PET

TOF-PET System
Development of BresTome™

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1. Introduction

Positron emission tomography (PET) emerged from the field of research into brain function. FDG was also a PET drug developed to target the brain that visualizes glucose metabolism. Later, FDG was also recognized to be useful for cancer screening, which led to the increased prevalence of whole-body PET systems for use in cancer screening and the continued development of whole-body PET systems to this day. Recently, whole-body PET image resolution has been approaching a theoretical limit due to the size of the ring diameter (clear bore) used by PET scanners that image the whole body.

Since it launched the first dedicated head PET/SPECT system in 1981, Shimadzu has released many PET systems to market. To achieve image resolutions unattainable by scanners with large bore diameters, Shimadzu has developed the BresTome TOF-PET system that produces high-resolution PET images of the head and breast by positioning new high-resolution PET detectors with inbuilt time of flight (TOF) function proximally to the subject. The name BresTome is an abbreviation of “Brain and Breast Tomography for rest,” intended to represent a head and breast tomography system designed for comfort. This article describes the BresTome dedicated the head and breast TOF-PET system that was approved by the Japan’s Pharmaceuticals and Medical Devices Agency in October 2020.

2. System Features

2.1 Compact Design

BresTome has a compact design comprised of two parts: the main system unit that integrates the PET scanner, bed, and console equipped with a screen for GUI and panels to move the PET scanner; and a terminal (operating box) used to start imaging from an operation room. A remote terminal (subterminal) that can operate the screen on the main system unit from an operation room is also available as an optional product **(Fig. 1)**.

2.2 Simple Subject Positioning

When imaging the head, the subject lies supine with their head placed on a headrest, and when imaging the breast, the subject lies prone with a breast suspended in the detector hole. The operator moves the PET scanner to the examined site via the scanner control panel in the console **(Fig. 2)** and checks positioning via a real-time viewer that displays planar images in two views. Because the real-time viewer is displayed on a monitor in the console integrated into the main system unit, the operator can quickly complete positioning while checking both the position of the subject and the real-time viewer without moving between the examination room and operation room.

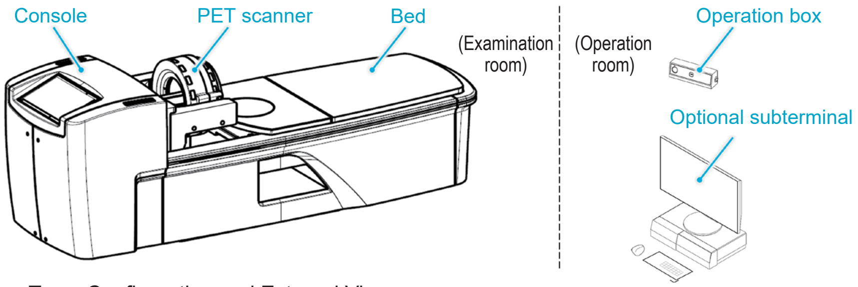

Fig.1 BresTome Configuration and External View

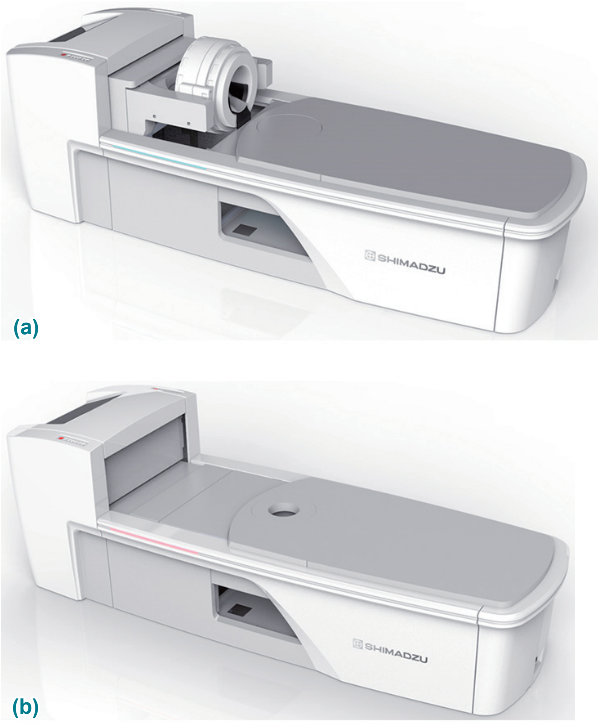

Fig.2 PET Scanner Movement Complete (for Head Imaging **(a)** and for Breast Imaging **(b)**)

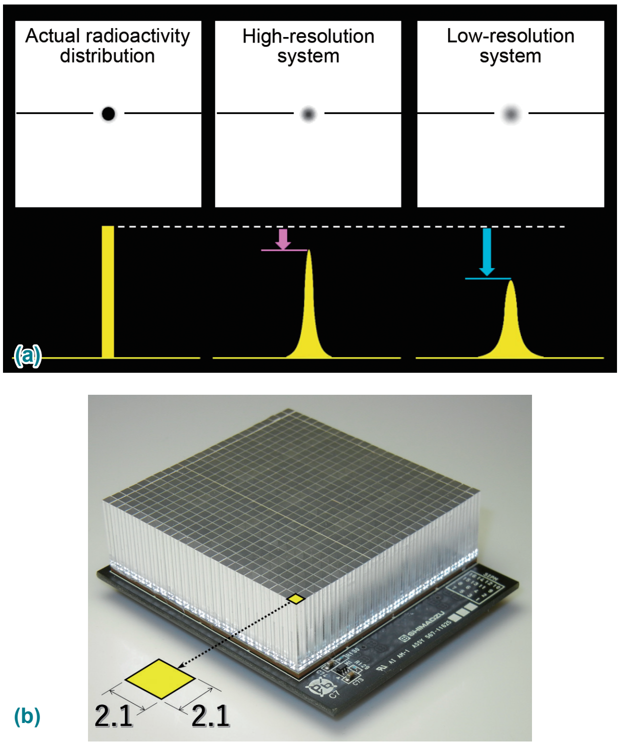

Fig.3 Schematic Diagram of Partial Volume Effect **(a)** and BresTome TOF-PET Detector **(b)**

2.3 High-Resolution Detector

The physical characteristics of PET systems cause a partial volume effect that lowers an object's radioactivity distribution at each pixel and reducing visualization performance **(Fig. 3a)**. This shortcoming has created a need for technical innovations that increase image resolution and reduce the partial volume effect. In one usage case, when diagnosing metastatic spread to small lymph nodes during cancer staging, such higher resolution images should help lower the likelihood of false negatives. High-resolution PET images require a small-form PET detector that has been optimized by combining very small scintillators with highly sensitive optical light-receiving elements with many light-receiving elements. Shimadzu achieved high-resolution PET imaging by combining new technology with PET detector technology cultivated by Shimadzu over the course of more than 40 years, and developed a small-form TOF-PET detector **(Fig. 3b)** capable of rapidly processing signals from scintillators that contain lutetium and silicon photomultipliers (SiPMs). In TOF-PET systems, the higher the TOF resolution performance, the better the PET image S/N ratio (TOF-Gain). BresTome achieves approx. 4 times the TOF-Gain when examining heads and other objects that are approx. 20 cm in diameter, promising images with an equivalent S/N ratio in just 1/4 the imaging time and without conventional TOF information.

2.4 Effective Field of View Optimized for Head and Breast Imaging

One more technique used to achieve high-resolution imaging is to arrange 16 small-form TOF-PET detectors in a ring in close proximity to the subject. A bore diameter of 283 mm is large enough to image the head, and also allows insertion of the breast up to the chest wall within the scan field of view during breast imaging. Arranging a maximum of three detectors axially also provides a 162 mm axial field of view (AFOV) capable of imaging the entire brain in a single acquisition (static). Stepwise movement of the PET scanner in the axial direction also provides a maximum AFOV of 200 mm capable of imaging even large breasts **(Fig. 4)**.

2.5 Attenuation Correction without Additional Exposure

BresTome is equipped with a boundary method[1)] that corrects for uniform absorbers based on emission data from PET drugs and a TOF-based maximum-likelihood attenuation corrector factor (ML-ACF) method[2)] that corrects for non-uniform absorbers using TOF information. These methods prevent additional exposure via external radiation from either CT or external radiation sources used for attenuation correction.

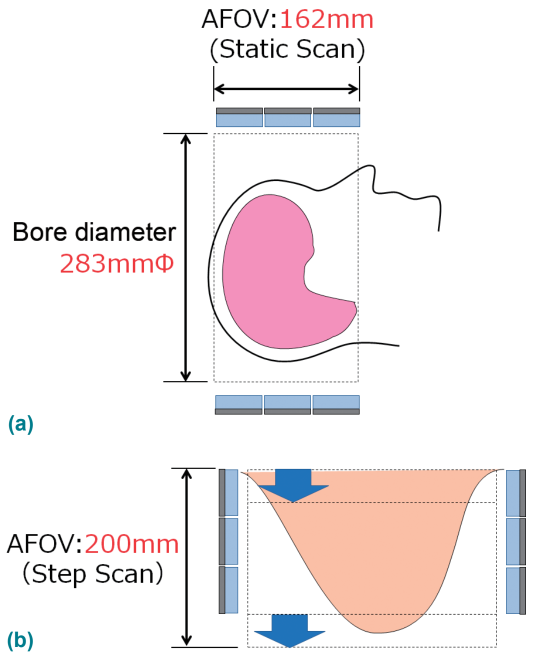

Fig.4 AFOV during Static Acquisition **(a)** and Step-and-Shoot Acquisition **(b)**

3. Applications

BresTome produces diagnostic images in the form of detailed information on the distribution of positron radioactive drugs in the head and breast after administration of a positron radioactive drug. For breast imaging, patients examined in a whole-body PET system can undergo a breast PET examination with BresTome on the same day without the administration of additional PET drugs. For head imaging, head PET examinations for epilepsy and brain function are performed using only BresTome (when there is no obvious medical need to use a whole-body PET system and BresTome on the same day), but in other situations, head PET examinations with BresTome are performed on the same day the subject is examined with a whole-body PET system **(Fig. 5)**. **Fig. 6** and 7 show images obtained with a prototype BresTome system and MRI/FDG-PET fusion images.

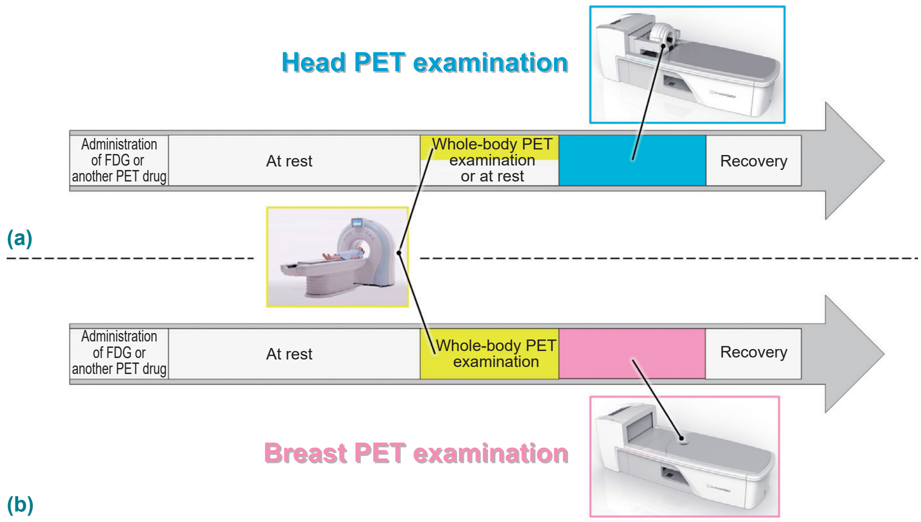

Fig.5 Example Examination Flow: Head PET Examination **(a)**, Breast PET Examination **(b)**

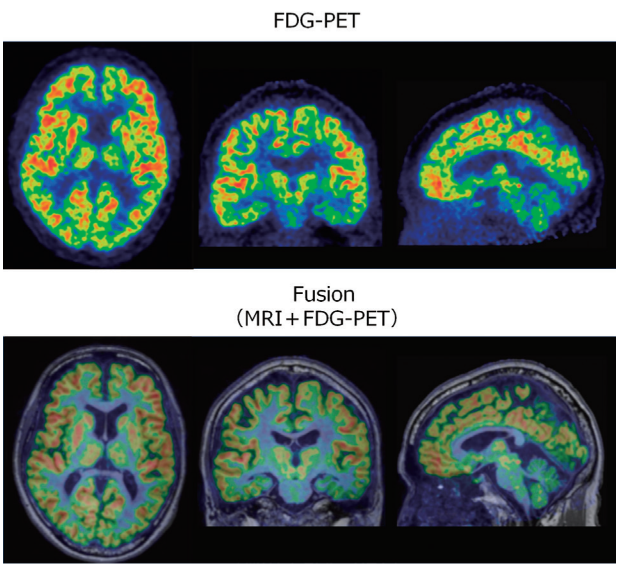

Fig.6 Head FDG-PET (Slice) Images (Top) Obtained with Prototype System and MRI/FDG-PET Fusion (Slice) Images (Bottom)

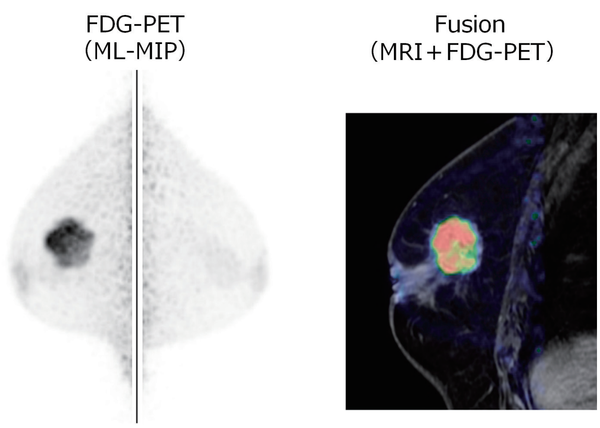

Fig.7 Breast FDG-PET (ML-MIP) Images (Left) Obtained with Prototype System and MRI/FDG-PET Fusion (Slice) Images (Right)

4. Conclusion

In recent years, PET drugs approved for use in Japan or overseas have allowed the visualization of amyloid beta peptides in Alzheimer's dementia, dopamine transporters in Parkinson's disease, and estrogen receptors in breast cancer. There are also growing hopes for the establishment of diagnostic methods that use PET drugs to visualize methionine in brain tumors and tau proteins in dementia. Immune checkpoint inhibitors and photoimmunotherapy are also emerging as new treatments for breast, head and neck, and other cancers, and there are hopes that PET examinations may be selected to determine the therapeutic effect of these new treatments[3]. Such diagnostic investigations require visualization, staging, and elucidation of localized lesion sites that, it is believed, will increase the demand for BresTome, a PET system designed to examine specific sites with excellent resolution.

BresTome is expected to play a role in new medical care and research beyond the role played by PET in medical care to date. Going forward, Shimadzu intends to investigate the utility of PET examinations with BresTome and establish examination methods for BresTome while also pursuing other technical innovations.

Lastly, Shimadzu is extremely grateful to Professor Kazunari Ishii of the Department of Radiology, Faculty of Medicine, Kindai University who plays the role of principal investigator in clinical research using the prototype BresTome system, and to the physicians and faculty of Kindai University Hospital and the Division of PET Molecular Imaging, Institute of Advanced Clinical Medicine, Kindai University. Shimadzu is grateful to the many parties who provided considerable assistance and advice in the development of BresTome.

References

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2) Michel Defrise, etc. : Time-of-flight PET data determine the attenuation sinogram up to a constant, Phys. Med. Biol., 57, 885-899, 2012
3) Shinsuke Sasada, etc. : Dedicated breast PET for detecting residual disease after neoadjuvant chemotherapy in operable breast cancer: A prospective cohort study. EJSO Vol.44, Issue 4:444–448, 2018

Editor's note:

This product is not available outside of Japan as of Feb. 2021. Please contact Shimadzu's local representative to confirm its latest availability for your country.

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