World's first demonstration of multicolor 3-D in vivo imaging using ultra-compact Compton camera

May 22 2017

The Compton camera only weighs 580g and is palm-sized, making it the world most compact medical gamma-ray detector. Credit: Waseda University

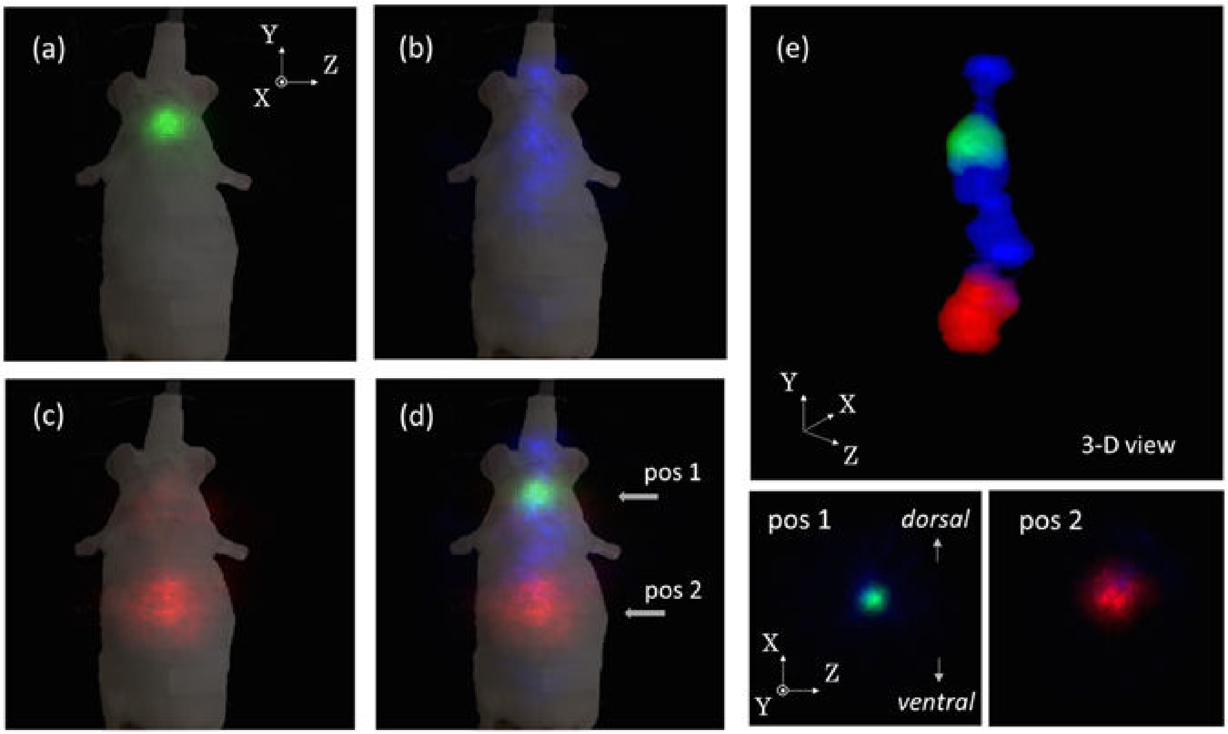
As represented by conventional radiograph, radiological images provide only black and white figures in 2D space. The situation is basically the same for Single photon emission tomography (SPECT) and positron emission tomography (PET), which are the two most common molecular imaging techniques used in nuclear medicine. PET is used especially for early cancer and Alzheimer's disease detection, but radioactive tracers suitable for each detector are limited in terms of energy. For example, PET can only image monochromatic gamma rays thus provide black and white 2D images. Moreover, production of PET tracers, usually made by a cyclotron facility in medical centers, is inevitably costly.

"All of these problems could be addressed if gamma rays of arbitrary energy could be easily visualized in 3D space," points out Jun Kataoka, professor of applied physics at Waseda University. "This would be as revolutionary as black and white television turning into color, dramatically increasing the amount of information we could obtain from an image."

Thus, Professor Kataoka's research group invented a medical gamma-ray detector (Compton camera) and succeeded in high-resolution, multicolor 3D molecular imaging of a live mouse which was administered with three different radioactive tracers. They discovered that the tracers iodine, strontium, and zinc accumulated in the thyroid, bones and liver respectively, confirming that these new tracers concentrated in each target organ.

What's more, this camera only weighs 580g and fits in the palm of a hand, making it the world's most compact Compton camera.

"The measurement time took 10 minutes per angle, so we were able to obtain an image taken from 12 angles in just 2 hours. The time could be reduced even more by using multiple Compton cameras. For example, if there are 12 Compton cameras surrounding an object, the same image as this study could be obtained in just 10 minutes, suggesting a new way to understand biodynamics by looking at how a drug is taken into the body in 10-minute increments."



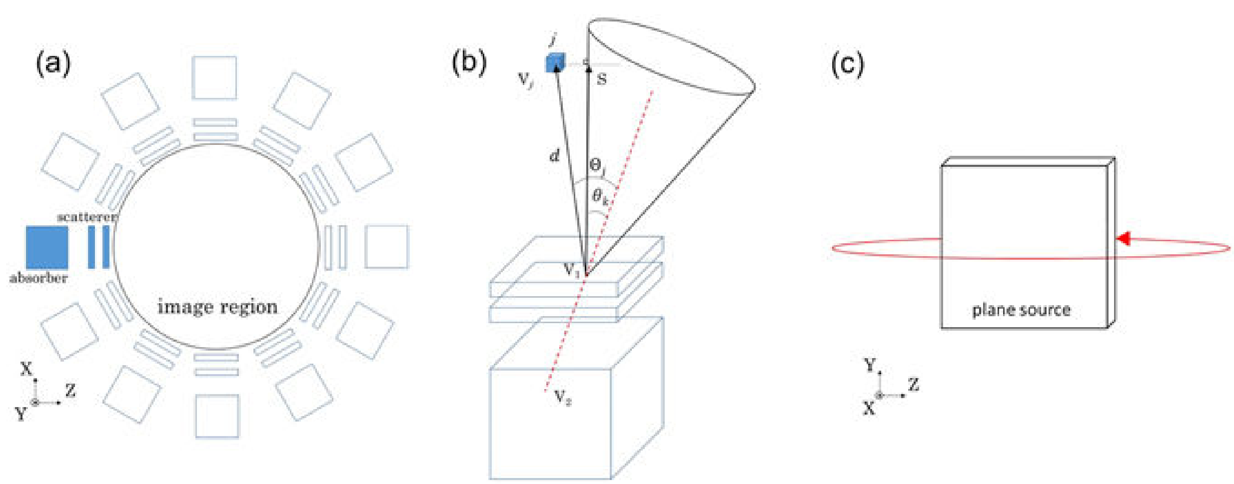
Results of representative 2-D slice in the Z-Y plane of 3-D mouse Imaging. (a) Image of 131I, (b) 85Sr, (c) 65Zn, (d) fused images of all three tracers, and (e) the 3-D view image and the tomographic images of the fused image in the Z-X plane at the two indicated positions. Credit: Waseda University

This research was published in *Scientific Reports*.

Although SPECT and PET are widely used, the radioactive tracers suitable for each detector have been limited. SPECT only images low-energy gamma rays less than 400 kilo-electron volts (keV), and PET can image only positron emitting sources of 511keV. Thus, the use of a Compton camera, which can image energy from a few hundred keV to more than mega-electron volts (MeV), was eagerly awaited for, along with development of new potential tracers.

Professor Kataoka's research group developed the world's lightest, medical Compton camera with high detection efficiency and practical spatial resolution, enabling flexible measurements. The camera was then rotated around the mouse from 12 angles, which was administered with three different radioactive tracers: iodine (131I, 364 keV), strontium (85Sr, 514 keV), and zinc (65Zn, 1116 keV). The measurement time totaled 2 hours, and the group successfully demonstrated the effectiveness of simultaneous in vivo imaging of multiple tracers and imaged the gamma rays nearly real-time with a resolution of 3mm, equivalent to PET.

Based on this study, Professor Kataoka is now working towards developing a gamma-ray camera which works like the human eye. "The human eye can instantly distinguish the colors and brightness of light from all directions, as well as determine the object's shape in 3D from the displacement between the left and right eye. Therefore, stereoscopic imaging becomes theoretically feasible by using multiple ultra-compact Compton cameras."



(a) Configuration of the multi-angle data acquisition measurement, (b) diagram of the 3-D MLEM reconstruction, and (c) configuration of the measurement of the plane source. Credit: Waseda University

Though not limited to the medical field, this technology could help track behaviors of cancer cells and minerals in the body by combining the conventional PET drugs with newly found tracers, calculate the survival rate of a transplanted organ, develop cheaper and more convenient drugs for medical imaging, and monitor online the effectiveness of particle therapy by measuring various prompt gamma rays emitted during treatment.

"As radiation technology is still emerging, we look forward to expanding the possibilities of next-generation radiation imaging with this 'on demand' Compton camera," Professor Kataoka says.

More information: Aya Kishimoto et al, First demonstration of multi-color 3-D in vivo imaging using ultra-compact Compton camera, *Scientific Reports* (2017). DOI: 10.1038/s41598-017-02377-w

Provided by Waseda University