New diagnosis of breast cancer with Ultra-High-Resolution Computed Tomography

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Learning objectives

The purpose of this educational exhibit is to:

1. introduce about Ultra-High-Resolution Computed Tomography (U-HRCT).
2. depict the fine breast tissue with U-HRCT.
3. introduce the characteristics of U-HRCT comparing to the other medical images and specimen.
4. evaluate the future prospects of diagnosing breast cancer with U-HRCT.
Background

Breast cancer is the most common cancer among females and it is a leading cause of female cancer-related mortality\(^1,\,2\). In Japan, breast cancer morbidity and mortality is 18.9 % and 20.6 % \(^3\) respectively.

To detect breast cancer, contrast enhanced CT examinations have been implemented in Japan\(^4\text{-}\,7\). We acquire the CT images at the same position as surgery\(^4\text{-}\,7\), however, Practice Guidelines of Breast Cancer in Japan doesn’t recommend deciding on courses of treatment with CT images\(^8\). American College of Radiology\(^9\) and Mann RM \textit{et al.}\(^10\) say that we should decide on courses of treatment with MRI images. But certain patients with pacemakers or clips or who are suffering from claustrophobia cannot take MRI examinations. In these cases, CT examinations would be recommended as the primary methods for detection of breast cancer.

CT has been improved and U-HRCT was developed\(^11\). This system has 0.25 mm detector width and the spatial resolution is 120 µm. U-HRCT has potential for depicting microcalcifications.

U-HRCT has a potential to become a new clinical diagnostic device for breast cancer.
Findings and procedure details

1 Introduction of U-HRCT

Conventional CT has 0.5 mm detector width and this detector size was minimum size. To achieve better image quality for CT, technologies of CT device have been developed from various viewpoints and prototype of U-HRCT was developed in 2013. Fig. 1 on page 8 shows the appearance. Table 1 on page 34 shows the basic performance of this system. Fig. 2 on page 8 shows the Modulation Transfer Function acquired with U-HRCT and Conventional Multi-Detector CT (MDCT). U-HRCT improves the spatial resolution dramatically.

Fig. 3 on page 9 and Fig. 4 on page 10 show the clinical images acquired with U-HRCT. These images provide fine structures which MDCT cannot provide.

2 Patients and Specimens

We scanned resected specimens of 4 patients (all women, median age 58 years old, range, 39 - 66 years old) who were diagnosed as breast cancer.

Table 2 on page 35 shows the details of patients.

3 Comparing U-HRCT and the other modalities images

To explain the features of U-HRCT images, we exhibit the other modalities images.

- Mammography (MMG)
- MDCT
- Magnetic Resonance Imaging (MRI)
- Ultrasonography (US)
All specimens were scanned with MMG, U-HRCT, MDCT. MRI and US images were acquired before surgery. All MRI images exhibited here were scanned with 3T MRI.

3-1 Comparing the U-HRCT and MDCT images

U-HRCT images were clearly and provided the any size microcalcifications, however, MDCT images were blurring and provided the large size microcalcifications and small size microcalcifications were not provided (Fig. 5-8, 13-15, 17-20, 24-26). In condition microcalcifications neighbor in small area, U-HRCT image depicted that microcalcifications were separating in a few part, however, MDCT image couldn't depict that microcalcifications were separating because of limitation of resolution (Fig. 8, 20).

Although Mammography provide designated directions images, i.e. Mediolateraloblique and Craniocaudal view, U-HRCT provided the image of arbitrary cross section with Multi Planar Reconstruction(MPR) because this system has 3 dimensional information. MPR images would provide the location of microcalcifications in more details.

3-2 Comparing the U-HRCT and MRI images

U-HRCT provided tumor and fine structures that MRI provided (Fig. 9, 10, 21). However MRI couldn't provide microcalcifications, U-HRCT provided these fine tissues (Fig. 10). Cilotti A et al. 12) and Bazzocchi M et al. 13) say MRI is not recommended as a diagnostic tool for evaluating microcalcifications. These images had a similar finding.

Fat saturation method is one of the important techniques to diagnosis the breast. But distortion of the breast from partial excision would lose a step of fat saturation.

3-3 Comparing the U-HRCT and US images

U-HRCT provided tumor and fine structures that US provided (Fig. 11, 22).

We diagnose the whole breast with U-HRCT images, however we cannot diagnose the whole breast with US images.

In case breast contain large amount of mammary gland, US images provide better images than MMG because US images are made of differences of acoustic impedance. But the
quality of US image varies considerably because it depends on practitioner's skill. On the other hands, CT examination doesn't need to the special skill for practitioners. The use of contrast enhancement is helpful to distinguish tumor and mammary gland.

4 Evaluating the future prospects of diagnosing breast cancer with U-HRCT

U-HRCT provides microcalcifications more clearly and this performance is superior to MDCT. We would be able to determine that there is a microcalcification in breast or not with U-HRCT images.

Ductal carcinoma in situ (DCIS) of the breast represents the lesions confined to ducts and lobules. DCIS is the cancer in an early stage and the risk of metastases and/or death is rare. Women in high-income countries who were diagnosed as DCIS dramatically increased. This increase is due to the widespread of mammographic screening in these countries. DCIS is incidentally diagnosed as the detection of non-palpable calcified lesion with mammography.

Table 3 on page 36 shows the screening rate in some countries. According to the data from International Cancer Screening Network (ICSN), screening rate in Japan is the lowest despite high rate in other developed countries.

There is the potential for an increase in discovery rate of DCIS if we scan with U-HRCT in daily medical practice and this would contribute to reduce the mortality of breast cancer in Japan.

As mammography, we have to apply compression to the breast and this procedure is painful. Especially, patients who underwent the surgical resection often feel extreme pain. The breast should be compressed uniformly to display the whole breast with appropriate image density. But it is technically difficult to compress the partial excision breast uniformly. We would acquire images with U-HRCT unpainfully because we don't require to compress the breast for CT examination and these images have the equivalent diagnostic performance to mammography.

U-HRCT has the wide scan rage relative to other modalities and we can exam primary cancer, lymph nodes and throughout the body metastases at the same time.

The volume data acquired with U-HRCT is very useful and these data provide the MPR images. Tozaki M et al. say MPR images acquired with MDCT are corresponding to pathological cross section. We create Volume Rendering (VR) images with sending
the volume data to 3D workstations (Fig. 12, 16, 23, 27). These VR images are the useful surgery supporting images because the scanning position of CT is supine and this position is same as surgery\(^{4-7}\). To acquire the accurate MPR and VR images, high-quality volume data is required and we would resolve this issue with U-HRCT.

The use of CT is beset with the problem of X-ray exposure. International Commission on Radiation Protection changed the tissue weighting factor for the breast and this factor dramatically increased from 0.05 \(^{19}\) to 0.12 \(^{20}\).

In tandem with the technological advances of CT, various X-ray exposure reduction techniques have come into existence. The detector performance has improved and less conventional reconstruction methods, i.e. Iterative Reconstruction, have been used lightly. These techniques enable us to acquire the U-HRCT images with less amount of exposure maintaining the image quality.

### 5 Study Limitations

In this exhibit, we evaluated the visibility of only fine structures of breast with specimens. Further clinical study should be warranted.
Images for this section:

(a) The appearance of U-HRCT, (b) the details of detectors.

**Fig. 1:** The picture of U-HRCT. (a) the appearance of U-HRCT, (b) the details of detectors.

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Fig. 2: Modulation Transfer Function acquired with U-HRCT(yellow curve) and MDCT(blue curve). (a) X-Y axis, (b) Z axis.

Yoshihiro N, Hirobumi N, et al., Evaluation of Spatial Resolution of Super-High-Resolution CT with 0.25-mm Slice Thickness × 128 Detector Rows. RSNA2015

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**Fig. 3:** 3D-CTA images acquired with (a) MDCT, (b) U-HRCT. U-HRCT can provide more fine cerebral blood vessels. Yellow boxes show expanded image.

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Fig. 4: The expanding reconstructed image of lung with (a) MDCT, (b) U-HRCT. MDCT image is so blurring that we cannot depict fine structures. On the other hands, U-HRCT can provide fine structures. (c) The coronal image of lung with U-HRCT. This image represent fine peripheral blood vessels clearly.
Figure 5. (a) MMG image and MIP images acquired with (b) U-HRCT and (c) MDCT. Slice thickness is 40 mm.

**Fig. 5:** (a) MMG image and MIP images acquired with (b) U-HRCT and (c) MDCT. Slice thickness is 40 mm.

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Fig. 6: MIP images acquired with (a) U-HRCT and (b) MDCT. Slice thickness is 10 mm. Yellow boxes show expanded image of microcalcifications.

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Fig. 7: Axial images acquired with (a)U-HRCT and (b)MDCT. Yellow boxes show expanded image of microcalcifications.
Figure 8. Expanded images of microcalcifications acquired with (a) U-HRCT and (b) MDCT. Yellow arrows indicate the same micocalcifications. U-HRCT image depicted that microcalcifications were clearly separating in two parts, however, MDCT image was so blurring that we couldn’t determine certainly there were two microcalcifications.
Fig. 9: The comparison between (a) U-HRCT and (b) MRI images. Yellow dotted circles indicate the same structure.
Fig. 10: The comparison between (a)U-HRCT and (b)MRI images. Yellow dotted circles indicate the same structure. U-HRCT provided the microcalcifications, however, MRI couldn’t provide these.

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Fig. 11: Axial images acquired with (a)U-HRCT and (b)US images. Yellow dotted circles indicate same structure and the interruption of the anterior border of the mammary gland was provided by each image.

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Fig. 12: (a) Whole and (b) parted specimen images. (c) Volume Rendering image and MPR image at the same slice. Each image created with U-HRCT image data. Yellow arrows indicate the same structure.

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Case number: 002

![Image of MMG image and MIP images acquired with (b)U-HRCT and (c)MDCT. Slice thickness is 40 mm.](image)

**Figure 13:** (a)MMG image and MIP images acquired with (b)U-HRCT and (c)MDCT. Slice thickness is 40 mm.

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Case number: 002

Figure 14. MIP images acquired with (a)U-HRCT and (b)MDCT. Slice thickness is 40 mm. Yellow boxes show expanded image of microcalcifications.

**Fig. 14:** MIP images acquired with (a)U-HRCT and (b)MDCT. Slice thickness is 40 mm. Yellow boxes show expanded image of microcalcifications.

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Fig. 15: Axial images acquired with (a)U-HRCT and (b)MDCT. Yellow boxes show expanded image of microcalcifications.

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Fig. 16: (a) Whole and (b) parted specimen images. (c) Volume Rendering image and MPR image at the same slice. Each image created with U-HRCT image data. Yellow arrows indicate the same structure.

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Figure 17. (a)MMG image and MIP images acquired with (b)U-HRCT and (c)MDCT. Slice thickness is 40 mm.

Fig. 17: (a)MMG image and MIP images acquired with (b)U-HRCT and (c)MDCT. Slice thickness is 40 mm.

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Fig. 18: MIP images acquired with (a)U-HRCT and (b)MDCT. Slice thickness is 40 mm. Yellow boxes show expanded image of microcalcifications.

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Fig. 19: Coronal images acquired with (a)U-HRCT and (b)MDCT. Yellow boxes show expanded image of microcalcifications.

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Case number: 003

Figure 20. Expanded images of microcalcifications acquired with (a) U-HRCT and (b) MDCT. Yellow arrows indicate the same miclocalcifications. U-HRCT image depicted that microcalcifications were separating in a few parts, however, MDCT image couldn't depict that microcalcifications were separating and we mistakes there is one microcalcification.

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Figure 21. The comparison between (a)U-HRCT and (b)MRI images. Yellow arrows indicate the enhanced lesion. Blue arrows indicate the same structure.

**Fig. 21**: The comparison between (a)U-HRCT and (b)MRI images. Yellow arrows indicate the enhanced lesion. Blue arrows indicate the same structure.

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Fig. 22: Axial images acquired with (a)U-HRCT and (b)US images. Yellow arrows indicate the same tumor. Yellow dotted circles indicate the same structure.
Fig. 23: (a) Whole and (b) parted specimen images. (c), (d) Volume Rendering image and MPR image at the same slice. Each image created with U-HRCT image data.

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Fig. 24: (a) MMG image and MIP images acquired with (b) U-HRCT and (c) MDCT. Slice thickness is 40 mm.

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Fig. 25: MIP images acquired with (a)U-HRCT and (b)MDCT. Slice thickness is 20 mm. Yellow boxes show expanded image of microcalcifications.
Fig. 26: Axial images acquired with (a) U-HRCT and (b) MDCT. Yellow boxes show expanded image of microcalcifications. Yellow arrows indicate the same tissues. U-HRCT provided clearly the rim. MDCT provided blurry.

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**Case number: 004**

**Figure 27.** (a) Whole and (b) parted specimen images. (c) Volume Rendering image and MPR image at the same slice. Each image created with U-HRCT image data.

**Fig. 27:** (a) Whole and (b) parted specimen images. (c) Volume Rendering image and MPR image at the same slice. Each image created with U-HRCT image data.

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Table 1. The basic performance of prototype U-HRCT developed in 2013

<table>
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<tr>
<th>Field of view</th>
<th>500 mm</th>
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<tr>
<td>Number of cannels</td>
<td>1792 ch.</td>
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<tr>
<td>Detector width</td>
<td>0.25 mm</td>
</tr>
<tr>
<td>Detector rows</td>
<td>128 rows</td>
</tr>
</tbody>
</table>

Table 1: The basic performance of prototype U-HRCT developed in 2013

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Table 2: The details of patients

<table>
<thead>
<tr>
<th>Case number</th>
<th>Sex</th>
<th>Age</th>
<th>T</th>
<th>Pathological findings</th>
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</thead>
<tbody>
<tr>
<td>001</td>
<td>f</td>
<td>60</td>
<td>2</td>
<td>Invasive ductal carcinoma, scirrhous, G3, NG3</td>
</tr>
<tr>
<td>002</td>
<td>f</td>
<td>39</td>
<td>Tis</td>
<td>Predominantly intraductal carcinoma(papillotubular ca.), G2, NG3</td>
</tr>
<tr>
<td>003</td>
<td>f</td>
<td>56</td>
<td>2</td>
<td>Invasive ductal carcinoma, scirrhous, G3, NG3</td>
</tr>
<tr>
<td>004</td>
<td>f</td>
<td>66</td>
<td>1</td>
<td>Invasive ductal carcinoma, scirrhous, G2, NG2</td>
</tr>
</tbody>
</table>

Table 2: The details of patients

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Table 3: Number of women screened and participation rate in 2010 according to ICSN

<table>
<thead>
<tr>
<th>Country</th>
<th>Number of Women Screened</th>
<th>Participation Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>196,187</td>
<td>47.30%</td>
</tr>
<tr>
<td>Denmark</td>
<td>275,000</td>
<td>73.00%</td>
</tr>
<tr>
<td>France</td>
<td>2,343,980</td>
<td>52.30%</td>
</tr>
<tr>
<td>Iceland</td>
<td>20,517</td>
<td>60.00%</td>
</tr>
<tr>
<td>Israel</td>
<td>220,000</td>
<td>72.00%</td>
</tr>
<tr>
<td>Italy</td>
<td>1,340,311</td>
<td>60.50%</td>
</tr>
<tr>
<td><strong>Japan</strong></td>
<td><strong>2,492,868</strong></td>
<td><strong>19.00%</strong></td>
</tr>
<tr>
<td>Korea</td>
<td>2,602,928</td>
<td>39.30%</td>
</tr>
<tr>
<td>Netherlands</td>
<td>961,766</td>
<td>80.70%</td>
</tr>
<tr>
<td>New Zealand</td>
<td>211,922</td>
<td>67.50%</td>
</tr>
<tr>
<td>Norway</td>
<td>199,818</td>
<td>76.00%</td>
</tr>
<tr>
<td>Poland</td>
<td>985,364</td>
<td>39.00%</td>
</tr>
<tr>
<td>Saudi Arabia</td>
<td>6,200</td>
<td>19.00%</td>
</tr>
<tr>
<td>Sweden</td>
<td>14,140,007</td>
<td>70.00%</td>
</tr>
<tr>
<td>Switzerland</td>
<td>60,700</td>
<td>48.20%</td>
</tr>
<tr>
<td>United Kingdom</td>
<td>1,957,124</td>
<td>73.30%</td>
</tr>
<tr>
<td>United States</td>
<td>416,000</td>
<td>66.50%</td>
</tr>
</tbody>
</table>
Conclusion

U-HRCT provides the fine breast tissue. These findings suggest that U-HRCT has the potential for a new diagnostic device for breast cancer.
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References


