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Title: Clinical Imaging of Microwave Mammography

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Author Questionnaire

1. **Microscopy**: Does your protocol require the use of a dissecting or stereomicroscope for performing a complex dissection, microinjection technique, or something similar? **No**

2. **Software:** Does the part of your protocol being filmed include step-by-step descriptions of software usage? **Yes, all done**

3. **Filming location:** Will the filming need to take place in multiple locations? **Yes, 200 m apart**

4. **Testimonials (optional):** Would you be open to filming two short testimonial statements **live during your JoVE shoot**? These will **not appear in your JoVE video** but may be used in JoVE's promotional materials. **No**

Current Protocol Length
Number of Steps: 18
Number of Shots: 35

Introduction

Videographer: Obtain headshots for all authors available at the filming location.

INTRODUCTION:

1.1. **Yoshihiko Kuwahara:** We aim to develop a clinical imaging system for early breast cancer detection using microwave technology.

1.1.1. INTERVIEW: Named Talent says the statement above in an interview-style shot, looking slightly off-camera.

1.2. **Yoshihiko Kuwahara:** The use of AI is being actively considered as progress in image reconstruction algorithms and antennas has stalled.

1.2.1. INTERVIEW: Named Talent says the statement above in an interview-style shot, looking slightly off-camera.

CONCLUSION:

1.3. **Yoshihiko Kuwahara:** We demonstrated that microwave imaging can distinguish malignant from normal breast tissue in clinical tests.

1.3.1. INTERVIEW: Named Talent says the statement above in an interview-style shot, looking slightly off-camera.

1.4. **Yoshihiko Kuwahara:** We address the lack of noninvasive, radiation-free breast cancer imaging techniques.

1.4.1. INTERVIEW: Named Talent says the statement above in an interview-style shot, looking slightly off-camera.

1.5. **Yoshihiko Kuwahara:** Our method offers safe, low-cost imaging without radiation or contrast agents.

1.5.1. INTERVIEW: Named Talent says the statement above in an interview-style shot, looking slightly off-camera.

Videographer: Obtain headshots for all authors available at the filming location.

Ethics Title Card

This research has been approved by the Institutional Review Board (IRB) at Aichi Medical University

Protocol

2. Microwave Imaging Setup and Image Reconstruction Using Analyzer Control and MATLAB/Excel Integration

Demonstrators: Yoshihiko Kuwahara and Kimihito Fujii

2.1. To begin, launch the measurement program **Analyzer Control** on the laptop **[1]**.

2.1.1. WIDE: Talent powering on the laptop and launching the Analyzer Control program from the desktop.

2.2. Enter the **start frequency** as 1000 megahertz, the **stop frequency** as 6000 megahertz, the **number of data points** as 101, and the **response waiting time** as 200 milliseconds **[1]**. Use default values for all other parameters **[2]**.

2.2.1. SCREEN: 69288_screenshot_1 00:11-00:30

2.2.2. SCREEN: 69288_screenshot_1 00:31-00:37

2.3. Press the **DIO** *(D-I-O)* button, then press the **GPIB** *(G-P-I-B0* **Confirmation** button **[1]**. If all connections are correct, the **CAL Wizard** *(cal-wizard)* , **CAL Load**, **Auto Measurement**, and **Manual Measurement** buttons will become active **[2]**.

2.3.1. SCREEN: 69288_screenshot_2 00:00-00:09

2.3.2. SCREEN: 69288_screenshot_2 00:10-00:15

2.4. Press **CAL Load**, select the appropriate file, and click **Apply** to load the calibration data into the vector network analyzer **[1]**.

2.4.1. SCREEN: 69288_screenshot_3 00:03-00:25

2.5. Set the **AUTO/MANUAL** *(Auto-or-Manual)* switch on the control unit to **AUTO [1]**.

2.5.1. Talent switching the AUTO/MANUAL toggle on the control unit from MANUAL back to AUTO.

2.6. Next, position the patient in a prone position on the bed **[1]**. Ask the patient to insert one breast into the imaging sensor, ensuring that no clothing obstructs the sensor **[2]**.

2.6.1. Talent guiding the patient to lie face-down on the examination bed.

2.6.2. Shot of the patient placing one breast securely into the imaging sensor.

2.7. Turn on the aspirator to initiate suction **[1]**.

2.7.1. Talent switching on the aspirator and observing the initiation of suction.

~~2.8.~~ Adjust the vacuum pressure to 0.04 to 0.06 megapascal using the **CTRL** *(control)* knob **[1]**. If the pressure cannot be reduced, reposition the patient until proper suction is achieved **[2]**. ~~Stop imaging if the aspirator pressure remains at 0 megapascal **[3]**.~~

2.8.1. Talent rotating the **CTRL** knob and monitoring the pressure gauge until it reaches the desired range.

2.8.2. Talent adjusting the patient's body position and rechecking suction connection.

~~2.8.3. Talent observing a reading of 0 megapascal and discontinuing the imaging session.~~

2.9. Press the **Auto Measurement** button **[1]**. The measurement status window will appear **[2]**. Set the measurement range to 1 through 28 and enable **Skip Reciprocity [3]**.

2.9.1. SCREEN: 69288_screenshot_4 00:00-00:07

2.9.2. SCREEN: 69288_screenshot_4 00:08
Video Editor: Please freeze frame here

2.9.3. SCREEN: 69288_screenshot_4 00:09-00:28

2.10. Now, press **Start Measurement** to begin data acquisition **[1]**. The transmission and reception combinations will be displayed during measurement **[2]**. After completion, results are saved in the **VNA_Results** *(V-N-A-Results)* folder in CSV *(C-S-V)* format **[3]**.

2.10.1. SCREEN: 69288_screenshot_5 00:07-00:12

2.10.2. SCREEN: 69288_screenshot_5 00:13-00:23

2.10.3. SCREEN: 69288_screenshot_6 00:12-00:28

2.11. To create a patient spreadsheet for use in the image reconstruction program, open the **data_read** *(data-Reed)* program in MATLAB *(mat-lab)* and process the information in the measurement file **[1]**.

2.11.1. SCREEN: 69288_screenshot_7 00:00-00:11

2.12. Set the file path and specify the measurement files, then assign an output data name **[1]**. Click the **RUN** button in the MATLAB editor to generate a MAT file for a spreadsheet **[2]**.

2.12.1. SCREEN: 69288_screenshot_7 00:12-00:20

2.12.2. SCREEN: 69288_screenshot_7 00:25-00:33, 00:37-00:40

2.13. Next, open the **initialize_for_clinic** *(initialize-for-clinic)* program in MATLAB **[1]**. Enter the reconstruction frequency, path and names of the measurement files, breast designations, and patient worksheet path and name **[2]**.

2.13.1. SCREEN: 69288_screenshot_8 00:00-00:08

2.13.2. SCREEN: 69288_screenshot_8 00:10-00:36

2.14. Click the **RUN** button to generate a patient worksheet for **Excel VBA** use **[1]**. A directory is automatically created to store the reconstruction results **[2]**.

2.14.1. SCREEN: 69288_screenshot_9 00:03-00:11

2.14.2. SCREEN: 69288_screenshot_9 00:14-00:25

2.15. Open the **image_reconstruction_#** *(image-reconstruction-number)* MATLAB file **[1]**. Specify the patient worksheet and name, reconstruction frequency, and calibration file, then save the settings **[2]**.

2.15.1. SCREEN: 69288_screenshot_10 00:00-00:07.

2.15.2. SCREEN: 69288_screenshot_10 00:10-00:36

2.16. Now , open the **multi_person** *(multi-person)* Excel image reconstruction program **[1]**. Enter the patient worksheet names created earlier **[2]**.

2.16.1. SCREEN: 69288_screenshot_11 00:00-00:14

2.16.2. SCREEN: 69288_screenshot_11 00:15-00:36

2.17. Then open the VBA program from the Excel add-in **[1]**. Specify the worksheet processing range from 1 to 8 **[2]**. Confirm that worksheet directories are correctly set in the **Data_read** and **Data_write** standard modules **[3]**.

2.17.1. SCREEN: 69288_screenshot_12 00:00-00:10

2.17.2. SCREEN: 69288_screenshot_12 00:11-00:17

2.17.3. SCREEN: 69288_screenshot_12 00:18-00:33

2.18. Select **getPDTdata** *(get-P-D-T-Data)* and click the **Play** button to begin the image reconstruction process **[1]**. After processing, verify that the reconstructed 3D tomographic images are saved in the correct directory alongside the patient worksheets **[2]**.

2.18.1. SCREEN: 69288_screenshot_13 00:04-00:26

2.18.2. SCREEN: 69288_screenshot_14 00:04-00:12,00:15-00:26

Results

3. Results

3.1. High-permittivity and high-conductivity regions were observed in the left breast containing cancer **[1]**, whereas no such regions appeared in the right, cancer-free breast of Patient 1 **[2]**.

3.1.1. LAB MEDIA: Figure 10 *Video Editor:Please highlight images A, C and D*

3.1.2. LAB MEDIA: Figure 10 *Video Editor:Please highlight images B, E and F*

3.2. In Patient 2, contrast-enhanced MRI clearly detected the cancer in the left breast **[1]**, but it was difficult to identify on X-ray mammography **[2]**. High-permittivity and high-conductivity areas were also observed in the left breast using the prototype **[3]**, but no significant regions were detected in the cancer-free right breast **[4]**.

3.2.1. LAB MEDIA: Figure 11 *Video Editor:Please highlight images C to E*

3.2.2. LAB MEDIA: Figure 11 *Video Editor:Please highlight images A And B*

3.2.3. LAB MEDIA: Figure 11. *Video Editor:Please highlight images F and G*

3.2.4. LAB MEDIA: Figure 11. *Video Editor:Please highlight images H and I*

3.3. In Patient 3, the cancer was visible near the nipple on MRI images before chemotherapy **[1]**, but was absent after treatment **[2].** Images obtained with the prototype also confirmed the disappearance of the cancer after chemotherapy **[3]**.

3.3.1. LAB MEDIA: Figure 12 *Video Editor:Please highlight image A*

3.3.2. LAB MEDIA: Figure 12 *Video Editor:Please highlight image B*

3.3.3. LAB MEDIA: Figure 12 *Video Editor:Please highlight images C to F*

- **Analyzer**
  - Pronunciation link: https://www.merriam-webster.com/dictionary/analyzer Merriam-Webster+1
  - IPA: /ˈæn.əl.aɪ.zɚ/ Cambridge Dictionary+1
  - Phonetic Spelling: an-uh-ly-zer
- **Megahertz**

- Pronunciation link: https://www.merriam-webster.com/dictionary/megahertz Merriam-Webster+1
- IPA: /ˈmɛg-ə-ˌhɝts/ or /ˈmeg-ə-ˌhərts/ Merriam-Webster+1
- Phonetic Spelling: meg-uh-hurts

- **Aspirator**
  - Pronunciation link: https://www.merriam-webster.com/dictionary/aspirator Merriam-Webster+1
  - IPA: /ˈæs-pə-ˌreɪ-tər/ Merriam-Webster+1
  - Phonetic Spelling: as-puh-ray-ter

- **Megapascal**
  - Pronunciation link: https://www.howtopronounce.com/megapascal howtopronounce.com+1
  - IPA: /ˌmɛg-ə-ˈpæs-kəl/ howtopronounce.com+1
  - Phonetic Spelling: meg-uh-pas-kul

- **MATLAB**
  - Pronunciation link: https://www.howtopronounce.com/matlab howtopronounce.com+1
  - IPA: /ˈmætˌlæb/ howtopronounce.com+1
  - Phonetic Spelling: mat-lab

- **Tomographic**
  - Pronunciation link: https://www.howtopronounce.com/tomographic howtopronounce.com+1
  - IPA: /ˌtɑː.məˈgræfɪk/ (US) howtopronounce.com+1
  - Phonetic Spelling: tah-muh-graf-ik

- **Permittivity**
  - Pronunciation link: https://www.merriam-webster.com/dictionary/permittivity Merriam-Webster+1
  - IPA: /ˌpər-ˌmɪ-ˈtɪ-və-ti/ Merriam-Webster+1
  - Phonetic Spelling: per-mi-tiv-i-tee

- **Conductivity**
  - Pronunciation link: https://www.merriam-webster.com/dictionary/conductivity Merriam-Webster+1
  - IPA: /ˌkɑːn-ˌdʌk-ˈtɪ-vɪ-ti/ or /ˌkən-ˌdʌk-ˈtɪ-vɪ-ti/ Merriam-Webster+1
  - Phonetic Spelling: con-duck-tiv-i-tee

- **Mammography**
    - Pronunciation link: https://www.merriam-webster.com/dictionary/mammography Dictionary.com+1
    - IPA: /mæˈmɑː-grə-fi/ (or /mæˈmæ-grə-fi/)
    - Phonetic Spelling: ma-muh-gra-fee

- **Chemotherapy**
    - Pronunciation link: https://www.merriam-webster.com/dictionary/chemotherapy Dictionary.com+1
    - IPA: /ˌkiː-moʊ-ˈθer-ə-pi/ or /ˌkem-oʊ-ˈθer-ə-pi/
    - Phonetic Spelling: kee-moh-thay-ruh-pee