3D Roadmap" overlaying preoperative 3D-CT and 3D-MRA on fluoroscopy was executed (Fig.3). The registration of preoperative MR/CT data to XperCT manually was important step for obtaining accurate roadmap image. The image of preoperative 3D-CTA (Fig.4) was registered and overlaid on fluoroscopy (Fig.5). The image of preoperative 3D-MRA (Fig.6) was registered and overlaid on fluoroscopy (Fig.7). Preoperative images of MR/CT were used for the correct registration with perioperative XperCT. For the correct registration with CT dataset, lumbar bone and iliac crest were used as landmark. However as 3D-MRA dataset doesn't show bone information to be compared with 3D-CTA aorta or calcified lesions which were contacting aorta were made use of as landmark.
Fig. 1: Amount of contrast medium (Cases were in ascending order of contrast amount.)

Table 1: Difference of contrast medium usage between Standard fluoroscopy guided

<table>
<thead>
<tr>
<th></th>
<th>3D Roadmap</th>
<th>Standard</th>
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</thead>
<tbody>
<tr>
<td>Amount of minimum contrast medium (ml)</td>
<td>25</td>
<td>30</td>
</tr>
<tr>
<td>Amount of maximum contrast medium (ml)</td>
<td>185</td>
<td>320</td>
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<tr>
<td>Amount of average (ml)</td>
<td>77</td>
<td>113</td>
</tr>
<tr>
<td>Reduction rate (%)</td>
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Fig. 2: Fluoroscopy time (Cases were in ascending order of Fluoroscopy time.)

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<tr>
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<th>3D Roadmap</th>
<th>Standard</th>
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<tbody>
<tr>
<td>Minimum fluoroscopy time (min)</td>
<td>9</td>
<td>6</td>
</tr>
<tr>
<td>Maximum fluoroscopy time (min)</td>
<td>109</td>
<td>146</td>
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<tr>
<td>Average fluoroscopy time (min)</td>
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<td>41</td>
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<tr>
<td>Reduction rate (%)</td>
<td>12.1</td>
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Table 2: Difference of Fluoroscopy time usage between Standard fluoroscopy guided

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Fig. 3: 3D Roadmap that used Overlay MR image

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Fig. 4: Before piling up Overlay CT image and Primary image

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Fig. 5: After piling up Overlay CT image and Primary image

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Fig. 6: Before piling up Overlay MR image and Primary image

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Fig. 7: After piling up Overlay MR image and Primary image

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Conclusion

It was possible to reduce the 46% of contrast media by using "3D Roadmap". Fluoroscopy time could be reduced to 86% in average. "3D Roadmap" was valuable in terms of reducing irradiation dose and procedure time less invasively.

Unlike "3D Roadmap" using CT datasets, it is important to make use of aorta or calcified lesion which were contacting aorta as landmarks for cases of "3D Roadmap" using MRI dataset. Then, the clear depiction of aorta and calcifications in fluoroscopy was necessary for the angiographic system.

It was possible to omit CT scan prior to EVAR by using 3D-MRA. We can decide the length of the device without contrast media during the EVAR procedure. In addition, the "3D Roadmap" overlaying MRA on fluoroscopy made us possible to reduce the total volume of contrast media and fluoroscopy time.

Especially for the patients who have renal dysfunction, "3D Roadmap" overlaying MRA on fluoroscopy was quite useful and it should be useful not only for EVAR procedure but also for whole intervention procedures.
References

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