A multi-wire proportional counter for measurement of positron-emitting radionuclides during on-line blood sampling

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Introduction. Pharmacokinetic analyses of PET data require the exact determination of the input function, i.e. the determination of radioactivity concentrations in blood and plasma. Silicon diodes have been used for the measurement of blood radioactivity during PET imaging of rodents [1]. Conventional BGO detectors are widely used for blood radioactivity measurements in human studies (Allog Ab, Sweden). The purpose of the present study was to develop a flow-through multi-wire proportional counter with high sensitivity for positrons emitted from the commonly used positron emitters ^{11}C, ^{15}O, ^{18}F and ^{68}Ga. The proportional counter used in this work was a multi-wire flow-through detector filled with argon-methane gas (P10). The detector system was tested for measurements of ^{11}C, ^{15}O, ^{18}F and ^{68}Ga with mean positron energies in the energy interval 250 - 830 keV. Although the sensitivity of a gas-filled detector is low for 511 keV photons, positrons in the mentioned energy range will give an efficient signal when they interact with the detector fill gas. This type of detector requires only light lead shielding and the detector system can be installed very close to the animal or patient. The detector was used in studying time-activity curves in rats after i.v. injection of [^{15}O]water. Our measurements indicate that the conventional proportional counter technique is useful for routine on-line analyses of blood samples obtained during PET studies of rodents and humans.

Materials and Methods. The multi-wire proportional counter (Fig. 1) was constructed in our laboratory. The electronics was purchased from Oxford Instruments Analytical Oy (Finland). The detector was equipped with an aluminium tube window (thickness 100 µm, diameter 13 mm, length 78 mm). The detector was filled with argon-methane gas (P10) and closed at 1060 mbar pressure. The counter electronics, preamplifier, linear amplifier and high-voltage power supply were all placed in the same aluminium box. The counter A/D converter and software for data collection were custom made. The detector was shielded with 50 mm of lead (25 kg). The background count rate was 2-4 cps. The stability and working conditions of the detector were tested with a ^{241}Am X-ray source. The performance of the multi-wire proportional counter was tested with known activities of ^{11}C, ^{15}O, ^{18}F and ^{68}Ga in water solutions. Oxygen-15 was produced with the Cyclone 3 cyclotron (IBA, Belgium) of the Turku PET Centre. [^{15}O]water was produced with a Hidex Radiowater Generator (Hidex Oy, Finland). ^{11}C and ^{18}F sources were produced with the MGC-20 and CC-18/9 cyclotrons of the Turku PET Centre. ^{68}Ga-chloride solution was obtained from a ^{68}Ge/^{68}Ga generator (Obninsk, Russia).

The rats were anesthetized with isoflurane. [^{15}O]water (50 - 60 MBq, 500 µL) was manually injected via tail vein using a cannula. The blood sampling tube (Teflon, i.d. 0.5 mm, o.d. 1.0 mm) was installed through the detector. A peristaltic pump was used for blood sampling from the arteria femoralis. The blood-flow rate through the detector was 500 µL/min. The animals were placed in a PET scanner (HRRT, Siemens) in order to get a reference input function from the heart left ventricle.

Results and Discussion. Fig. 2 shows the detector efficiency as a function of the mean energy of positrons. The radionuclides ^{11}C, ^{15}O, ^{18}F and ^{68}Ga in water solutions in the Teflon tubing (i.d. 1.5 mm, o.d. 2.5 mm) were used as positron sources. The graph reflects a linear relationship between the detector efficiencies and the mean energies for positrons of the four radionuclides (R^2 = 0.9982). The multi-wire proportional counter responses to ^{11}C, ^{15}O, ^{18}F and ^{68}Ga activities in the Teflon tubing are shown in Fig. 3. The detector response was linear for ^{15}O in the range 5 - 80 kBq/mL with the i.d. 1.5 mm Teflon tubing and in the range 100 - 1300 kBq/mL with the i.d. 0.5 mm Teflon tubing. These ranges cover the radioactivity concentrations for both human and

rat studies. Radioactivity levels in humans are about 20 times lower but still well above the signal to noise level.

Blood time-activity curves (arteria femolaris) were recorded for [^{15}O]water in rat studies. Our results show that a multi-wire proportional counter setup can be used for measurements of blood time-activity curves in PET studies with [^{15}O]water. Blood radioactivities with injection of ^{11}C, ^{18}F and ^{68}Ga labelled tracers can also be measured. The detector efficiency for ^{18}F is low (0.9 - 4.0 %, depending on wall thickness and i.d. of sampling tubing), which limits the use of the detector in ^{18}F applications. Taking into account the abundance of positron decay of ^{68}Ga (86%) the actual detector efficiency for ^{68}Ga is slightly less than for ^{15}O (positron decay 100%).

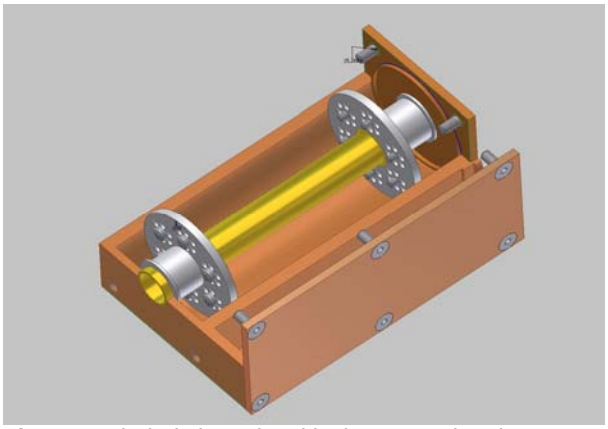

Fig. 1. Exploded view of multi-wire proportional counter.

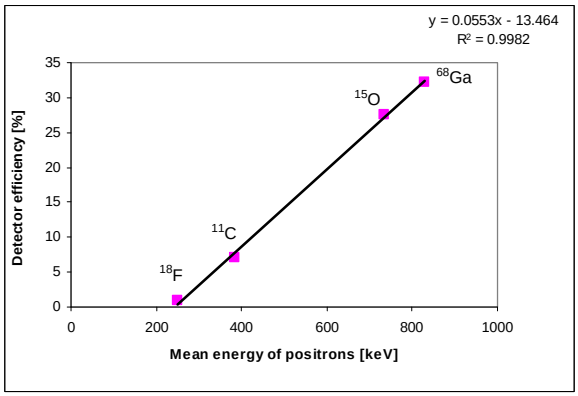

Fig. 2. Detector efficiency versus mean energy of positrons. Radionuclides ^{11}C, ^{15}O, ^{18}F and ^{68}Ga were used as positron sources.

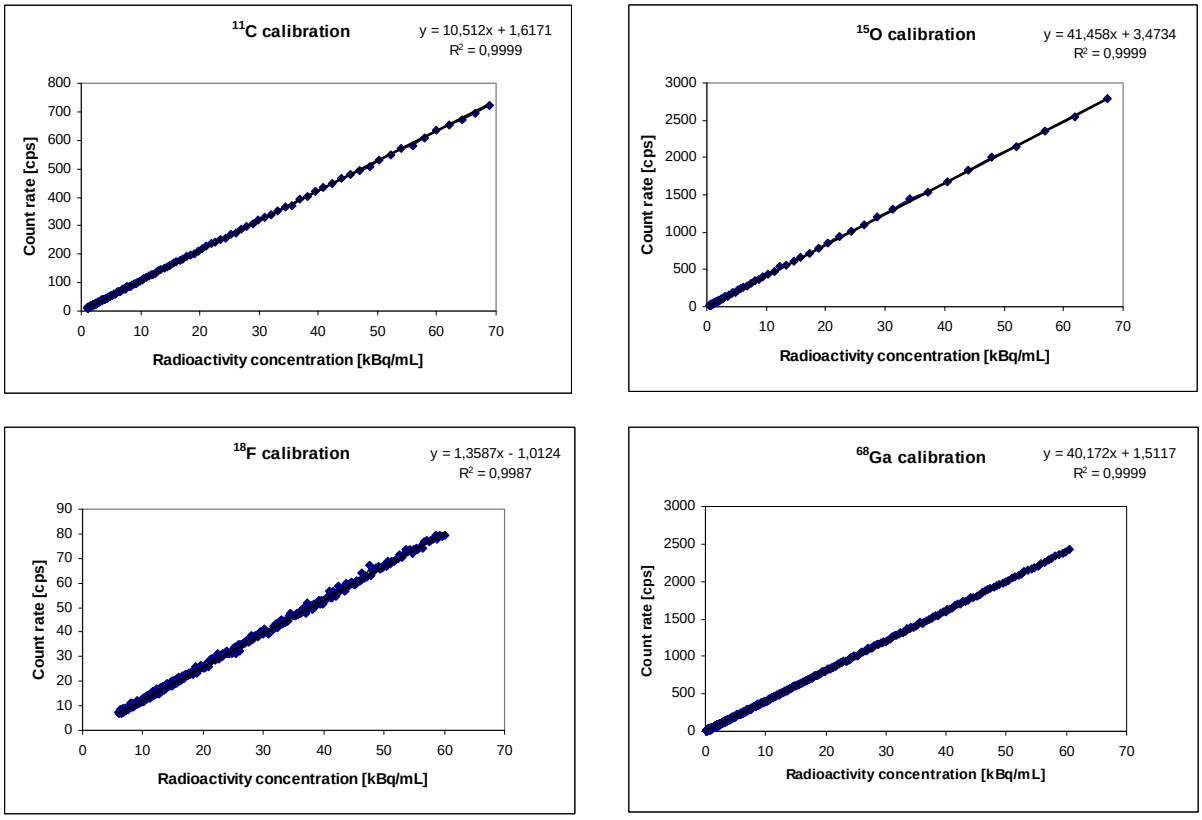

Fig. 3. Multi-wire proportional counter response to ^{11}C, ^{15}O, ^{18}F and ^{68}Ga activities in Teflon tubing.

Reference. 1. Jean-Marc Reymond, David Guez, Sophie Kerhoas, Philippe Mangeot, Raphael Boisgard, Sebastien Jan, Bertrand Tavitian and Regine Trebossen, Nuclear Instr. Meth. **A571** (2007) 358–361.