RI imaging tracers for Na^+/K^+ dynamics in a living body

S. Motomura,[*1] I. Kii,[*2] H. Haba,[*3] H. Yakushiji,[*1] Y. Watanabe,[*1] and S. Enomoto[*4]

Sodium (Na) and potassium (K) are essential metal elements that play important roles in our body. Both metal elements exist as ions in the body and each constitutes approximately 0.2% of the body weight. Although they both are alkali metals located in group 1 of the periodic table of elements, the ions Na^+ and K^+ behave very differently in a living body. For example, the concentration of Na^+ is higher in the extracellular fluid than that in the intracellular fluid, while the concentration of K^+ is conversely higher in the cell than that in the extracellular fluid.

The different behaviors of Na^+ and K^+ are caused by certain functions of some biomolecules that can significantly distinguish the ions. An example of such molecule is Na^+/K^+-ATPase, which takes in two K^+ ions into a cell and takes out three Na^+ ions out of a cell in one cycle. This mechanism is used to form the membrane potential in neurons, reabsorption of Na^+ ions in kidneys, etc.

The idea of the MetalloDiagnosis is to obtain the diagnostic information of molecular functions by observing the behavior of associated metal elements (Fig. 1). Various metal elements are controlled by some biomolecules in a living body. Thus, the behavior of the metal elements can be altered corresponding to whether the molecule is functioning normally or not. If we can non-invasively visualize the different behavior of the associated metal elements, we can make non-invasive imaging diagnosis of the molecular functions.

We are trying to use our imaging apparatus called GREI[1)] to realize the MetalloDiagnosis. The GREI is a kind of gamma-ray imaging camera with an imaging principle called the Compton camera made of germanium semiconductor radiation detectors. The GREI can take three-dimensional images of radio-tracers injected into living animals even by using a single GREI imaging head without any rotation or movement.[2)] Furthermore, the GREI can identify each radioisotope injected simultaneously into an animal by distinguishing the gamma-ray energy in the energy range from 100 keV to 2 MeV, owning to the excellent energy resolution of the semiconductor detectors.

To realize the MealloDiagnosis by GREI, we need to prepare radioisotopes of each metal element that we are going to take images of the behavior in a living body. For the MetalloDiagnosis of Na and K, we chose ^{24}Na, ^{42}K, and ^{43}K that have the half-lives of 15-, 12-, and 22-hours, respectively (Table 1). We established the preparation schemes for these radioisotopes utilizing the nuclear reactions of $^{\mathrm{nat}}\mathrm{Mg}(d,\mathrm{x})^{24}\mathrm{Na}$ and $^{\mathrm{nat}}\mathrm{Ca}(d,\mathrm{x})^{42,43}\mathrm{K}$. We have also established a delivery scheme for these radioisotopes from Wako to the molecular imaging facility in the RIKEN Kobe campus. It should be noted that we have made delivery of ^{24}Na, ^{42}K, and ^{43}K radioisotopes 6 times in FY2018.

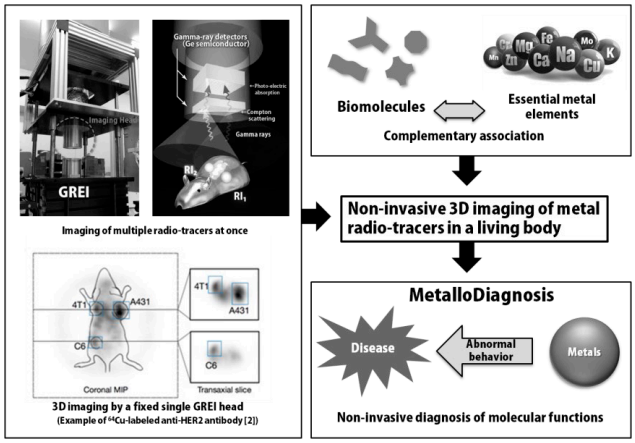

Fig. 1. Concept of MetalloDiagnosis by GREI. Diagnostic information is obtained by observing the associated metals.

Table 1. Radioisotopes of Na and K for GREI imaging.

Nuclide	Half life	Gamma-ray energy (keV)
^{24}Na	15.0 h	1368.6, 2754.0
^{42}K	12.4 h	1524.7
^{43}K	22.3 h	372.8, 617.5

In the RIKEN Kobe campus, it was the first time that we have used the radioisotopes of ^{24}Na, ^{42}K, and ^{43}K for experiment. We have started GREI imaging experiment of living mice injected the Na and K radioisotopes simultaneously. For each GREI experiment, approximately 1 MBq and 100 kBq of ^{24}Na and ^{43}K, respectively, were used for the time-course imaging of Na^+/K^+ dynamics in a living mouse, and it was possible to visualize the different behavior of Na^+ and K^+. This study is ongoing and the results are being prepared to consider for publication.

*1 RIKEN Center for Biosystems Dynamics Research
*2 Compass to Healthy Life Research Complex Program, RIKEN
*3 RIKEN Nishina Center
*4 RIKEN Center for Life Science Technologies

References

1) S. Motomura *et al.*, J. Anal. At. Spectrom. **28**, 934 (2013).
2) T. Ida, S. Motomura *et al.*, Jpn. J. Appl. Phys. **58**, 016002 (2019).