Method Note

Acquisitions for the PET Q Factor Calibration

Introduction

Quantitative imaging in PET requires to correct for dead time, scatter, and random coincidences as well as radioactive decay. This ensures the proportionality between activity within the FOV and the image value.

The highest level of quantification accuracy is achieved by applying attenuation correction using the anatomical information that Bruker PET/CT and PET/MRI systems provide.

Even after applying the normalization and the above corrections, the reconstructor engine returns an image with arbitrary units. This means that the image needs to be multiplied by an overall scaling factor to give the image absolute units. This enables the calculation of SUV and allows the comparison of images taken under different conditions.

This global image factor is known as the Quantification or simply Q factor and it is generated after a set of known concentrations in a phantom is correlated with the image intensity obtained in the reconstructed images. Once the factor is calibrated, it is input into the system database and from then on, the system automatically reconstructs images absolutely calibrated. All Bruker PET systems provide fully quantitated images in kBq/ml or SUV (% injected activity) because this Q factor calibration happens for every system in the factory.

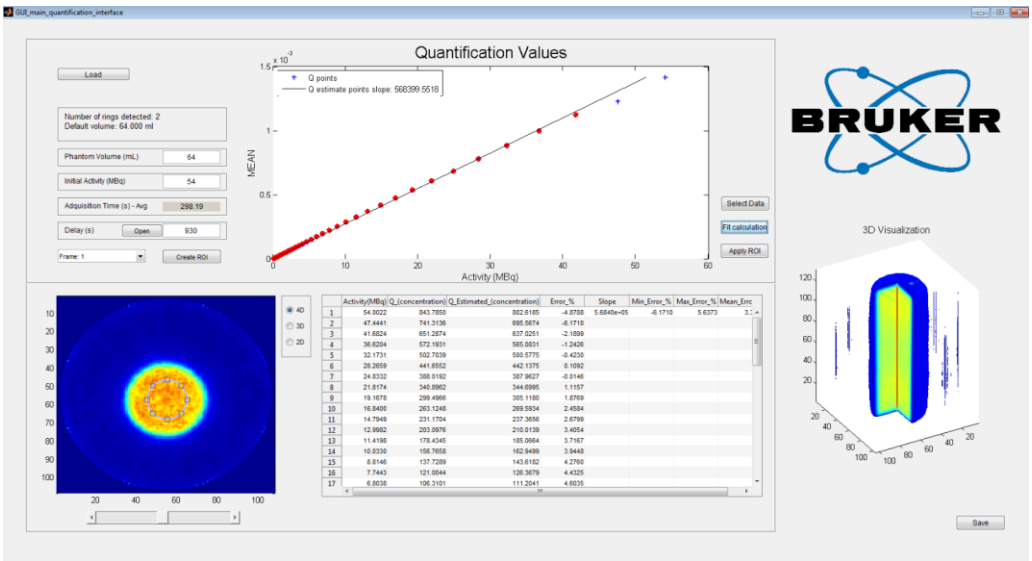

FIGURE 1. A. Bruker internal software used in calculated the Q factor to convert images from arbitrary units to kBq/ml. A linear regression performed fitting measured concentrations in a phantom to image intensity values. The slope of the straight line is the Q factor. For each voxel size, a different Q factor is calculated. This is why when calibrating a Q factor we really mean a set of Q factors

During preventive maintenance operations, after major PET repair operations or major software upgrades, a new Q factor calibration might be necessary. Sometimes the use of specific isotopes will require also new Q factors. The present note is intended to guide Bruker PET users in the acquisition of images from which Bruker personnel will generate new Q factor calibrations.

Data Acquisition

The user is assumed to be familiar with Bruker PET quality control workflows. Please refer to the specific instrument manual for guidance on the use of phantoms, their holders, protocols etc.

There are two alternatives to carry out the acquisitions that will enable Q factor calibrations. The first one involves a long acquisition typically to happen overnight in which the Bruker QC phantom is loaded with a high activity and left to decay over several half-lives inside the scanner. This procedure is adequate for short lived isotopes like C11 and medium lived PET isotopes like F18 and Ga68. For longer lived isotopes like Cu64 and Zr89 it makes more sense to carry out dilutions.

Long decay scan inside the scanner (adequate for F18, Ga68 and C11):

- Fill the QA phantom with 35 – 40 MBq. As few minutes will go by before the acquisition starts, it is also acceptable to load a slightly higher value such that by the time the acquisition starts at least 30 MBq remain in the phantom.
- The exact value to be used in not important, what matters is that the value is known. Please write down the time and precise activity measured using the laboratory dose calibrator. It is essential that the laboratory dose calibrator is properly maintained and calibrated. Please, also make sure that the dose calibrator clock and the imaging device computer are synchronized.
- Inserting the QA phantom directly in the dose calibrator is a quick procedure but can lead to imprecisions. It is recommended for a 1 ml or similar syringe to be used, measuring the activity in the syringe before and after injecting the activity in the phantom. The difference, if no spill has happened, is the activity in the phantom.
- The phantom can be prefilled with water. Distilled water is recommended to avoid the growth of algae or other microorganisms.
- After the injection of the activity and when topping up with water to completely fill the phantom, try as practically as possible to minimize the size of the remaining bubble. The calibration process assumes that the full volume of the phantom is utilized.
- Screw the lid on the phantom and wipe off the phantom on the outside to avoid the presence high activity concentration droplets which will generate hotspots in the PET image. Once closed, gently shake the phantom.
- Ensure the phantom is centered in the FOV within a few millimeters. The situation to be avoided is when part of the active volume of the phantom is on the edge of the FOV or altogether outside. The specific phantom holder for each PET system makes this easy. It is useful to perform a quick PET Localizer acquisition (that is simply a 5 or 10 second duration acquisition and fast reconstruction), check the resulting image and correct the horizontal position as needed.
- Load and launch a dynamic scan of the following pattern repeated 18 times completing a total of 6 hours
    - 5 min acquisition.
    - 15 min pause.

- C11 is considerably shorter lived, hence 12 repetitions of 5 min acquisition + 5 min pause completes 2 hour and this will be sufficient.
- Reconstruction settings: deactivate the decay correction.

Dilutions procedure (adequate for Cu64, Zr89 and similarly long-lived isotopes):

- Use the QC phantom or a 50 ml falcon tube.
- Suggested dilutions are 1, 5, 15 and 35 MBq. Carry out separate acquisitions for each of dilution.
- The exact value in each case is not relevant, what is important is for the time and precise activity value to be recorded. Try to cover a range of activities from 1 MBq to 35 MBq, adding more concentrations is acceptable.
- Acquire for 5 min.
- Follow the instructions above about centering the phantom.

Data Processing and Calibration

The data processing and calibration is performed by the Bruker Service team. Please contact your Bruker PET service team making sure to send remote access details and information on scanner availability. Many image reconstructions are needed but these can be started towards the end of the working day so they happen overnight.

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