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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

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***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

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## 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. 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\_Updated 00:00-00:09
- 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\_Updated 00:10-00:27
- 2.12.2. SCREEN: 69288\_screenshot\_7\_Updated 00:29-00:45, 00:55-00:57
- 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\_Updated 00:03-00:13

2.13.2. SCREEN: 69288\_screenshot\_8\_Updated 00:20-00:42

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\_8\_Updated 00:45-00:55

2.14.2. SCREEN: 69288\_screenshot\_8\_Updated 01:05-01:15

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\_9\_Updated 00:05-00:11.

2.15.2. SCREEN: 69288\_screenshot\_9\_Updated 00:10-00:30

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\_10\_Updated 00:02-00:07

2.16.2. SCREEN: 69288\_screenshot\_10\_Updated 00:14-00:22

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\_10\_Updated 00:25-00:32

2.17.2. SCREEN: 69288\_screenshot\_10\_Updated 00:32-00:36

2.17.3. SCREEN: 69288\_screenshot\_10\_Updated 00:39-00:51

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\_10\_Updated 00:55-01:16

2.18.2. SCREEN: 69288\_screenshot\_11\_Updated 00:07-00:27

# Results

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### 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*

## Pronunciation Guide

### Analyzer

- Pronunciation link: <https://www.merriam-webster.com/dictionary/analyser> [Merriam-Webster+1](#)
- IPA: /'æn.əl.əɪ.zə/ [Cambridge Dictionary+1](#)
- Phonetic Spelling: an-uh-ly-zer

### ② Megahertz

- Pronunciation link: <https://www.merriam-webster.com/dictionary/megahertz> [Merriam-Webster+1](#)
- IPA: /'mɛg-ə-,hɛts/ or /'meg-ə-,hɛrts/ [Merriam-Webster+1](#)
- Phonetic Spelling: meg-uh-hurts

### ② Aspirator

- Pronunciation link: <https://www.merriam-webster.com/dictionary/aspirator> [Merriam-Webster+1](#)
- IPA: /'æs-pə-,rɛɪ-tər/ [Merriam-Webster+1](#)
- Phonetic Spelling: as-puh-ray-ter

### ② Megapascal

- Pronunciation link: <https://www.howtopronounce.com/megapascal> [howtopronounce.com+1](#)
- IPA: /,mɛg-ə-'pæs-kəl/ [howtopronounce.com+1](#)
- Phonetic Spelling: meg-uh-pas-kul

### ② MATLAB

- Pronunciation link: <https://www.howtopronounce.com/matlab> [howtopronounce.com+1](#)
- IPA: /'mæt,læb/ [howtopronounce.com+1](#)
- Phonetic Spelling: mat-lab

### ② Tomographic

- Pronunciation link: <https://www.howtopronounce.com/tomographic> [howtopronounce.com+1](#)
- IPA: /,tə:.mə'græfɪk/ (US) [howtopronounce.com+1](#)
- Phonetic Spelling: tah-muh-graf-ik

**¶ Permittivity**

- Pronunciation link: <https://www.merriam-webster.com/dictionary/permittivity> [Merriam-Webster+1](#)
- IPA: /pər-ˌmɪ-ˈtrɪ-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: /kə:n-ˌdʌk-ˈtrɪ-vi-ti/ or /kən-ˌdʌk-ˈtrɪ-vi-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: /mæˈma:-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: /ki:-moo-ˈθer-ə-pi/ or /kem-oʊ-ˈθer-ə-pi/
- Phonetic Spelling: kee-moh-thay-ruh-pee